REG. No. 24918 / 64
ISSN: 0022 - 1155
CODEN: JFSTAB

JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

SOCIATION OF FOOD SCIENTISTS & TECHNOLOGISTS (INDIA)

ol. 32, No. 2 March-April 1995

ASSOCIATION OF FOOD SCIENTISTS AND TECHNOLOGISTS (INDIA) MYSORE-570 013

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JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

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JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

Volume 32 Number 2 March-April 1995

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Journal of Food Science and Technology, devoted to original R & D contributions in all branches of Science, Technology and Engineering of Foods and Food Products, is a bimonthly publication of the Association of Food Scientists and Technologists (India), Mysore. Review papers are also published to a limited extent.

The Editor reserves the privilege of editing the manuscript and adding or deleting relevant parts, to make it suitable for publication in the Journal.

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The Instructions to Authors are published in the January-February issue of the journal. These are required to be followed *in toto*. No deviation is accepted.

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REVIEW *J. Food Sci. Technol., 1995, Vol. 32, No. 2, 81-93*

Methods for Dehulling of Pulses : A Critical Appraisal

UMAID SINGH

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru-502 324, India.

Pulses, the edible seeds of legumes, are dehulled into *dhal* (decorticated dry split cotyledons) for use as human food. Not only does dehulling reduce cooking time and antinutrients, it also improves protein quality, palatability, and digestibility of pulses. An efficient and improved dehulling of pulses is of vital importance in reducing dehulling losses and thus increasing the availability of *dhal* in the daily diets of the people. In spite of several advances in dehulling methodology of pulses, *dhal* millers and villagers are still using the age-old traditional practices of dehulling, consequently incurring significant quantitative and qualitative losses. *Dhal* yield, which is a function of dehulling efficiency, is highest in chickpea and lowest in pigeonpea in case of both small scale (stone *chakki*) and large scale (*dhal* mill) operations. Mean dehulling loss is nearly 33% in stone *chakki* and 25% in *dhal* mills. Of the various pre-treatments, heating of seed before dehulling appears to improve the *dhal* yield in pulses, particularly in pigeonpea. Pulse varieties with uniform and round seeds are preferred for higher *dhal* yields. Genotypic differences exist in the dehulling characteristics of different pulses, as evaluated by using laboratory method. This paper reviews in-depth, several aspects of dehulling, such as methodology, pre-treatments, physical, morphological and chemical nature of seed, with respect to dehulling characteristics, nutrient losses and varietal, differences in dehulling quality.

Keywords : Pulses, Traditional and modern methods of dehulling, Pre-treatments, Seed characteristics, Varietal differences, Nutrient losses.

As a matter of convenience, grain legumes, such as chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* L.), *mung* bean (*Vigna radiata* L.), urd bean (*Vigna mungo* L.) and lentils (*Lens esculenta* L.), are commonly referred to as pulses in the Indian sub-continent. Chickpea and pigeonpea are very important pulse crops in India, as they occupy nearly 45% of the total pulse area and contribute about 60% of the total pulse production in the country. Approximately 75% of the total world yield of pulse is produced in the developing countries and India accounts for about 70% and 85% of the total world production of chickpea and pigeonpea (Singh and Singh 1992). India produces over 12 million tonnes of pulses annually and this figure has almost remained static for the last three decades (Sharma 1994). It is not surprising that per capita availability of pulses has fallen significantly, as the population is expanding at the rate of 2.1% per annum in India (World Bank 1991). Further, the pulse production is stagnant and imports are negligible, until recently. The low production and productivity of pulses are because of the fact that these energy-rich crops are grown under the condition of energy deprivation, i.e., low input management practices (Jeswani and Saini 1981). Over 90% of the area under pulse cultivation is confined to un-irrigated lands, and in the foreseeable future, this situation is unlikely to change. In addition, pulses also suffer considerable quantitative and qualitative losses during transportation, post-harvest handling, dehulling, and storage (Singh and Jambunathan 1990).

Dehulling process, also called primary processing, converts the whole seed of pulses into *dhal* (decorticated dry split cotyledons), which is consumed in various forms. Dehulling is the most important operation of post-harvest handling of pulses, and hence plays an important role in processing and utilization of pulses in the daily diets of the people. Although the exact figures are not available for different pulses, currently it is estimated that over 75% of chickpea and 85% of pigeonpea produced in India are dehulled to produce *dhal*. Earlier, about 80% of the grain legumes produced in India were dehulled and milled to produce splits *(dhal)*, before consumption (Parpia 1973). There are several thousands of dehulling units of varying capacities for processing the annual total production of pulses in India (Kurien 1981). Although it will depend on the methods and machinery used for dehulling, several factors such as environment, agronomic practices, genotypes, and pre-treatments influence the dehulling process and consequently, the *dhal* yield (Singh and Jambunathan 1981; Ramakrishnaiah and Kurien 1983; Reichert et al. 1984). In recent years, the processing of pulses has become more attractive, and there are continuing efforts to improve the *dhal* yield of pulses either through better processing techniques or availability of more suitable genotypes or both (Kurien 1984; Ehiwe and Reichert 1987; Singh et al. 1992a; Saxena et al. 1993; Williams

Submitted as JA # 1717 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

et al. 1993). In view of this, an attempt is made in this paper to present a comprehensive review on dehulling of pulses in India and suggest future research needs.

Advantage of dehulling

Dry whole seeds of pulses possess a fibrous seed coat, or testa (husk, hull, or skin). The seed coat is often indigestible and sometimes causes a bitter taste (Singh and Singh 1992). Therefore, pulses are mostly consumed after dehusking to improve their palatability and taste. The most beneficial effect of dehulling is the reduction of cooking time in terms of removing the impermeable seed coat of pulses, which hinder water uptake during cooking (Williams et al. 1993). The polyphenols, also called tannins, which are considered to be the potential antinutritional factors are mostly present in the seed coat. In case of pulses, seed coats account for 80-90% of the total seed polyphenols (Rao and Deosthale 1982; Singh 1993), which are significantly reduced by dehulling (Rao and Deosthale 1982; Singh 1984, 1993). Removal of hull facilitates a reduction of fibre and tannin contents and improvement in the appearance, texture, cooking quality, palatability and digestibility

Fig. 1. Traditional method of dehulling pulses using pestle and mortar.

Fig. 2. Traditional method of dehulling pulses using stone *chakki*

of the grain legumes (Kon et al. 1973; Deshpande et al. 1982). Dehulling improves the protein quality in pulses. For example, the true protein digestibility and net protein utilization of *dhal* components were significantly higher than those of the whole seed of pigeonpea, indicating the beneficial effects of removal of seed coat (Singh 1993).

Methods of dehulling

Historically, the processing of food legumes in developing countries has been done in the home by women, as part of the meal preparation. The conversion of pulses into *dhal* is an age old method, practised in the homes and slowly adopted by the agro-processing industry, in the form of commercial *dhal* mills. Both small and large scale industries have evolved to some extent from these traditional food processing methods. *Dhal* milling is an important industry, comparable with rice milling and flour milling industries, in terms of capital investment. The dehulling methods can be broadly classified into two categories :

1. Traditional methods of dehulling : a) Small scale processing generally adopted by the households

in villages and b) Large scale processing adopted by the commercial *dhal* mills in urban areas.

2. Modern methods of dehulling : a) Laboratory-type dehullers and b) Mini-*dhal* mills.

Traditional methods

Small scale processing : Since ages, the dehulling of pulses has been practised in traditional ways in India. In the early days, dehulling of pulses was accomplished traditionally with a mortar and pestle (Fig.1). In some African countries, dehulling of legumes is still carried out with a mortar and pestle (Dovlo et al. 1976). The traditional dehulling of pulses is often laborious, time-consuming and inefficient (Singh et al. 1992b).

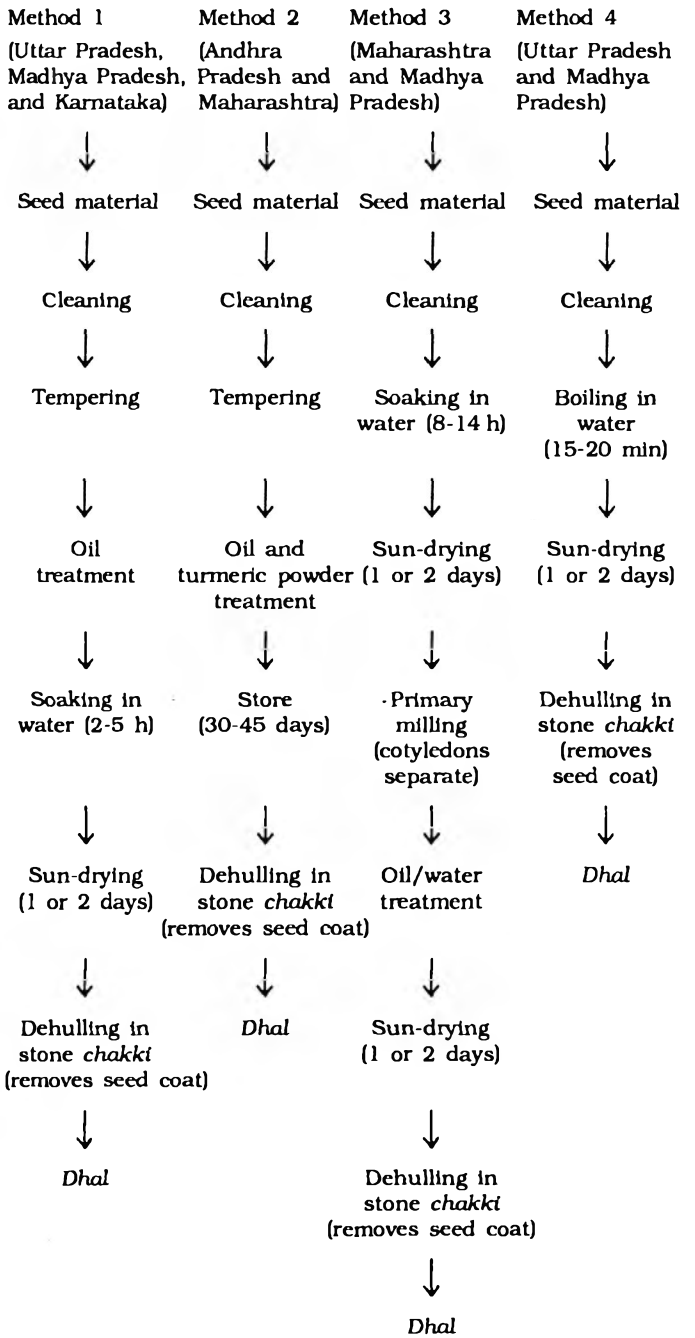

Fig. 3. Traditional methods of dehulling pigeonpea followed in various Indian States.

In case of small scale dehulling, which is generally practised by the villagers, the basic unit is a stone *chakki* (Fig. 2). The *chakki* is a quern, consisting of two grinding stones, the lower one being immovable and the upper one rotating. It is operated manually and used mainly to dehull small quantities of pulses for domestic consumption. The stone pieces generally vary from 30 to 40 cm diam and 4 to 6 cm thickness (Singh et al. 1992b). The pre-treatments given before dehulling in a *chakki* vary from region to region as shown in Fig. 3. The grains of pre-treated pulses are slowly and uniformly added through a central hole in the upper stone of the *chakki*, which is gently and continuously rotated manually until the material is processed. Depending on the seed size and different species of pulses, the gap between the upper and lower stones could be adjusted by a wooden structure supported at the bottom. After the operation, the upper stone is removed and the processed material is collected for separation into *dhal*, brokens, powder and husk fractions by winnowing.

Large scale processing : According to the dehulling procedure that is commonly used for large scale processing of pulses, commercial *dhal* mill is a basic dehulling unit for processing large quantities of pulses in urban areas of the country. Eventhough the basic approach is similar, details of dehulling procedures vary widely from one *dhal* mill to another *dhal* mill and one region to another region. The use of an emery-coated roller is a common practice in commercial *dhal* mills (Kurien 1981). The emery-coating, also called as carborundum, is made of silicon carbide (carbon + crystallized alumina) and used for abrasive or refractory action. Some millers use a roller (Fig. 4) for both dehusking and splitting, while others use a roller and disc sheller alternatively for this purpose. The disc sheller is generally used for wet-processing and works on the principles of attrition, which removes the husk and splits the cotyledons simultaneously (Kurien 1981). However, its functioning mechanism is not properly understood and excessive breakage in this machine is common, especially when the grains are not size-graded (Kurien 1981). The disc-shellers are generally used for dehusking rice (Kurien 1981). The roller machine, which is most commonly employed for dehulling pulses in India, is used in dry method of processing

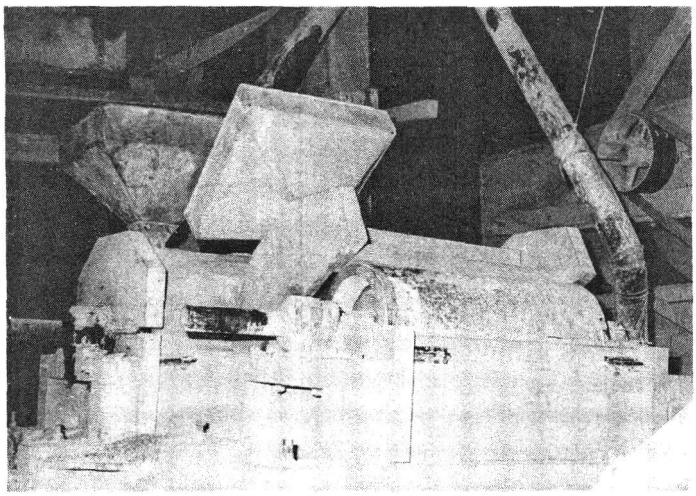

Fig.4. A commercial method of dehulling pulses using a roller machine in a *dhal* mill

and it works on the principle of abrasive action (Singh and Jambunathan 1990).

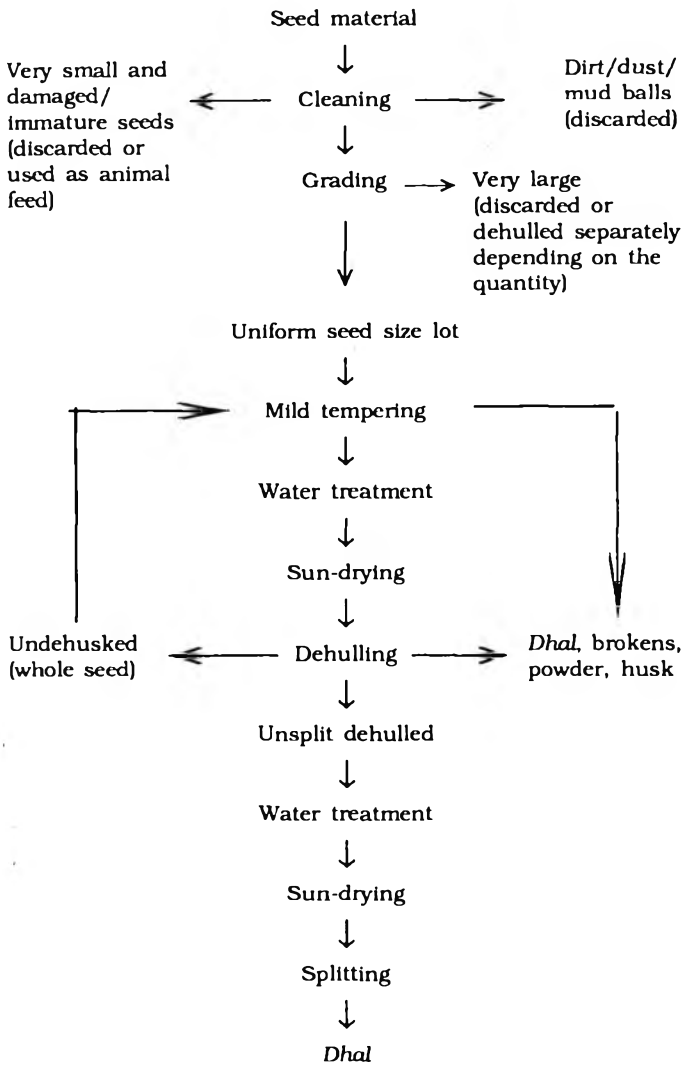

Fig.5. Chickpea dehulling procedure followed in Indian *dhal* mills

As shown in Fig. 5, there are several steps involved in the large scale processing of the pulses. The flow diagram described for chickpea (Fig. 5) is generally applicable for other pulses, excepting pigeonpea, which is processed in a different way (Fig. 6). In large scale processing of pulses, foreign material is first removed by sieving and exposure to fans. This removes soil, straw, pods, weed, and very small immature seeds (Singh and Jambunathan 1981). Then, seed material is graded into different sizes depending on the species. At least, seed lots are graded into two sizes, i.e., average and uniform seed size lots, which are processed, while very bold seed size lots are generally discarded or separately dehulled (Singh and Jambunathan 1981). After grading, the seed lots are passed through a roller machine, which causes a mild abrasion- the tempering operation. This tempering causes slight scratches on the seed coat, testa, and enhances their oil- and water-absorbing efficiency. The oil/ water treatment (Fig. 6) is commonly employed in

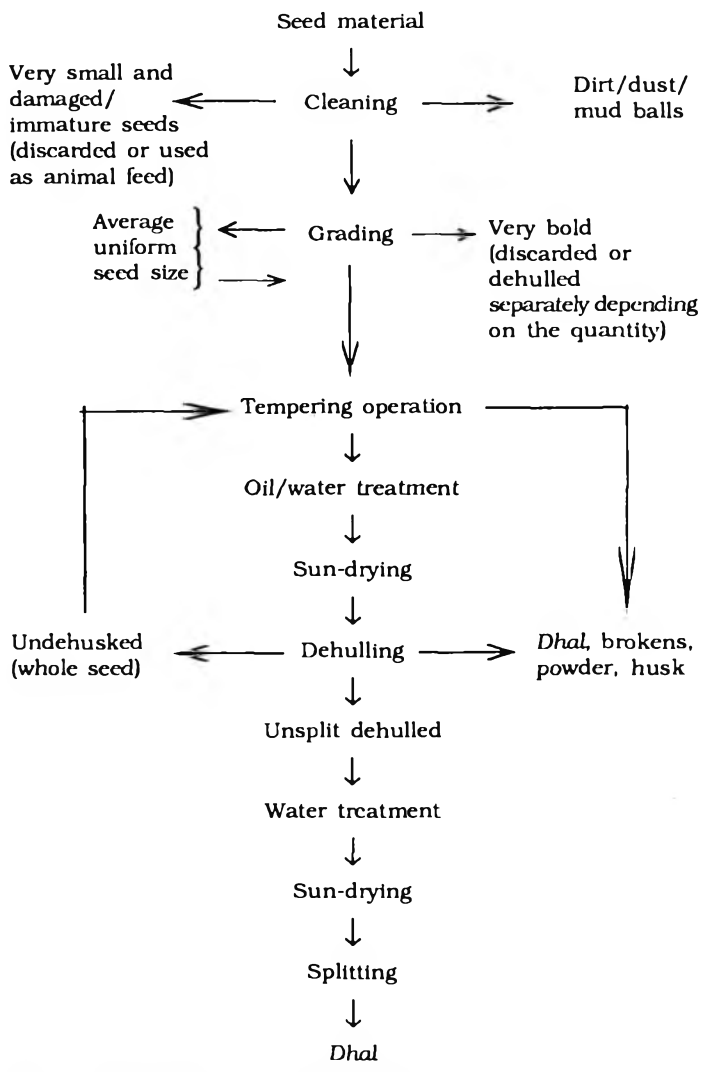

Fig.6. Pigeonpea dehulling procedure followed in Indian *dhal* mills

case of pigeonpea, whereas water treatment (soaking or moistening) is followed (Fig. 5) in case of other pulses, including chickpea (Singh and Jambunathan 1981). The material is then treated with oil and water and processed. After pre-treatments, pulses are dehusked in a similar way with a roller machine, and different fractions of dehulling are separated and collected.

Modern methods of dehulling : In recent years, efforts have been made to develop improved methods and machinery to process pulses more efficiently (Reichert et al. 1986) and economically as the traditional methods are laborious, time consuming, and incur heavy losses during dehulling (Singh and Jambunathan 1990). A new technology and machinery for dehulling pulses was developed at the Central Food Technological Research Institute, Mysore, India (Kurien 1981). According to this technique, loosening of the husk is achieved by an incipient toasting of the grain in a current of hot air, followed by tempering, when the seed coat is loosened (Kurien 1981). This technique is reported to be more suitable for dehulling pigeonpea, but can be used for other pulses also (Kurien 1981). However, the technique was not adopted by the commercial *dhal* millers because of its high cost of operation (Singh and Jambunathan 1990). Several machines developed for processing cereal grains can be used for dehulling pulses (Reichert et al. 1984). Although the attrition-type dehullers (*dhal* mills) are mostly suitable for dehulling coarse grain cereals, these can be conveniently used for dehulling some grain legumes (DeMan et al. 1973). The roller mills are more suitable for dehulling pulses (Singh and Sokhansanj 1984; Kurien 1984). Attrition-type dehullers and roller mills are particularly suitable for dehulling and splitting pulses with loose seed coats (Reichert et al. 1984), whereas abrasive type dehullers are more suitable for dehulling pulses with more tightly adhering seed coats (Reichert and Young 1976). Of late, efforts have been made to develop laboratory methods for dehulling and to identify genotypes with improved yield (Reichert et al. 1984; Ehiwe and Reichert 1987).

As shown in Fig. 7, an intermediate-sized, batch dehuller, capable of processing 2-8 kg of a wide variety of cereal and legume grains has been developed (Reichert et al. 1984). According to this technique, grains are dehulled by abrasion, provided by abrasive wheels (25 cm diam) mounted on a horizontal shaft. The tangential abrasive dehulling device (TADD) was reported to be suitable for studying variability in dehulling quality of cowpea, pigeonpea and *mung* bean cultivars (Ehiwe and Reichert 1987). More recently, Singh et al (1992b) compared the suitability of two laboratory methods, namely, barley pearler and the tangential abrasive dehulling device (TADD), to evaluate genotypic differences in dehulling quality of pigeonpea and both methods were found highly comparable and reliable.

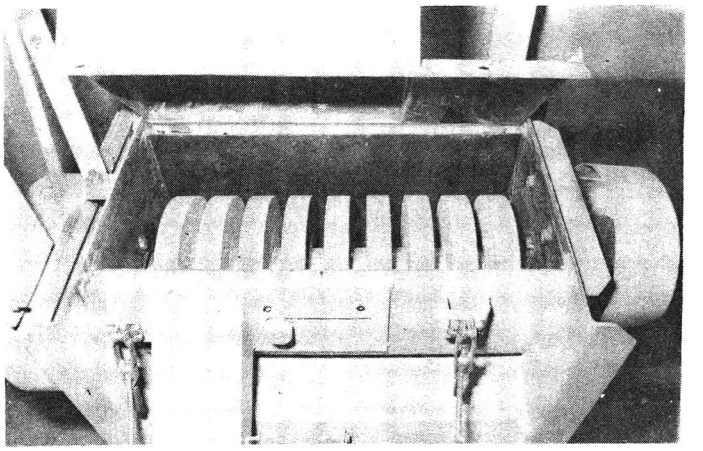

Fig. 7. New method of dehulling pulses using an intermediate-sized, batch dehuller.

Dehulling pre-treatments

In both small scale and large scale processing of pulses, two major operations are involved : a) loosening the seed coat from cotyledons, and b) removing the seed coat and splitting the cotyledons. The pre-treatments are generally employed to loosen the seed coats and these can be grouped into two categories : a) wet-treatments and b) dry-treatments.

Wet-treatment : This method of dehulling generally involves water soaking and sun-drying, and is common in many parts of India (Singh and Jambunathan 1981). According to this method, soaking and drying are considered as effective techniques to loosen the husk. The wet-method has the advantage of facilitating good dehusking and splitting of the cotyledons, giving less breakage, though it may adversely affect the cooking quality. The method is also labour intensive, and is completely dependent upon climatic conditions for drying the soaked seeds. The entire process usually takes about 5-6 days, and only limited quantities can be processed at any given time. *Dhal* produced by the wet-method tastes better, but takes longer time to cook (Kurien and Parpia 1968).

Soaking in water : A survey, conducted some time ago, indicated different types of soaking-pre-treatments for different pulses processed in different regions of India (Singh and Jambunathan 1981).

For chickpea, soaking in water is a common practice only in case of large scale processing i.e., *dhal* mills. This is commonly followed in the States of Punjab, Haryana, Rajasthan, and certain parts of Uttar Pradesh. For small scale dehulling of pigeonpea, different pre-treatments employed in different States are summarized in Fig. 3. The soaking of pigeonpea in water ranging from 2 to 14 h is a common practice in Maharashtra, Uttar Pradesh, and Madhya Pradesh. Soaking for longer period is preferred in certain regions, when pulses are processed in summer season. According to Kurien (1981), dehulling can be rendered more easy by prolonged soaking in water for 12 h or more, but the *dhal* remains uncooked and tough even on prolonged boiling. In some households, pigeonpea is first split using a *chakki*, then treated with water and finally hand-pounded to remove seed coat (Singh and Jambunathan 1981). Soaking in water, followed by coating with red earth slurry and sun-drying for several hours is a household practice for dehulling pigeonpea in some Southern States of India. Treatment with red earth is said to impart a good yellow colour to the finished product, possibly by preserving its natural colour.

Chemical treatment : The use of chemicals as pre-treatment to loosen the seed coats of pigeonpea has been reported. Reddy (1981) used sodium bicarbonate (5% solution), and reported an increase in *dhal* yield (75%). Krishnamurthy et al (1972) substituted *sirka* (vinegar) for vegetable oil in the dry milling process. These authors also tried sodium bicarbonate, sodium hydroxide, acetic acid, and ammonia as a replacement for vegetable oil in the traditional process and reported a considerable improvement in *dhal* yield, when sodium bicarbonate was used. Saxena et al (1981) treated pigeonpea grains with aqueous solutions of calcium hydroxide, sodium hydroxide, sodium bicarbonate, sodium carbonate or sodium chloride of different normalities. Normal sodium bicarbonate solution was reported to be the most effective, resulting in a *dhal* yield of 78%. These authors also recommended the use of sodium bicarbonate not only to loosen the husk, but also to reduce the cooking time of *dhal*. Srivastava et al (1988) have also reported high dehusking efficiency, when sodium bicarbonate was used as a soaking solution (Table 1).

Dry-treatment : This method of dehulling is more applicable for chickpea dehulling by stone *chakki* and for pigeonpea dehulling by *dhal* mill. Dry-method of dehulling is said to produce *dhal* that cooks faster than the *dhal* produced by the wet-method (Kurien and Parpia 1968). The major disadvantage of the dry-method is the high dehulling losses due to breakage and powdering. In the dry method, oil/water application, followed by sun-drying, are the important steps, which are involved in processing of pulses.

TABLE 1. EFFECT OF SOAKING ON DEHULLING EFFICIENCY (%) ON PIGEONPEA SEEDS[a]

Cultivar	Control	Pre-soaking treatment			
			$NaHCO_3$, %		
		Water	4	6	8
'UPAS'	65.4	66.3	71.1	81.3	77.2
'T 21'	70.4	71.2	87.2	80.5	80.3
'Pant A 3'	69.1	72.3	80.8	74.2	82.5
'Pant 10'	74.6	77.8	87.2	88.1	85.3

a. Seeds were soaked in water or sodium bicarbonate solution for 1 h at room temperature, and oven-dried at 65°C for 150 min to obtain 10% moisture content. Source : Srivastava et al (1988)

Oil-treatment : The application of edible oil, as a pre-treatment, is mostly confined to pigeonpea, where seed coat is more tightly bound to the cotyledons, as compared to other pulses. This treatment is generally followed in case of large scale dehulling of pigeonpea by the commercial *dhal* mills. After tempering operation, grains are thoroughly mixed with about 1% oil (preferably linseed), either manually or in a worm mixer, and the oiled-grains are then sun-dried for 2-3 days. Oil appears to penetrate through the husk to the cotyledons and releases its binding under the mild heat of the sun. This loosening process may be slow, but the husk can be totally loosened, if the treatment is extended to several days. In certain parts of India, oil and turmeric powder as a pre-treatment are also given in case of small scale dehulling of pigeonpea.

Heat-treatment : It was reported that pre-treatment of pigeonpea seed with hot air at 120-180°C was quite effective in loosening the seed coat (Kurien 1981). This could be achieved in conditioning chambers, where the grain temperatures are 70-95°C, depending on the cultivar. In some parts of Uttar Pradesh, villagers use sand roasting at 100-125°C for 5-10 min, as a pre-treatment to improve the *dhal* yield in pigeonpea (Singh and Jambunathan 1981). The heating of pigeonpea seed in a pan (150°-200°C for 2-3 min), with or without sand before dehulling in stone *chakki*, is also followed in certain parts of Uttar Pradesh.

Seed characteristics that affect dehulling

Several seed characteristics affect the dehulling efficiency in terms of loosening the seed coat, and

TABLE 2. VARIABILITY IN SEED COAT CONTENT OF DIFFERENT PULSES

Pulse	Number of genotypes	Range	Mean	Reference
Chickpea, *desi*	21	9.7 - 17.3	14.2	Kumar and Singh (1989)
Chickpea, *kabuli*	19	3.7 - 7.0	4.9	Kumar and Singh (1989)
Pigeonpea	22	12.6 - 17.2	14.4	Sharma et al (1987)
Mung bean	24	7.4 - 11.4	8.8	Ehiwe and Reichert (1987)
Urd bean	5	8.9 - 11.6	10.4	Uma (1993)
Lentil	6	7.0 - 8.0	7.2	Williams et al (1992)

govern the *dhal* yield and nutrient losses in different pulses. In this context, interaction of pre-treatments of dehulling and the seed characteristics play an important role in determining the dehulling quality.

Nature of seed coat : Generally, it is expected that *dhal* yield would depend on the seed coat content - higher the seed coat, lower will be the *dhal* yield. As shown in Table 2, mean seed coat ranges between 4.9 and 14.4% for different pulses, indicating a large variability. This would significantly affect the expected *dhal* yields. The theoretical yields of dehulled grain, primarily determined by subtracting the seed coat content from the seed mass, are generally higher than those obtained by the mechanical methods (Table 3). However, there was no correlation between the theoretical *dhal* yield and the *dhal* yields obtained by mechanical methods in pigeonpea, thereby implying that dehulling machinery and methodology would play a greater role in determining the *dhal* yields (Singh et al. 1992).

Dehulling characteristics are to some extent governed by seed morphology and anatomy, which vary immensely among legumes (Singh et al. 1984, and Reichert et al. 1984). In pulses, cell arrangements of seed coats are very different and these could influence dehulling characteristics. The seed coat in cowpea consists of highly organized palisade cell structure. Sefa-Dedeh and Stanley (1979) suggested that cowpea varieties with thick, smooth seed coats (highly organized palisade cells) dehulled more satisfactorily than those with thin, rough seed coats. In *kabuli* chickpeas, the outermost layer (epidermis) develops into a uniseriate palisade layer without thickening of the cell wall, whereas in *desi* chickpeas, it develops into a multiseriate palisade layer, which later becomes thick-walled sclereids, heavily stainable with toluidine blue (Singh et al. 1984). This would probably explain that dehulling of *desi* varieties (generally smaller seeded and brown seed coat) is easier than *kabuli* varieties. Further, the chemicals associated with the seed coat such as gums and non-starchy polysaccharides, present in the interspace between the husk and cotyledons, have been implicated in the adherence of husk to the cotyledons, thereby making the dehulling operation difficult (Ramakrishnaiah and Kurien 1983).

Physical characteristics of grains : Seed size is the most important factor affecting the dehulling process in pulses (Ehiwe and Reicher 1987; Singh et al. 1992b). Seed size is a varietal characteristic, which can be strongly influenced by growing season and location of pulses (Erksine et al. 1985; Williams and Singh 1987; Ehiwe and Reichert 1987). Seed size affects the efficiency of dehulling and splitting of cotyledons. Dehulling efficiency is negatively and significantly correlated with seed size in *mung* bean and cowpea (Ehiwe and Reichert 1987). As shown in Table 4, pigeonpea *dhal* yield obtained by TADD and barley pearler was negatively correlated with grain volume and seed size, implying that bolder grains would reduce the *dhal* yield (Singh et al. 1992). Although the magnitude of correlations was low, grain hardness was negatively correlated (Singh et al. 1992) with TADD and barley *dhal* yields (Table 4). This implies that hard grain genotypes of pigeonpea would produce lower *dhal* yield. It has been shown that greater than 75% of the variability in dehulling efficiency or *dhal* yield could be accounted for by grain hardness and resistance to splitting of the grain into individual cotyledons (Reichert et al. 1984). Further, swelling capacity and floatation values of pigeonpea genotypes were not correlated with the *dhal* yield obtained by different methods (Singh et al. 1992). The splitting is as important as dehulling for commercial *dhal* mills and household dehulling by stone *chakki* (Singh and Jambunathan 1990). The larger seeds split

TABLE 3. *DHAL* YIELD (%) ACHIEVED BY DIFFERENT PROCESSING METHODS

Pulse	Stone *chakki*[a]	*Dhal* mill[a]	Max (thermetical)[b]
Chickpea	70.8	80.0	85.8
Pigeonpea	61.0	70.1	85.6
Mung bean	65.0	74.0	89.2
Urd bean	70.5	73.5	89.6
Lentils	66.4	75.0	92.8
Mean	66.7	74.5	88.6

[a] Based on survey data of household practices and *dhal* mills.
[b] Calculated by subtracting the values on seed coat percentage as given in Table 2.

TABLE 4. CORRELATION COEFFICIENT BETWEEN PHYSICAL CHARACTERISTICS AND *DHAL* YIELD OF PIGEONPEA GENOTYPES.

	1	2	3	4	5	6	7	8
Moisture	1.00							
100-seed mass	- 0.38	1.00						
Grain volume	- 0.28	0.94**	1.00					
Floatation value	- 0.10	- 0.36	- 0.28	1.00				
Swelling capacity	- 0.17	0.05	- 0.07	0.46	1.00			
Grain hardness	- 0.20	0.81*	- 0.72*	- 0.29	- 0.11	1.00		
Dhal yield[a]	- 0.03	- 0.76*	- 0.82*	0.24	- 0.12	- 0.65	1.00	
Dhal yield[b]	- 0.20	- 0.67	- 0.71*	0.36	- 0.16	- 0.57	0.97**	1.00

[a] *Dhal* yield by TADD, [b] *Dhal* yield by barley pearler. Source : Singh et al (1992b).

more readily than smaller seeds and reduce the requirement for recycling (Williams et al. 1993). On the other hand, if the dehulling equipment, roller machine or stone *chakki*, is not properly set up, large seeds are most likely to incur breakage, resulting in heavy losses during dehulling (Singh and Jambunathan 1981). These workers further suggested that uniform and medium seed size of pigeonpea would improve the efficiency of dehulling. Very small to small seeds are more difficult to dehull and split and require several recycling steps and are, therefore, not generally preferred by *dhal* millers. Williams et al (1993) reported that efficiency of dehulling and splitting of lentil is favoured by large seed size, thin testa, short storage period and correct wetting and drying practices. Further, they reported that very bold seeds are not accepted in *dhal* mills, because heavy losses are incurred due to broken seeds.

Like seed size, seed shape is a varietal characteristic in pulses (Erskine et al. 1985; William and Singh 1987). This characteristic is generally not affected by growing environment. The rounder the seeds, the better they are for dehulling (Singh and Jambunathan 1990). Very angular seeds lose excessive amounts during the dehulling, because the dehulling process attacks sharper edges preferably and more seed mass is removed from flatter seeds (Williams et al. 1993). As a result, the flatter the seeds, the higher the amount of powder and brokens, i.e., small pieces of cotyledons. In addition, rounder seeds split more readily than flatter seeds, thus improving the efficiency of dehulling/splitting (Kurien 1984). *Dhal* yield is affected by seed size and shape of lentils (Williams et al., 1993). According to these workers, the rounder, (i.e., less lenticular) the seeds, the better they are for dehulling and *dhal* milling.

In addition, several environmental factors may influence the *dhal* yield from pulses. Variations in milling characteristics of pigeonpea, as influenced by variety and agroclimatic conditions, have been reported (Ramakrishnaiah and Kurien 1983). According to a survey report, location and maturation of pigeonpea, which influence seed size, shape and grain hardness would directly affect the *dhal* yield in small and large scale processing operations (Singh and Jambunathan 1981). Further, this report indicates that the farmers feel that pigeonpeas grown on light soils have better dehulling and cooking qualities (Singh and Jambunathan 1981). Some *dhal* mill owners also have preferences in seed colour, favouring white pigeonpea for two reasons : 1) *dhal* yield is better when compared with other pigeonpeas, 2) *dhal* with a lesser degree of dehusking, but less visible white spots of leftover husk, can be sold in the market at a higher price than *dhal* obtained from coloured seeds.

Comparison of dehulling methods

Several methods are used to dehull pulses and numerous factors influence the efficiency of the methods. Although it is difficult, some efforts have been made to compare different methods in the

TABLE 5. *DHAL* YIELD OF PIGEONPEA GENOTYPES OBTAINED BY DIFFERENT METHODS OF DEHULLING

Genotype	*Dhal* yield, %			
	MNM	SNC	BRP	TADD
'C 11'	85.8	45.6	71.8	75.7
'BDN 2'	85.2	49.9	66.9	76.7
'T 15-15'	88.4	51.4	73.2	78.5
'ICPL 87049'	86.4	46.7	55.6	54.1
'ICPL 87052'	86.6	54.0	73.7	80.0
'ICPL 87053'	85.9	42.6	72.5	75.5
'ICPL 87066'	88.2	54.5	57.6	56.6
'ICPL 87075'	87.0	59.0	69.2	73.5
Mean	86.7	50.5	67.6	71.3
SEM	± 0.36	± 1.84	± 0.51	± 0.28

MNM = manual method, SNC = stone *chakki*, BRP = barley pearler, TADD = tangential abrasive dehulling device. Means of three independent determinations. Source : Singh et al (1992b).

TABLE 6. *DHAL* YIELD LOSSES IN CHICKPEA AND PIGEONPEA

Pulse		Large scale processing		Small-scale processing	
		Range	Mean	Range	Mean
Chickpea[a]	*Dhal*	75.0 - 85.0	80.0	50.0 -80.0	70.8
	Brokens	1.0 - 5.0	2.6	5.0 -20.0	8.6
	Powder	5.0 - 10.0	6.7	7.0 -20.0	7.0
	Husk	8.0 - 14.0	11.8	10.0 -20.0	13.5
Pigeonpea[b]	*Dhal*	60.0 - 85.0	70.1	50.0 -80.0	61.0
	Brokens	2.0 - 10.0	4.4	5.0 -20.0	10.6
	Powder	9.0 - 18.0	12.8	7.0 -20.0	12.6
	Husk	8.0 - 25.0	12.9	10.0 -25.0	15.2

[a] Based on 20 respondents in large-scale and 60 respondents in small scale processing in Punjab, Haryana, Rajasthan, and Maharashtra. [b] Based on 46 respondents in large scale and 136 respondents in smallscale processing in Madhya Pradesh, Maharashtra, and Uttar Pradesh. Source : Singh and Jambunathan (1981).

laboratory using the same varieties of pigeonpea (Singh et al. 1992b). Excluding manual method, average *dhal* yield (Table 5) was the highest (71.3%) in TADD, followed by barley pearler (67.6%), and the lowest in stone *chakki* (50.5%). The average *dhal* yield of pigeonpea genotypes analyzed by TADD is comparable with that of the commercial *dhal* mills (70.1% *dhal*) in India (Table 6), but is considerably lower than that of the improved commercial dehulling method developed for dehulling of pigeonpea (Kurien 1981). The value for *dhal* yield was the highest (80.0%) for 'ICPL 87052', and the lowest (54.1%) for 'ICPL 87049', when dehulled in the TADD (Singh et al. 1992b). Similar variations in *dhal* yield of these genotypes were observed, when dehulled by using the barley pearler (Table 5). A statistical comparison between dehulling methods indicated that the standard error (SE) and coefficient of variation (CV) of the procedures were the highest for stone *chakki* and the lowest for TADD. Not only did the stone *chakki* produce the highest percentage of brokens as dehulling losses (Table 6), it also led to highly variable and erroneous results on the *dhal* yield. Further, *dhal* yield obtained by a stone *chakki* was neither correlated with TADD nor with the barley pearler (Singh et al. 1992b). But, there were significant and highly positive correlations between TADD and barley pearler for *dhal* yield and broken fractions. These results indicate that, depending on the availability, either of these two methods could be used to evaluate the dehulling quality of pulses. Saxena et al (1993) reported that a metal *chakki* (similar to stone *chakki*) may be suitable for small scale processing of pigeonpea in Sri Lanka.

Dehulling losses

The primary objective of dehulling is to remove the seed coat from the cotyledons, but noticeable amounts of cotyledons and germs are removed during the operation (Aykroyd and Doughty 1964; Siegel and Fawcett 1976). As a result, considerable quantitative and qualitative losses occur during dehulling of pulses. The dehulling losses would primarily depend on the dehulling methods and seed characteristics of pulses (Matanhelia 1994). The dehulling losses in terms of brokens were the highest (24.6%) in the stone *chakki* and this might have been due to the attrition action of the stones employed for dehulling in this method (Singh et al. 1992b). In commercial *dhal* mills, *dhal* yields only approach 70%, which are much lower than the theoretical *dhal* yields (Natarajan and Shankar 1980). Parpia (1973) reported that the average *dhal* yield from household and traditional commercial dehulling methods varied from 68 to 75%, which was 10 to 17% less than the theoretical average value of 85%. Table 6 summarizes the survey data on dehulling losses in terms of powder, broken and husk fractions in case of *dhal* yield of chickpea and pigeonpea obtained by large and small scale dehulling methods. This study reports that *dhal* yields are higher in chickpea than in pigeonpea. Further, *dhal* yield in pigeonpea varies between 50% and 80% with a mean of 61% in small scale and between 60 and 85% with a mean of 70.6% in large scale processing. Similar figures were

TABLE 7. EFFECT OF DEHULLING ON THE CHEMICAL CONSTITUENTS OF *DHAL* AND POWDER FRACTIONS OF CHICKPEA (CV. 'ANNIGERI') AND PIGEONPEA (CV. 'C11')

Dehulling time, min	*Dhal*			Powder		
	Protein, %	Calcium, g.100 g^{-1} sample	Iron, %	Protein, %	Calcium, g.100 g^{-1} sample	Iron, %
0	18.6[a]	43.0	5.7	-	-	-
	21.4[b]	64.9	5.7			
2	18.0	39.5	5.0	23.6	85.0	12.0
	20.8	51.7	4.1	31.2	167.8	17.3
4	17.5	38.0	4.8	21.8	65.5	10.5
	19.6	45.7	3.6	27.1	94.1	9.2
8	17.5	36.5	4.3	19.8	45.0	8.5
	19.6	45.7	3.6	27.1	94.1	9.2
12	16.4	35.0	3.8	18.9	45.0	7.0
	20.3	51.1	4.0	29.7	118.8	11.9
SEM	± 0.18	± 1.80	± 0.40	± 0.21	± 2.90	± 0.30
	± 0.17	± 2.83	± 0.19	± 0.15	± 2.00	± 1.63

[a] Chickpea, [b] Pigeonpea. All units are averages of two replicates, and expressed on a moisture-free basis. Source : Singh et al (1989, 1992a)

noticed for chickpea (Table 6). This indicates that dehulling losses are significant, and vary with the scale of operation and the pulse crop. The highest *dhal* yield was reported to be obtained from a modern *dhal* mill, where material is heated in the hot air before dehulling (Kurien 1981). High *dhal* yield in small scale processing of pigeonpea was also obtained by stone *chakki*, when material was heated in an open-pan before dehulling (Singh and Jambunathan 1981). Losses in terms of brokens, and powder fractions are higher, when a village *chakki* is used, i.e., in small scale processing. *Dhal* yields obtained by household dehulling practice are noticeably lower than those obtained by the large scale dehulling from commercial *dhal* mills (Table 6). When four methods of dehulling were compared, the yields were the highest in dehulling by the tangential abrasive dehulling device (Singh et al. 1992b). Significant differences were observed in dehulling characteristics of cowpea, pigeonpea, and *mung* bean (Ehiwe and Reichert 1987). This study further reported that dehulling quality was generally poor, because of low yield and long dehulling time in *mung* bean.

Effect of dehulling on nutrient losses

Proper dehulling of pulses for human nutrition essentially relates to efficient separation of the seed coat from the cotyledons (Aykroyd and Doughty 1964). Most common methods of dehulling of legumes remove the germ along with the husk and thereby incur losses of vitamins and proteins, the important dietary constituents (Aykroyd and Doughty 1964). As shown in Table 7, there was a decrease in protein, calcium and iron contents of *dhal* of chickpea and pigeonpea with an increase in dehulling time (Singh et al. 1989, 1992a). This indicated that outer portions of cotyledons were richer sources of protein, calcium and iron. When the outer layers of the cotyledons of pigeonpea are scarified, there is a 12% yield loss known as the powder fraction (Singh et al. 1989), which is a rich source of protein, calcium and iron (Singh et al. 1989). This loss is assumed to be an equivalent of traditional dehulling in terms of quantitative losses of powder fraction. Considerable amounts of calcium (about 20%) and iron (about 30%) were removed by scarification in dehulling of pigeonpea (Singh et al. 1989). A similar observation was noticed in chickpea, where considerable amounts of calcium, iron and zinc were removed by dehulling for 4 min (Singh et al. 1992a). This study further reported that dehulling of chickpea may not affect the protein quality in terms of amino acids. The outer layers of pigeonpea cotyledons are rich sources of proteins (Reddy et al. 1979). These layers are removed during dehulling, resulting in considerable protein losses. Singh et al (1989) reported that calcium and iron were concentrated in the outer layers of cotyledons and would be lost during dehulling. Protein, calcium, and iron are important nutrients, which are deficient particularly in the diets of, infants, pre-school children and pregnant and lactating women of low income group. Losses of protein, calcium and iron in such processing practices of pulses will lead to further deficiencies among these vulnerable groups.

Effect of dehulling on cooking time of *dhals* of pulses

The cooking time of *dhals* of pulses is influenced by dehulling method (Singh 1987). This review has reported that there may not be a direct effect of the dehulling machines on the cooking time. It is not the mechanical action of the roller machines or disc shellers that influence the cooking time, but the pre-treatments given to pigeonpea seeds before dehulling that considerably influence the cooking time (ICRISAT 1981). Soaking the seeds in water and subsequent sun- or oven-drying increases the cooking time in grain legumes (Paredes-Lopez et al. 1991). As reported in Table 8, soaking and oven-drying (65°C overnight) of pigeonpea seeds before dehulling considerably increased the cooking time, as compared to the control i.e., untreated seed used for dehulling. Further, it was observed that while soaking the whole seed in water increased the cooking time of *dhal*, soaking in 1% solution of sodium carbonate decreased it considerably. This study was conducted by dehulling the pre-treated seeds in the tangential abrasive dehulling device (ICRISAT 1981). According to this study, not only differences in cooking time of *dhal* due to genotypes and pre-treatments were significant, interactions between genotypes and pre-treatments on cooking time were also significant. This implies that genotypes will also play an important role in influencing the cooking time due to pre-treatments. Eventhough it is very difficult, such studies on the effect of pre-treatments should be conducted on *dhal* prepared by the commercial *dhal* mills.

Varietal differences in dehulling quality

As shown in Table 8, a large variability existed in dehulling quality of *mung* bean, cowpea, chickpea, and pigeonpea cultivars, as determined by the

TABLE 8. THE COOKING TIME (Min) OF PIGEONPEA *DHAL* OBTAINED BY VARIOUS PRE-TREATMENTS BEFORE DEHULLING

Cultivar	None	Pre-treatment procedures[a]			
		Oil (1% w/w)	Water (1%w/v)[b]	NaCl (1% w/v)[b]	Na_2Co_3 (1% w/v)[b]
'BDN-1'	20	20	26	20	16
'C 11'	16	20	24	20	16
'No 148'	16	16	20	14	12
'LRG-30'	16	18	22	18	14
'LRG-36'	14	18	24	14	12
SEM ±	1.0	0.8	0.9	1.0	0.7

[a] After pre-treatments, samples were dried at 65°C overnight before dehulling in tangential abrasive dehulling device (TADD). [b]Stored for 6 h.

tangential abrasive dehulling device (Ehiwe and Reichert 1987; Singh et al. 1992b). Pigeonpea varieties exhibited less variations in dehulling characteristics than cowpea varieties (Ehiwe and Reichert 1987). The *dhal* yield (47.8-90.2%) and dehulling time of cowpea genotypes varied widely, suggesting that it may be desirable to monitor these characteristics in a cowpea breeding programme. The dehulling quality of the *mung* bean cultivars was generally poor, because of low yields and long dehulling time (Ehiwe and Reichert 1987). These workers suggested that resistance to seed splitting during dehulling and a loosely bound state of seed coat to the cotyledons were the major seed factors responsible for good dehulling quality of these legumes. Variations in the degree of dehusking obtained with different pigeonpea varieties are possibly the result of varying extents of loosening of husk from the cotyledons after pre-milling treatments (Ramakrishnaiah and Kurien 1983). These workers reported that degree of dehusking of pigeonpea varieties ranged between 67.1% and 100.0%. Different varieties of pigeonpea displayed varying dehulling characteristics, independent of their size and husk contents, but were greatly influenced by other varietal characteristics, like quantity of germs and moisture level of grain (Ramakrishnaiah and Kurien 1983). In a recent study, *dhal* yield of pigeonpea genotypes ranging from 54.1% to 80.0% was reported (Singh et al. 1992b). This study also reported that some newly developed varieties of pigeonpea showed very good dehulling quality. Kurien and Parpia (1968) reported that smaller seeded varieties of pigeonpea grown in North India produced lower *dhal* yield, because the seed coats were firmly attached to the cotyledons. Parpia (1973) reported that *dhal* yields of white pigeonpeas were considerably higher than those of the red pigeonpeas. However, a recent study indicated no correlation between *dhal* yield and seed colour of pigeonpea varieties, thereby suggesting that the seed colour may not influence the dehulling quality of pigeonpea (Singh et al. 1992b).

TABLE 9. VARIABILITY IN *DHAL* YIELD OF DIFFERENT PULSES[a]

	Number of genotypes	*Dhal* yield	
		Range	Mean
Cowpea	11	47.8 -90.2	76.0
Chickpea[b], *desi*	58	71.1 -87.3	79.5
Chickpea[b], *kabuli*	12	89.6 -93.8	91.4
Pigeonpea	23	79.0 -83.8	81.8
	10[c]	54.1 -80.0	71.3
Mung bean	24	58.2 -73.8	65.2

[a]All *dhal* yield values were obtained by using the tangential abrasive dehulling device (TADD). [a] Source : Ehiwe and Reichert (1987). [b] Source : Singh 1993 (unpublished). [c] Source : Singh et al (1992b).

Dhal yield of *desi* varieties of chickpea ranges between 71.1% and 87.3% and of *kabuli* varieties between 89.6 and 93.8% (Table 9). *Dhal* yield of *kabuli* varieties are generally higher than those of the *desi* varieties, because of their lower seed coat content. From the results of the above mentioned studies (Table 9), it is apparent that large variability exists in dehulling quality of different varieties of grain legumes. However, such a variability has not been used in the breeding programme to develop high *dhal* yielding varieties. It is also apparent that dehulling quality of pigeonpea has been the subject of several studies in the past. More efforts are needed to study this aspect in other pulse crops.

Future research needs

The greatest potential for providing high protein pulse food products to a large number of vegetarian population living in developing countries is by means of improving production and processing of these crops. There are possibly two approaches to improve the processing and consequently, the *dhal* yield in pulses : 1) development of suitable method and machinery for dehulling and 2) identification and development of suitable varieties of pulses with high dehusking efficiency. Over 90% of the pulses produced in the country are dehulled by the traditional methods. So far, the dehulling technology developed by the research organizations have not become popular with the users, primarily for economic reasons. Now, it is highly desirable that research and development activities must be geared towards developing efficient and economical methods

for dehulling. Since ages, stone *chakki* has been used for dehulling. It is high time to replace it by a suitable dehulling unit that could be conveniently adopted by the households in villages. Suitable mini *dhal* mills should be developed so that these could be used by the cooperatives and other organizations engaged in similar activities. For this purpose, attrition type (disc sheller) or abrasion type (roller machine) should be thoroughly compared and investigated for their efficiency for dehulling different pulse crops.

The genotypic differences exist in the dehulling quality of pulses, and these have to be exploited by the plant breeders. Efforts are needed to investigate the physical and chemical nature of seed coat of different pulses in the light of differences in their dehulling characteristics, and to develop improved varieties. Also, it is desirable to develop varieties with uniform and round seed shape to increase *dhal* yield. The identification and development of varieties with improved dehulling characteristics must receive increasing attention in the future.

Improved crop value will ultimately depend on the commodity characteristics assessed by processors and consumers. Pre-treatments of dehulling should be refined and further developed as suitable processing package not only to improve the *dhal* yield, but also improve its acceptance and nutritive value. To reduce nutrient losses, efforts should be made to develop suitable methods to separate husk from the cotyledons, and to avoid the splitting step to save the germ portion, which is a rich source of vitamins.

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Received 23 July 1994; revised 2 January 1995; accepted 4 January 1995

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 94-97

Surface Heat Transfer Coefficient of Faba Bean (*Vicia faba.* L) Puffed with Sand

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An unsteady state heat transfer analysis was made on faba bean grain, while it was being manually agitated inside heated sand. The analysis considered faba bean grain as short cylinder, with heat transfer taking place along the radial as well as axial directions. The studies involved 'JV-2' variety of faba bean at four levels of moisture content (15, 25, 30 and 35% d.b) and at four levels of sand temperature (200, 210, 220 and 230°C). Estimated values of thermal properties of faba bean grain indicated that the value of heat transfer coefficient on the grain surface was more along the axial direction, as compared to the radial direction.

Keywords : Unsteady state, Heat transfer coefficient, Thermal conductivity, Fourier's number, Biot number, Temperature ratio.

Dry cooking of foods includes puffing, toasting and roasting (Paulus 1984). Among these, puffing of legumes is practised all over India (Pratape and Kurien 1986), as puffed legumes are very popular snack foods. Pratape and Kurien (1986) have standardized the puffing of *Bengal*gram and reported that varietal as well as agroclimatic factors, physico-chemical properties and husk of the grain plays a crucial role in puffing. In the process of puffing, foodgrain is heated in puffing medium (usually sand), where heat transfer takes place from the medium to the product and within the product (Das and Shrivastava 1989). Foodgrain at a particular moisture content and temperature puffs-off i.e., the vapour pressure of water within the grain develops so high that the grain can no longer hold it in vapour form .and it comes out with an explosion (Sahu 1988). In some cases, the processing conditions have been worked out (Murugesan and Bhattacharya 1986). Pre-conditioning of grain with moisture and subsequent heating helps the grain to retain moisture to a pressure higher than the atmospheric pressure and these two steps probably bring about some changes in the surface starch and block surface pores, thereby resulting in the retention of moisture inside the grain to a higher pressure (Das and Shrivastava 1989).

Heat transfer coefficient data of heat transferring medium and thermophysical properties of the grain are important to understand the entire heat transfer mechanism during cooking (Paulus 1984). Biot number (Bi = hx/k), a ratio of heat transfer coefficient at the surface and heat conductance to the centre of solid (Earle 1966), helps in understanding the unsteady state heat flow. When Biot number is small (< 0.1), the interior of the solid and its surface may be considered to be all at one uniform temperature (lumped parameter approach), while high Biot number (> 0.1) refers to the existence of temperature gradient within the solid (Earle 1966). Surface heat transfer coefficient (72 $w/m^2°C$) of rice puffed in agitated sand medium was reported by Das and Shrivastava (1989), when computed as assumed value of 'h' for faba bean. Then, the Biot number is ($72 \times 3.3 \times 10^{-3}/0.23$) =1.03, which is 10 times larger than the limit specified for lumped parameter approach. Thus, there exists a significant variation of temperature within the faba bean grain during puffing in agitated hot sand. Hence, temperature gradient at the surface of the grain will not be equal to the temperature of the sand and a convective resistance to heat transfer will be present. The present investigation was undertaken to find the convective heat transfer coefficient on the surface of faba bean in an agitated sand bed during puffing.

Materials and Methods

Cleaned and graded faba bean seeds ('JV-2') at 10.5% (d.b.) moisture content were obtained from the Department of Plant Breeding and Genetics of the Vishwa Vidyalaya. Four levels of moisture contents (15,20,30 and 35±1% d.b.) of grain and four levels of puffing temperature (200, 210, 220 and 230±1°C) were considered for the puffing experiment. The initial moisture contents of faba bean seeds were adjusted by following the method of Kulkarni et al (1993).

Puffing of faba bean seeds was done, 48 h after the pre-conditioning process, in an open aluminium pan with a grain to sand (30 mesh B.S.) ratio of 1:10. The heating was carried out using a liquified

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petroleum gas burner. Sand in the pan was manually agitated with a stainless steel ladle. Two thermometers (mercury-in-glass) were used separately to record temperature of hot sand and temperature of product. When sand attained the desired temperature, the gas burner was turned off and the faba bean seeds (50 g) were added. The seeds were vigorously agitated and a stopwatch (least count 0.1 second) was used for noting the time required for the start and finish of puffing. For the analysis of heat transfer, the average values of these two times were calculated. After completion of puffing, the faba bean - sand mixture was poured on a sieve for separating the puffed product from the sand. The size of sieve was large enough to sieve-off the sand almost instantaneously. The puffed faba bean was quickly collected at one corner of the sieve and the tip of the thermometer (0-100°C, least count 0.1°C) was inserted in to the centre of the heaped mass of faba bean for recording maximum indicated temperature. This temperature was considered as the temperature, at which the puffing of faba bean took place. Thermal properties, i.e., thermal conductivity (k) and thermal diffusivity (α) of faba bean were estimated, based on weighed average of the respective values for moisture and dry solid present in the grain (Loncin and Merson 1979).

Heat conduction in faba bean : In the present investigation, faba bean seed has been considered as short cylinder (Fig. 1), as the length (average 8.54 x 10^{-3}m) of the seed is little more than the width (average 6.58 x 10^{-3}m). In such a situation, the principle of superposition, i.e., to combine the solution for one dimensional heat conduction in the X and Y directions in to an overall solution for simultaneous conduction in two directions is applicable (Geankoplis 1978). In short cylinder with

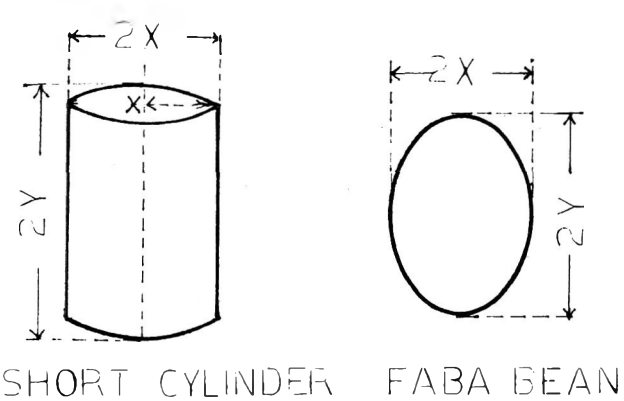

Fig. 1. Two dimensional unsteady state conduction heat transfer in short cylinder.

radius X, and length 2Y, the heat transfer occurs both in radial and axial directions. Hence, one dimensional heat conduction in the X direction is given (Geankoplis 1978);

$$\frac{\delta T}{\delta t} = \frac{\alpha \delta^2 T}{\delta x^2}$$

Similarly, one dimensional heat conduction in Y direction could be specified.

Faba bean seed has low thermal conductivity (K<1) and, when exposed to high heat transfer condition during puffing, results in temperature gradient within the seed. Thus, 'T' is not just a function of time (t), but 'T' (t, x, y) and then, the analytical solution becomes too complicated. Hence, use of Hessler's chart (Geankoplis 1978), which gives various values of temperature ratio (θ) at various Fourier number $\left\langle N_{FO} = \frac{\alpha t}{x^2} \right\rangle$ and Biot number (Bi), can be a simple and convenient procedure for determining the value of heat transfer coefficient. For short cylinder, data on radial (θ_x) and axial (θ_y) conductions are obtained from the Hessler's chart for cylinder and plate separately (Geankoplis 1978). Then, simultaneous transfer in both direction becomes;

$$\theta_{x,y} = (\theta_x)(\theta_y) = \frac{T_1 - T_{x,y}}{T_1 - T_0}$$

Where $T_{x,y}$ is the temperature at t and position X and Y respectively, Hence :

$(N_{FO})_x = \alpha t/x^2$ is the Fourier's number in the X direction

$(N_{FO})_y = \alpha t/y^2$ is the Fourier's number in the Y direction

Having obtained the values of $(N_{FO})_x$ and $(N_{FO})_y$, the line of 1/Bi could be located at each value of θ in the Hessler's chart. From the corresponding value of 1/Bi (k/h.x or k/h.y), the value of surface heat transfer coefficient is calculated for radial (h_r) and axial (h_l) direction.

Results and Discussion

Physical and thermal properties of faba bean seed : Length and diameter of faba bean seed vary with levels of initial moisture content. Mean diam and length were 6.58, 6.99 and 8.55 and 9.08 x 10^{-3}m, respectively, at 15 and 35% (d.b.) moisture.

Thermal conductivity (k) and thermal diffusivity (α) were estimated at the mean of initial grain

TABLE 1. THERMAL PROPERTIES OF FABA BEAN AT VARIOUS LEVELS OF MOISTURE CONTENT AND MEAN TEMPERATURE

Moisture content, % d.b	Mean temperature, °C	k_0, w/m°C	α, m^2/s
15	76.00	0.23	1.00×10^{-7}
25	71.56	0.28	1.07×10^{-7}
30	69.42	0.30	1.10×10^{-7}
35	66.66	0.33	1.14×10^{-7}

temperature (25°C) and the average temperature of the product and the initial moisture content. It has been observed that both K and α varied with initial moisture content and mean temperature. The K and α values were 0.23 w/m°C and $1.0 \times 10^{-7} m^2/S$, 0.33 w/m°C and $1.146 \times 10^{-7} m^2/S$, respectively, at initial moisture content levels of 15 and 35% (d.b.) (Table 1).

Surface heat transfer coefficient (h) was calculated separately for radial and axial directions, as follows: At 15% moisture content, T_1=200°C, T=121.33°C, T_0=25°C. Therefore,

$$\theta = \frac{200 - 121.33}{200 - 25} = 0.45 \text{ and } (N_{FO})_x = \alpha t / x^2$$

$$= \frac{1 \times 10^{-7} \times 124}{(3.3 \times 10^{-3})^2} = 1.14$$

The value of 1/(Bi) = 2.0 was obtained from the Hessler's chart for cylinder (Geankoplis 1978) at $(N_{FO})_x$ = 1.14 and θ = 0.45. Therefore, h_r= (K/x)x = 1/2.0 = 0.23/3.3 x 10^{-3}x 2 = 34.85 w/m^2K. Similarly, surface heat transfer coefficient (h_l) in the axial direction could be calculated. Values of h_r and h_l, calculated at various levels of puffing medium temperature and initial moisture content of pre-conditioned faba bean seed, are given in Tables 2 and 3. The heat transfer coefficient (h), both in the radial and in the axial directions, has increased with the increase in temperature of puffing medium. It is interesting to note that heat transfer coefficient in the axial direction (h_l) was higher, in comparison to the radial direction (h_r). At a moisture content of 25% (d.b.) and 200°C sand temperature, the values of h_r and h_l were 54.34 and 331.87 w/m^2k, while these were 86.95 and 663.74 w/m^2k at 230°C sand temperature (Table 3). The value of heat transfer coefficient of faba bean was higher, as compared to that reported for grain pea during puffing (Vinod 1991). Grain pea puffed at 15% moisture content, had heat transfer coefficient of 20.88 w/m^2k at 200°C sand temperature. This might be due to the geometrical difference and thickness of husk.

Data obtained in the present studies, on the heat transfer characteristics of faba bean heated with sand, could be used for designing a continuous sand roaster/puffing machine, which requires the grain to attain an average temperature sufficient to puff at the discharge end of the roaster.

TABLE 2. HEAT TRANSFER COEFFICIENT (h) ON THE SURFACE OF FABA BEAN AT 15% (d.b.) MOISTURE CONTENT AND VARYING LEVELS OF PUFFING MEDIUM TEMPERATURE.

Sand temperature, °C	Product temperature, °C	Time puffing, S	θ	$(N_{FO})_x$	$(N_{FO})_y$	$1/(Bi)_x$	$1/(Bi)_y$	h_r*	h_l*
200	121.33	124.00	0.45	1.14	0.67	2.0	0.3	34.85	179.33
210	124.66	95.66	0.46	0.88	0.52	1.4	0.2	49.78	269.00
220	127.33	82.00	0.47	0.75	0.44	0.8	0.1	87.12	538.01
230	130.00	66.66	0.48	0.61	0.36	0.6	0.075	116.16	717.34

*h_l : Axial heat transfer coefficient, w/m^2k, *h_r : Radial heat transfer coefficient, w/m^2k.

TABLE 3. HEAT TRANSFER COEFFICIENT (h) AT VARIOUS LEVELS OF SAND TEMPERATURE AND INITIAL MOISTURE CONTENT OF FABA BEAN.

Temperature °C	Moisture content, % d.b. 25		30		35	
	h_r	h_l	h_r	h_l	h_r	h_l
200	54.34	331.87	35.61	340.13	47.14	333.33
210	62.11	663.74	44.52	680.27	52.38	333.33
220	72.46	663.74	55.65	680.27	67.34	333.33
230	86.95	663.74	63.60	907.02	78.57	333.33

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Received 17 August 1992; revised 23 May 1994; accepted 7 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 98-103

Influence of Malting Conditions on Amylase Activity, Physical Characteristics and Nutrient Composition of Wheat Malt

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Wheat germinated at 25°C exhibited higher levels of amylase activity than that germinated at 15, 20, 30 and 35°C for any given period upto 120 h germination. Malting loss increased proportionately with temperature and duration of germination. Kilning the green malt of 12% moisture content at 65°C produced the malt of desirable aroma, colour and retained 75% of its amylase activity. Germination led to 13.7 and 45.0% decrease in 1000 kernel weight and hardness, respectively, along with 12% loss in starch content at 72 h. Although there was no appreciable change in protein content on malting, the malt protein contained slightly higher proportion of lysine, while the malt rootlets contained 22% proteins and 1.3% lysine. Malting enhanced the acid extractable minerals, ascorbic acid, riboflavin and niacin, with a concomitant reduction in the dietary bulk (viscosity) of the malt slurry.

Keywords : Germination, Effect of temperature, Amylase activity, Mineral availability, Vitamins, Viscosity, Amino acids.

Production of wheat in India has increased from a meagre 10.4 million tonnes in 1965 to 56.7 million tonnes in 1992 (Anon 1992). Most of it is utilized in the country for conventional food preparations, and a small portion for baking. It is desirable to diversify its uses. Malting enhances the nutritional quality of cereals and legumes (Chavan and Kadam 1989) and malt could be used in the development of weaning foods with low dietary bulk, and also in brewing (Malleshi and Desikachar 1982; Livingstone et al. 1993). Indian malting and brewing industry is growing rapidly and there is need to find extenders to barley malt (Anon 1985), since barley production in the country is hardly 2 million tonnes. Wheat malt has promise in this direction. Information on malting of Indian wheat is scanty and there is no uniformity in malting procedures followed for wheat (Sethi and Bains 1978; Singh and Sosulski 1985). Hence, need exists to study steeping, germination and kilning conditions on the amylolytic enzymes as well as on the nutritional quality of wheat malt. The present study delineates the influence of malting conditions on biochemical and nutritional quality of wheat malt.

Materials and Methods

Wheat (*Triticum aestivum*) 'HD 2189', with over 95% germination rate, was purchased from the local market and stored at 8°C.

Malting conditions : The methodologies used for determining the influence of temperature of steep water on hydration characteristics; the effect of temperature and duration of germination on amylase activity as well as malting loss; details of kilning conditions; and the quality evaluation of malt were as reported earlier (Malleshi and Desikachar 1986a). Wheat steeped for 16 h and germinated for 72 and 120 h was dried in an air oven at 50°C to about 12% moisture and devegetated (Livingstone et al. 1993).

Physico-chemical properties : The 1000-kernel weight as well as volume, density and hardness of native wheat and malt samples were determined as per Kumar et al (1991). The devegetated malt samples were powdered in Udy cyclone sample mill, fitted with a 0.5 mm screen, and the whole meal was used for analysis. The samples were hydrolyzed with p-toluenesulphonic acid (Liu and Chang 1971) and the hydrolysates were analyzed for amino acid contents in a Dionex D-300 amino acid analyzer, using norleucine as an internal standard (Spackman et al. 1958). Proteins, crude fat, thiamin, riboflavin, ascorbic acid, calcium and phosphorus were assayed according to standard procedures (AACC 1986). Total, soluble and insoluble dietary fibre contents were determined by the method of Asp et al (1983). Free sugars were extracted and estimated as per Wankhede and Tharanathan (1976), whereas starch content was determined by enzymic digestion followed by measuring the resulting sugars using dinitro salicylic acid reagent (Chiang and Johnson 1977). Copper, zinc, iron and manganese were estimated in atomic absorption spectrophotometer (Perkin Elmer, model 460) using air acetylene flame (AOAC 1975). The acid extractability of minerals was determined as per Khetarpaul and Chauhan

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(1989). Cooked paste viscosity of samples, at 5 to 30% slurry concentrations was determined in a Brookfield viscometer (LVT model) as per Livingstone et al (1993), while viscoamylograms of 10% slurry were run as detailed by Malleshi and Desikachar (1986a). Native and 120 h germinated wheat kernels were cut open to expose the endosperm, coated with gold palladium alloy and scanned in an "auto scan" scanning electron microscope for photographing selective parts. All analytical determinations were conducted at least in duplicate and the mean values are reported.

Results and Discussion

Steeping characteristics : There was a rapid rise in moisture content of wheat during the first 4 h steeping at all temperatures, after which the rate of absorption slowed down (Fig. 1). Seeds imbibed water faster at higher steeping temperatures, and reached the near saturation moisture content of 36% by 8, 10, 16, 20 and 24 h steeping at 35,30, 25,20 and 15°C, respectively. Seeds steeped at 35°C for 24 h showed signs of chitting. Oguntunde and Adebawo (1989) have also reported that the moisture uptake in cereals takes place rapidly within the first few hours and the saturation moisture content is reached at about 36 h of steeping. Although, high temperature steeping reduces hydration time and

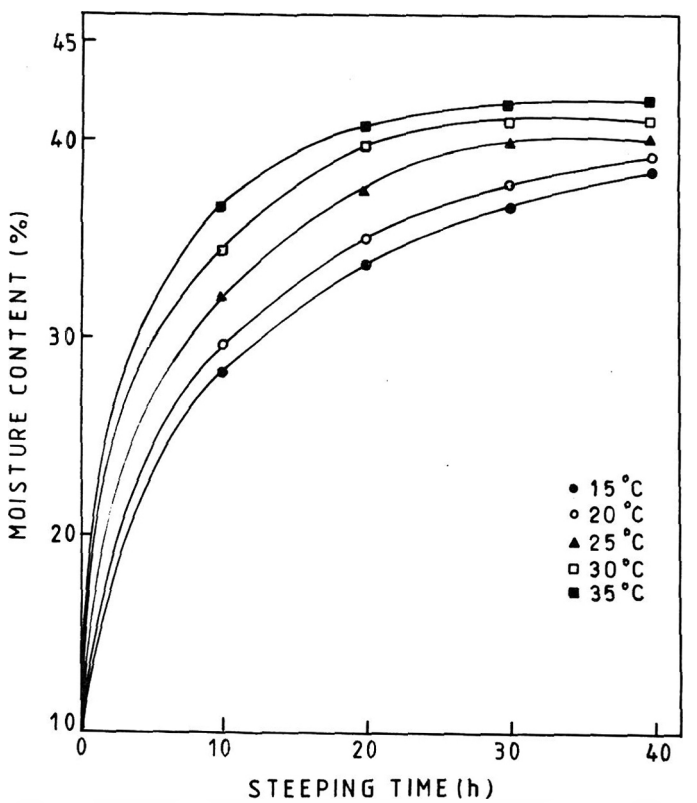

Fig. 1. Moisture uptake of wheat on steeping at different temperatures.

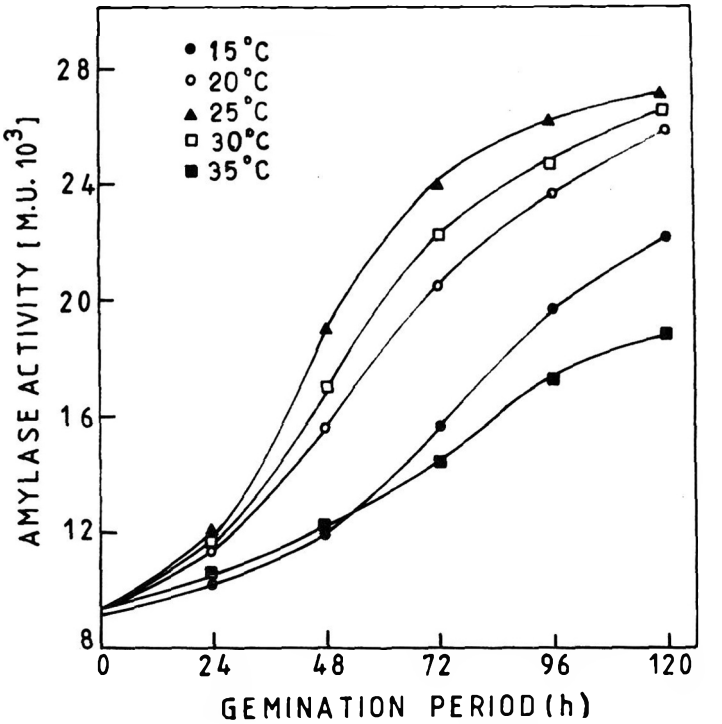

Fig. 2. Amylase activity of wheat germinated at different temperatures.

overcomes seed dormancy, steeping cereals above 40°C has been found to hamper seed viability, causing higher leaching losses (Reeves et al. 1980; Swanston and Taylor 1990).

Amylase activity : A continuous increase in the amylase activity on progressive germination at all temperatures was observed (Fig. 2). The increase in activity was higher at 20, 25 and 30°C than at 15 and 35°C. The sample germinated at 25°C exhibited higher amylase activity than others throughout the germination period. Reddy et al (1984) also observed that alpha-amylase activity in wheat increased, when the germination temperature was raised from 15 to 20°C, but the activity fell drastically, when germination was carried out at 30°C.

Malting loss : Malting loss caused by metabolic activity and separation of vegetative growth (root and shoot) increased with the increase in temperature and duration of germination (Fig. 3). The total malting loss (metabolic and rootlets) for samples germinated for 48 h at 25°C was 7.8%. Since, the germination was uniform at 25°C, amylase activity was high and malting loss was moderate, the same temperature could be recommended for malting of wheat.

Kilning : Kilning of green malt at 32% moisture resulted in the development of highly desirable malt aroma, but caused excessive browning and drastic

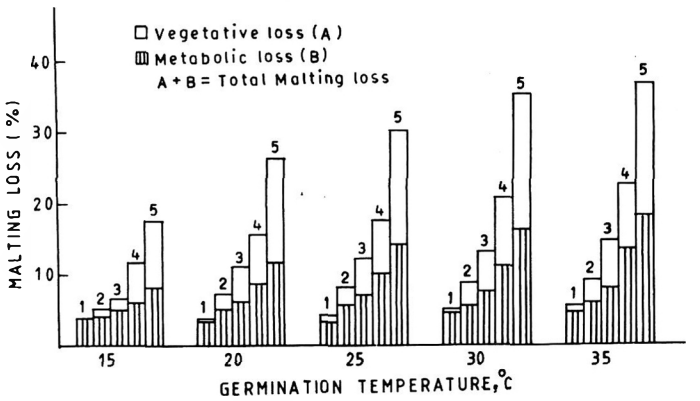

Fig. 3. Malting loss of wheat germinated at different temperatures. 1, 2, 3, 4 and 5 refer to samples germinated for 24, 48, 72, 96 and 120 h, respectively.

reduction (90%) in the amylase activity (Table 1). Similarly, kilning the malt at 17 and 22% moisture also resulted in considerable loss of amylase activity and the malt kilned at 7% moisture developed very undiscernible aroma. On the other hand, green malt kilned at 12% moisture retained about 75% of amylase activity and also possessed desirable aroma. From these studies, it can be inferred that kilning the green malt of 12% moisture level at 65°C for about 45 min could produce malt suitable for food uses.

Physico-chemical changes : The physico-chemical composition, some vitamin and mineral contents of native, 72 and 120 h germinated wheat are presented in Table 2. The 1000-kernel weight of malt samples were significantly lower than native wheat and the loss in weight was proportional to the degree of germination, which was reflected in the decrease in density also. Germination for 72 and 120 h resulted in 12% and 21% losses in 1000-kernel weights and 5.1% and 12.7% reductions in 1000-kernel volume, respectively. The malts had shrunken appearance and their hardness was considerably lower than the native wheat. Similar changes in the physical parameters on germination of wheat were observed by Sethi and Bains (1978). The changes in hardness or friability of barley on malting is considered as a good measure for the diastatic activity of malt or a measure of malt modification (Swanston and Taylor 1990), and this may also hold good for wheat.

There was not much change in total proteins, but starch content decreased on germination. A

TABLE 2. PHYSICO-CHEMICAL COMPOSITION, SOME VITAMIN AND MINERAL CONTENTS OF NATIVE, 72 AND 120 h MALTED WHEAT

	Native wheat	Malt	
		72 h	120 h
1000-kernel wt, g	51.00 ± 0.17	44.90 ± 0.88	39.90 ± 0.12
1000-kernel vol, ml	35.50 ± 0.16	33.70 ± 0.57	31.00 ± 0.09
Density, g/ml	1.44 ± 0.01	1.33 ± 0.01	1.29 ± 0.01
Hardness, kg/cm²	13.10 ± 2.90	7.20 ± 1.70	3.30 ± 2.00
Proteins, % (Nx5.7)	12.40 ± 0.07	12.00 ± 0.00	12.00 ± 0.07
Crude fat, %	1.86 ± 0.01	1.67 ± 0.01	1.64 ± 0.01
Starch, %	72.00 ± 1.90	60.40 ± 1.92	57.40 ± 0.89
Dietary fibre, %			
Total	13.20 ± 0.14	13.00 ± 0.50	19.50 ± 0.90
Soluble	3.40 ± 0.14	3.00 ± 0.07	5.30 ± 0.07
Ascorbic acid, mg %	0.67	1.14	-
Thiamin, mg %	0.27	0.28	-
Riboflavin, mg %	0.07	0.12	-
Niacin, mg %	2.62	2.74	-
Iron, mg %	7.26 (7.5)	6.74 (17.1)	6.28 (22.1)
Copper, mg %	0.69(20.8	0.66 (30.0)	1.00 (40.0)
Zinc, mg %	2.57(58.4)	2.67 (71.2)	2.93 (71.7)
Manganese, mg %	4.26(32.8)	4.01 (66.3)	3.99 (67.5)
Calcium, mg %	53.40(48.7)	60.12 (53.3)	66.60 (75.0)
Phosphorus, mg %	355.40(36.2)	374.10 (37.4)	407.50 (40.0)

Figures in paranthesis indicate % minerals extracted in HCl

TABLE 1. EFFECT OF MOISTURE CONTENT OF GREEN MALT DURING KILNING ON THE QUALITY OF WHEAT MALT

Moisture, %	Colour, reflectance	Hardness, kg	Free sugars, %	Amylase activity, maltose units
32	57.0 ± 0.26^{b}	7.1 ± 1.8^{b}	20.5 ± 0.32^{b}	144 ± 23^{b} (1.5)
22	64.2 ± 0.19^{c}	6.3 ± 1.5^{a}	8.6 ± 0.00^{c}	4270 ± 76^{c} (41.7)
17	65.9 ± 0.54^{d}	6.2 ± 1.0^{a}	8.7 ± 0.22^{c}	6339 ± 76^{d} (62.0)
12	66.7 ± 0.10^{e}	6.3 ± 1.9^{a}	8.3 ± 0.48^{c}	7764 ± 112^{e} (75.0)
7	66.8 ± 0.13^{e}	6.5 ± 1.4^{a}	8.7 ± 0.15^{c}	8916 ± 135^{f} (87.0)
Green malt	68.4 ± 0.22^{a}	6.4 ± 1.5^{a}	9.3 ± 0.05^{a}	10232 ± 158^{a}(100)

At 0.05 significance level, the means of any two groups in a column with the same letter are not significantly different according to Newman-Kewls multiple comparison test. Figures in parenthesis indicate percentage of amylase activity retained on kilning.

small decrease in the crude fat was also noticed. There are contradictory reports on the changes in the protein contents of wheat and other cereals on germination (Chavan and Kadam 1989), and this trend is attributed to the differences in the conditions of germination and varietal variations. A gradual decrease in starch content on germination was reported in wheat (Ibrahim and D'Appolonia 1979). The hydrolysis of fat by the lipases elaborated during sprouting of wheat (Drapron et al. 1969) would have caused a slight decrease in crude fat content. Malt from 120 h germinated wheat contained significantly higher proportions of soluble, insoluble and total dietary fibre. The partial loss in starchy endosperm during germination, causing *per se* increase in seed coat proportion could be the reason for increase in dietary fibre content on malting. Malleshi and Desikachar (1986b) also reported slight increase in crude fibre on malting of millets.

Malting enhanced ascorbic acid, riboflavin and niacin contents of wheat. However, there was no appreciable change in thiamin. An increase in some of the water-soluble vitamins in most of the cereals and a slight decrease in thiamin in sorghum on germination has been reported (Lorenz 1980). Since cereal grains are important sources of B-complex vitamins in Indian diets (Gopalan et al. 1989), an increase in vitamins through germination is nutritionally desirable.

Malted wheat contained slightly higher concentrations of zinc, calcium and phosphorus, as against lower concentrations of iron, manganese and copper. Ranhotra et al (1977) also observed a decrease in iron content and an increase in calcium and zinc contents in sprouted wheat. There was almost two-fold increase in acid extractability of iron, copper and manganese, but very little in case of zinc, calcium and phosphorus. The lower extractability of some of these minerals could be due to the presence of phytate. The improved bioavailability of minerals on germination of wheat is important, since the mineral availability in cereals is generally low (Sandstrom et al. 1987).

Amino acids : Data on the amino acid composition of wheat malt and rootlets are given in Table 3. A 23% increase in aspartic acid and a slight increase in valine, alanine, isoleucine contents, while a 10% decrease in glutamic acid and a little decrease in methionine and leucine contents was observed on 120 h germination. The lysine content increased by 4.8% on 72 h and 8% on 120 h germination. The rootlets contained about 22.0 and 1.3% proteins and lysine, respectively. Compared to malt, the rootlets were rich in aspartic acid and poor in glutamic acid and proline. A decrease in glutamic acid and proline with a concomitant increase in aspartic acid on malting of wheat and barley has been reported earlier (Finney 1982). Increase in lysine content on germination of wheat in several varieties has been reported by Singh and Sosulski (1986) also. According to Iliev et al (1992), the protein hydrolysates of barley rootlets (malt sprouts) met the requirements of the essential amino acids, suggested by FAO/WHO/UNU (1985) for children.

TABLE 3. AMINO ACID COMPOSITION OF NATIVE, 72 AND 120 h MALTED WHEAT AND ROOTLETS (g/100 g proteins)

Amino acid	Native	Malt		Rootlets	
		72 h	120 h	72 h	120 h
Aspartic acid	6.43	6.91	7.90	21.80	24.67
Threonine	3.28	3.26	3.35	4.61	4.36
Serine	5.24	5.10	5.06	4.40	4.30
Glutamic acid	29.66	28.37	26.61	14.93	13.68
Proline	7.92	8.05	7.86	2.54	2.80
Glycine	4.48	4.45	4.56	4.96	4.75
Alanine	4.32	4.41	4.72	6.96	6.60
Cystine	4.26	4.32	4.24	1.36	1.78
Valine	3.45	3.67	3.88	4.32	4.57
Methionine	1.81	1.74	1.61	1.50	1.33
Isoleucine	2.71	2.85	3.00	3.15	3.25
Leucine	6.83	6.91	7.00	6.93	6.79
Tyrosine	3.63	3.64	3.68	3.14	3.10
Phenylalanine	5.03	5.02	4.85	3.66	3.56
Histidine	3.21	3.29	3.44	3.20	3.38
Lysine	2.94	3.08	3.18	6.15	5.05
Arginine	4.70	4.94	5.10	4.98	4.54

Viscosity : Native wheat had significantly higher viscosity than germinated wheat at all slurry concentrations (Fig. 4). Lower viscosity results in reduced dietary bulk, which has special significance with reference to foods for weaned children, malnourished subjects and convalescents, who should be given nutrient-dense and easily digestible foods (Ljungqvist et al. 1981). The Brabender viscograms of native and enzyme-inhibited malt samples were similar. However, the malt viscograms exhibited higher gelatinization temperature (GT) and lower peak viscosity (PV). The PV values for native, 72 and 120 h germinated and amylase-inhibited samples were 510, 310 and 220 BU, while the GT values were 76, 78 and 80°C, respectively. On the other hand, the malt samples with active

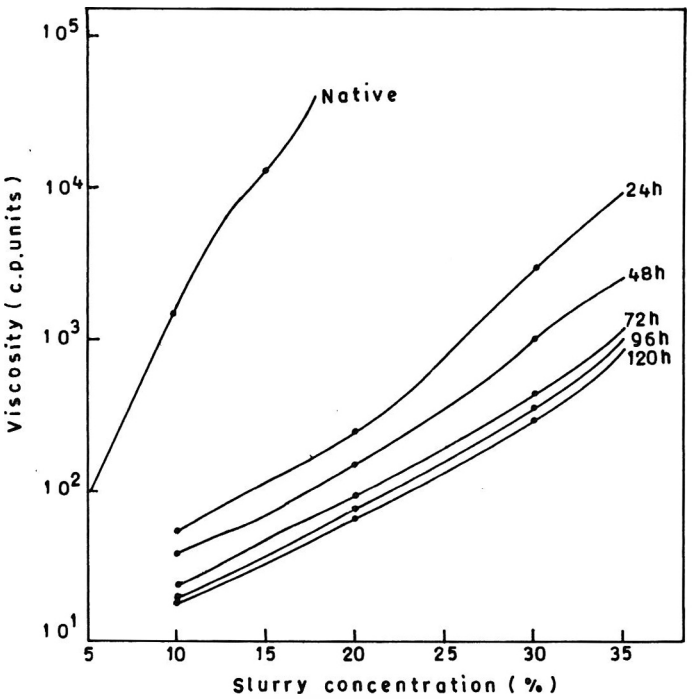

Fig. 4. Cooked paste viscosity of native and germinated wheat. 24, 48, 72, 96 and 120 h refer to duration of germination.

amylases did not show any change in viscosity on heating, because of the enzymic hydrolysis of starch.

Scanning electron microscopy : Microphotographs of native and 120 h malted wheat are shown in Fig. 5a and 5b, respectively. In case of native samples, the starch granules are embedded in amorphous matrix, which could be the adhering proteins. On germination for 120 h, disintegration of the protein matrix and pitting of the starch granules is observed. It can be seen that the central portion is completely digested in some of the granules. It is reported that, as germination progresses, the starch hydrolysis continues towards the centre of the granules (Dronzek et al. 1972).

Conclusions

Wheat malt produced by 16 h steeping, 48 h germination at about 25°C and kilning the green malt after drying to 12% moisture is suitable for food uses. Malting enhances lysine, riboflavin, niacin and ascorbic acid contents, in addition to mineral availability. Malted wheat exhibits significantly lowered viscosity (dietary bulk) than that of the native, thereby indicating its suitability for development of nutrient-dense health foods.

Acknowledgement

The authors thank Mr. Wayne Shope II for amino acids analysis and Mr. Vibhakara for mineral analysis. One of the authors (AWS) acknowledges the UGC for the award of Senior Research Fellowship.

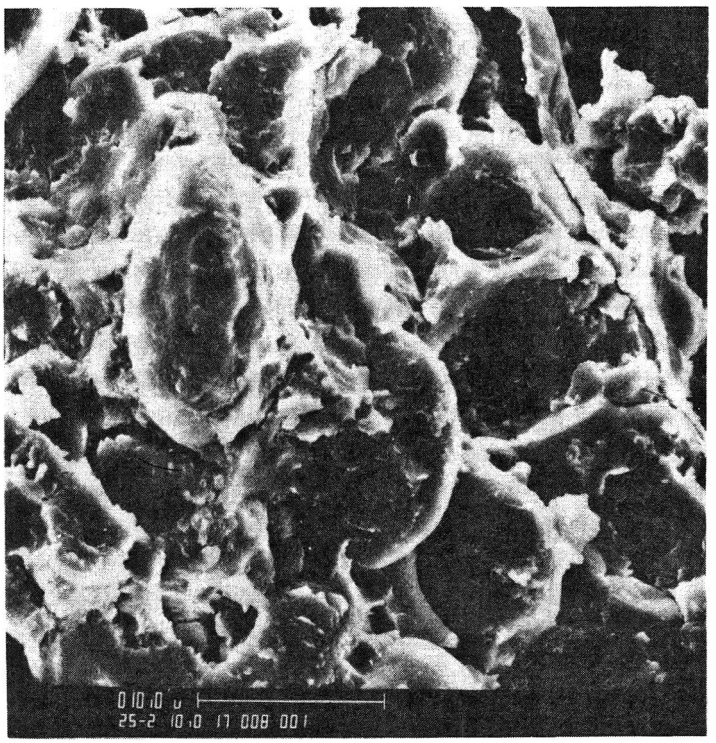

Fig. 5a. Scanning electron photomicrograph of native wheat,

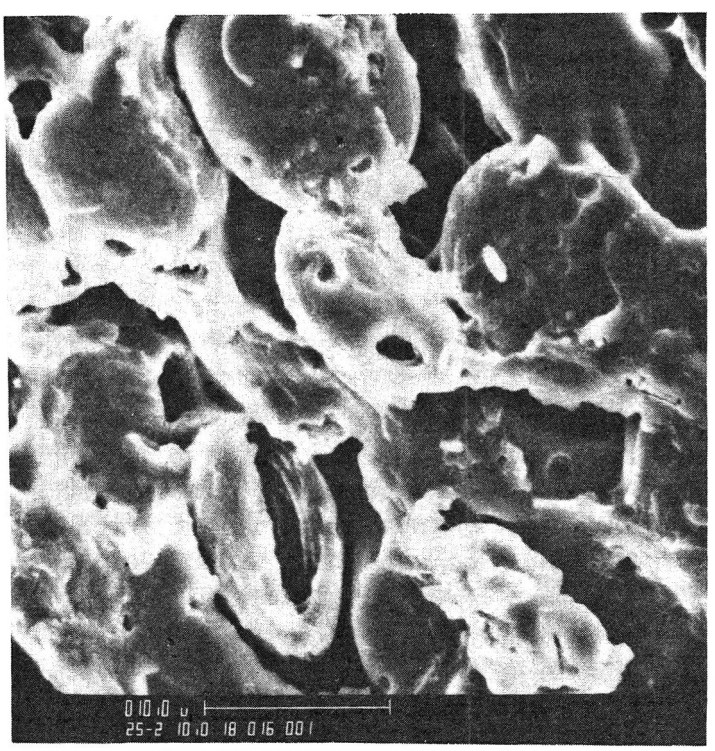

Fig. 5b. Scanning electron photomicrograph of 12h malted wheat,

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Received 16 December 1993; revised 4 November 1994; accepted 25 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 104-108

Individual Chlorogenic Acids and Caffeine Contents in Commercial Grades of Wet and Dry Processed Indian Green Robusta Coffee

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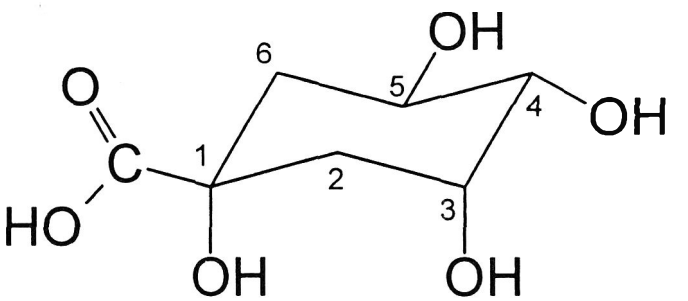
Individual chlorogenic acids and caffeine contents in Indian wet and dry processed green robusta coffee beans, obtained by reversed phase chromatography, have been studied. No significant differences in caffeine content, even at the 5% level, were observed, though significant differences (1% or 0.1% levels) with reference to individual chlorogenic acids, chlorogenic acid sub-groups or total chlorogenic acids were observed between (a) wet processed and dry processed flat bean coffees; (b) wet processed pea berry and wet processed flat bean coffees; (c) wet processed pea berry and dry processed flat bean coffees; and (d) immature dry processed flat bean and mature dry processed flat bean coffees.

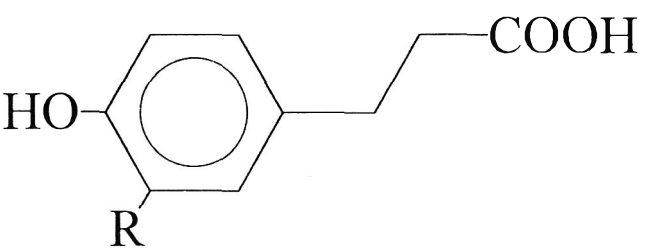
Keywords : Coffee, Robusta, High pressure liquid chromatography, Chlorogenic acids, Caffeine, Caffeoyl-tryptophan.

Esterified quinic acids, known collectively as chlorogenic acids (CGA), are a major component, accounting for some 7-10% d.b. of commercial green coffee beans (Clifford 1985 a, b). These CGA may be sub-divided into groups of three positional isomers, each depending on the position(s), at which the quinic acid is esterified, and according to the identity of the esterifying residue(s). The CGA found in coffee are mono- and di-esters of positions 3, 4 and 5 (Clifford 1985 a, b). The structure of quinic acid in its preferred conformation (carboxyl equatorial), with the ring carbons numbered according to IUPAC recommendations (IUPAC 1976), along with the structures of the esterifying residues (*E*--caffeic acid, *E*-ferulic acid and *E*-*p*-coumaric acid), associated with coffee CGAs are shown in Fig. 1 (Clifford 1985 a, b).

The six CGA sub-groups are caffeoylquinic acids (CQA), *p*-coumaroylquinic acids (*p*CoQA), feruloylquinic acids (FQA), dicaffeoylquinic acids (diCQA), caffeoylferuloylquinic acids (CFQA) and feruloylcaffeoylquinic acids (FCQA). The last three groups have been characterized recently (Clifford et al. 1989b). In addition to the CGAs, *N*-β-caffeoyl-L-tryptophan and *N*-β-caffeoyl-L-tyrosine and traces of unesterified *E*-caffeic acid, *E*-ferulic acid and *E*-*p*-coumaric acid have also been reported (Clifford 1985a,b; Clifford et al. 1989a). The mixed diesters and the amino acid derivatives are found in robusta, but not in arabicas, and the tyrosine derivative is apparently restricted to Angolan robustas (Clifford and Jarvis 1988; Clifford et al. 1989 a,b; Correia et al. 1994). The identity of some quantitatively minor CGA-like components of



A: Quinic Acid



B: *E*-Cinnamic Acids

R = H = *p*-Coumaric Acid
R = OH = Caffeic Acid
R = OCH_3 = Ferulic Acid

Fig. 1. Structure of a: quinic acid in preferred chair conformation; b: structure of esterifying residues found in coffee bean chlorogenic acids.

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commercial coffees and botanically distinct wild species remain to be characterized (Clifford and Jarvis 1988; Clifford et al. 1989c).

The changes in CGA contents of the bean during cherry maturation, the behaviour of CGA during roasting, the ability of some isomers to complex with caffeine and the associated sensory properties have led to beliefs, widely accepted but not necessarily proven, that the CGAs have an important role in determining bean and beverage quality (Clifford and Ohiokpehai 1983; Clifford 1985 a,b; Clifford and Kazi 1987; Clifford et al. 1987; Ohiokpehai et al. 1982). As a result, the HPLC analysis of the contents of individual CGA and caffeine in green and roasted coffee beans, instant coffee powders and coffee beverage has become a widely used technique to seek correlations between green bean composition, cup quality and price realised at auction, as well as for quality control purposes (Trugo and Macrae 1984; Humphrey and Macrae 1987). Despite many studies world wide (Clifford 1985a,b and references therein), only a few data have been published on the CGA contents of commercial Indian coffees. This paper provides analytical data for dry and wet processed pea berry and flat bean robusta produced in India.

Materials and Methods

Materials : Two samples each of dry processed and wet processed commercial grades of Indian green robusta coffee beans were kindly supplied in May, 1993 by Consolidated Coffee Ltd, Pollibetta, Kodagu, Karnataka, India. These were (1) dry processed (unwashed): (a) robusta cherry - 'AB' (flat bean and (b) robusta cherry - 'PB' (pea berry); and (2) wet processed (washed): (a) robusta parchment - 'AB' (flat bean) and (b) robusta parchment - 'PB' (pea berry). Prior to grinding and extraction, all abnormal beans were removed from each sample by manual sorting. In a second investigation, the immature (green coloured) beans were removed from the dry processed 'AB' sample, and these were analyzed separately from the mature (golden brown coloured) beans.

Caffeine, 5-CQA and trifluroacetic acid (TFA) were obtained from Sigma Chemical Company Ltd, Poole, Dorset, UK. Methanol and acetonitrile (HPLC grade) were obtained from Fisons, Loughborough, UK. Water/aqueous denotes distilled water, unless otherwise specified. All other reagents were of standard quality from reputable commercial sources. For Carrez reagent (Egan et al. 1981), reagent A was prepared by dissolving 21.9 g zinc acetate dihydrate in water, containing 3.0 g glacial acetic acid and diluting to 100 ml with water. Reagent B was prepared by dissolving 10.6 g potassium ferrocyanide trihydrate in 100 ml water. These reagents were stored at -4°C. Calibration standards of caffeine and 5-CQA were prepared in 70% (v/v) aqueous methanol (Clifford 1985 a,b).

Extractions : The green robusta coffee bean samples were frozen, ground in a hammer mill to pass 0.7 mm and 500 mg extracted (4 x 25ml, 25 min each) with 70% (v/v) aqueous methanol using a Tecator HT-1043 (Tecator, Sweden) continuous extraction system. The bulked extracts were treated with Carrez reagents (1 ml A plus 1 ml B) to precipitate colloidal material, diluted to 100 ml with 70% (v/v) aqueous methanol and filtered through a Whatman No. 1 filter paper. These extracts were stored at -4°C, and used directly for HPLC analysis.

HPLC analysis : A Spectraphysics P-4000 gradient pump, coupled to a Spectraphysics AS-3000 auto-sampler and a Spectrafocus forward optical scanning detector, were used in conjunction with a 250 mm x 4.6 mm internal diam column packed with Spherisorb S5 ODS2 (a fully endcapped 5 µ reverse phase packing material having a low content of residual silanol groups) prepared by Hichrom, Theale, Berkshire, UK. Chromatographic and spectral data collection as well as integration were performed, using Spectrafocus software on an IBM PS/2 computer. Sample or standard (20 µl) was analyzed using a gradient from 100% solvent A (aqueous 0.5% TFA) to 100% solvent B (45% acetonitrile in 0.5% aqueous TFA) in 56 min at a flow rate of 1 ml/min. Peaks were detected at 280 nm (caffeine) and 315 nm (CGA). As required, UV spectra were recorded between 200 and 360 nm. Peak identification was achieved, where possible, by spiking with authentic material or a combination of UV spectra data, relative retention time and the effect of treatment with tetramethylammonium hydroxide (Clifford et al. 1989 b,d). As necessary, the Spectrafocus data (BFF files) were exported (as CSV files), and imported into Fig. P (Biosoft, Cambridge, UK) for manipulation and labelling during the preparation of Fig. 2.

Moisture content : Duplicate 0.5 g samples of each ground coffee beans were dried conventionally to a constant weight at 105°C in a vacuum oven.

Results and Discussion

The mean moisture content (n=2, % dry weight) of robusta cherry 'AB', robusta cherry 'PB', robusta parchment 'AB' and robusta parchment 'PB' were

TABLE 1. RETENTION TIME (MIN), RELATIVE RETENTION TIMES AND λ_{max} FOR THE INDIVIDUAL CHLOROGENIC ACIDS AND CAFFEINE.

Compound detected	Retention time, min	Relative Retention Times*			λ_{max}
3-CQA	15.5	0.74		1.00	326
4-CQA	20.6	0.99		1.00[a]	328
5-CQA	21.0	1.00		1.00[b]	328
Caffeic acid	22.6	1.08			320
5-*p*-CoQA	24.7	1.18			313
4-FQA	25.1	1.20	0.96[a]	1.22[a]	326
5-FQA	26.2	1.25	1.00[a]	1.25[b]	327
Unknown 1	27.3	1.30			325
3,4-diCQA	31.6	1.51	1.00[b]	1.00[c]	327
3,5-diCQA	32.7	1.56	1.03[b]	1.00[d]	329
4,5-diCQA	34.9	1.66	1.10[b]		329
3C,4FQA + 3F,4CQA	36.0	1.71	1.00[c]	1.14[c]	328
3C,5FQA + 3F,5CQA	37.5	1.80[c]	1.04[c]	1.15[d]	329
Caffeoyl-tryptophan	39.3	1.88			222, 292 and 324
Unknown 2	43.1	2.05			222, 292 and 309 (sh)
Caffeine	24.7	1.18			274

* Relative retention times having the same superscript are directly comparable

7.5%, 7.6%, 7.8% and 8.9%, respectively. These values are commensurate with good commercial practice (Clarke 1985).

As in previous studies (Clifford et al. 1989 b,d), the three CQA isomers, caffeic acid, 5-*p*-COQA, two FQA isomers, three diCQA isomers and caffeoyl-tryptophan were located easily on the chromatograms by a combination of spiking with authentic material and behaviour, when treated with tetramethyl-ammonium hydroxide (data not shown). Further evidence of identity and purity was obtained from the calculation of relative retention times and spectral matching. These data, which were consistent with those obtained previously (Clifford et al. 1989 b,d) are presented in Table 1. It was not possible to locate 3-*p*-CoQA or 4-*p*-CoQA, which would be very minor components, or 3-FQA, which would be expected to coelute with 4-CQA, as reported previously (Clifford et al. 1989 b; Trugo and Macrae 1984).

The mixed diesters have previously (Clifford et al. 1989 a) been partially resolved into three peaks containing two isomers each (3C,4FQA+3F,4CQA; 3C,5FQA+3F,5CQA; and 4C,5FQA+4F,5CQA).

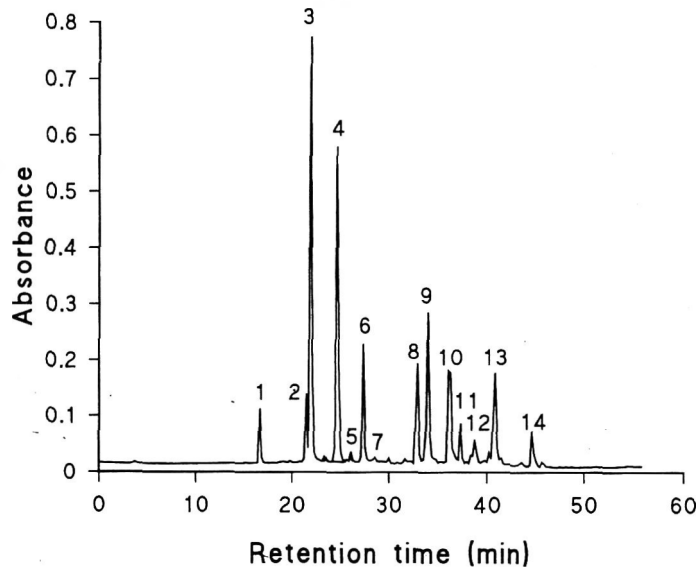

Fig. 2. Chromatogram of a 70% methanolic extract of an Indian dry processed green robusta coffee 'AB'. Chromatographic conditions : Solvent A: 0.5% TFA; Solvent B: 45% aqueous acetonitrile in 0.5% TFA; gradient 100% A to 199% B linearly in 56 min; column 25 cm x 4.6 mm packed with Spherisorb ODS2 5 µ; 20 µl injection; detection at 280 nm and 315 nm
Key: Peak 1 = 3-CQA; peak 2 = 4-CQA; peak 3 = 5-CQA; peak 4 = caffeine (at 280 nm) masking 5-*p*-COQA (at 313 nm); peak 5 = 4-FQA; peak 6 = 5-FQA; peak 7 = unknown 1; peak 8 = 3,4-diCQA; peak 9 = 3,5-diCQA; peak 10 = 4,5-diCQA; peak 11 = 3C, 4FQA + 3F,4FQA + 3F,4CQA; peak 12 = 3C, 5FQA + 3F,5CQA; peak 13 = caffeoyl-tryptophan with 4C,5FQA + 4F,5CQA on leading edge; peak 14 = unknown 2.

However, in the present case, the most hydrophobic pair coeluted with caffeoyl-tryptophan, where their presence on the leading edge of that peak was detectable spectrally. A specimen chromatogram is shown in Fig. 2. Only minute traces (<0.01%) of *p*-coumaric acid and ferulic acid were observed and these have not been included in the tabulated results.

As a preliminary element of this study, the commercial washed parchment 'AB' coffee was sampled extensively and the ground material was extracted, using each of the six sample positions on the Tecator HT 1043 apparatus, in order to properly assess, whether any significant variation was introduced due to this operational factor. The variation observed was no greater than that between-replicate variation associated with a single position and the nine sets of data so obtained were subsequently pooled and presented as such in Table 2.

The contents of caffeine and individual CGA (as CGA equivalents, without correction for individual response factors) were calculated using the regression equations :

TABLE 2. THE CONTENT OF INDIVIDUAL CHLOROGENIC ACIDS AND CAFFEINE (% DRY BASIS) IN INDIAN ROBUSTA COFFEE BEANS.

Compound quantified	Dry processed (unwashed)		Wet processed (washed)	
	Cherry 'AB' n = 6	Cherry 'PB' n = 3	Cherry 'AB' n = 9	Cherry 'PB' n = 3
3-CQA	0.425 ± 0.108	0.430 ± 0.131	0.441 ± 0.025	0.430 ± 0.008
4-CQA	0.480 ± 0.080	0.532 ± 0.078	0.573 ± 0.064	0.585 ± 0.033
5-CQA	3.485 ± 0.455	3.764 ± 0.637	4.493 ± 0.218	4.904 ± 0.099
CQA sub-total	4.390 ± 0.566	4.726 ± 0.843	5.507 ± 0.275	5.919 ± 0.140
Caffeic acid	0.066 ± 0.016	0.067 ± 0.014	0.065 ± 0.024	0.077 ± 0.012
5-*p*CoQA	0.052 ± 0.008	0.046 ± 0.003	0.045 ± 0.004	0.051 ± 0.002
4-FQA	0.105 ± 0.007	0.095 ± 0.006	0.093 ± 0.014	0.090 ± 0.005
5-FQA	0.834 ± 0.045	0.825 ± 0.011	0.893 ± 0.069	0.853 ± 0.046
FQA sub-total	0.938 ± 0.049	0.920 ± 0.013	0.986 ± 0.080	0.943 ± 0.051
Unknown 1	0.091 ± 0.009	0.082 ± 0.010	0.062 ± 0.019	0.079 ± 0.006
3,4-diCQA	0.443 ± 0.052	0.458 ± 0.066	0.524 ± 0.047	0.509 ± 0.031
3,5-diCQA	0.611 ± 0.080	0.668 ± 0.133	0.817 ± 0.084	0.765 ± 0.060
4,5-diCQA	0.475 ± 0.036	0.522 ± 0.029	0.471 ± 0.045	0.520 ± 0.080
diCQA sub-total	1.529 ± 0.160	1.648 ± 0.221	1.812 ± 0.151	1.794 ± 0.097
3C,4FQA + 3F,4CQA	0.154 ± 0.011	0.140 ± 0.017	0.127 ± 0.013	0.120 ± 0.006
3C,5FQA + 3F,5CQA	0.127 ± 0.010	0.122 ± 0.012	0.136 ± 0.023	0.117 ± 0.009
CFQA sub-total	0.280 ± 0.012	0.262 ± 0.028	0.263 ± 0.033	0.237 ± 0.013
Caffeoyl-tryptophan	0.451 ± 0.099	0.479 ± 0.087	0.579 ± 0.055	0.569 ± 0.033
Unknown 2	0.142 ± 0.018	0.150 ± 0.015	0.166 ± 0.012	0.169 ± 0.006
Total CGA	7.938 ± 0.806	8.380 ± 1.189	9.485 ± 0.431	9.838 ± 0.246
Caffeine	2.900 ± 0.441	2.700 ± 0.028	3.150 ± 0.212	3.000 ± 0.021

5-CQA (μg/ml) = 1.281 + 1.10×10^{-5} (peak area), $r > 0.9993$; and

Caffeine (μg/ml) = − 3.348 + 1.37×10^{-5} (peak area), $r > 0.9992$,

respectively. The data so obtained are presented (% d.b., mean ± s.d.) in Table 2. There were no statistically significant differences in composition between the two dry processed coffee samples even at the 5% level, whereas the wet processed pea berry coffee contained significantly more ($p<0.05$) 5-CQA and total CQA, than the corresponding flat beans. The two pea berry coffees differed only slightly (5% level) in their 5-CQA contents, whereas the two flat beans differed more extensively. The wet processed flat bean coffee had greater contents of 5-CQA and 3,4-diCQA (both $p<0.05$) total CQA, 3,5-diCQA and total CGA (all $p<0.01$) than the dry processed flat bean coffee. There were no significant differences in caffeine contents between any of the four samples of coffee, examined even at the 5% level.

The only previously published chromatographic data for Indian robusta (cherry 'AB', 1986) so far as the authors are aware (Clifford and Jarvis 1988) had a composition (5.81% total CQA; 0.69% 5-FQA; 1.38% total diCQA; 8.54% total CGA), which are closer to the data for parchment 'AB' analyzed in this study. The explanation for this is not known, but might reflect differences in weather or production area within India.

The mature (golden brown) dry processed flat bean coffee did not differ significantly from the unsorted commercial batch at the 5% level. In contrast, the immature (green-coloured) dry processed flat bean coffee analyzed during this study has a significantly lower 5-FQA (and hence total FQA) content and significantly higher 3,4-diCQA (and hence total diCQA) content, when compared with the mature (golden brown-coloured) beans from the same commercial batch (Table 3). The mature beans had slightly lower ($p<0.05$) caffeine contents than the immature beans.

Previously, Clifford and Kazi (1987) studied the progressive changes in the CGA contents of two clones of Ivory Coast robusta ('IC 182' and 'IC 503') as the fruits matured. However, a detailed comparison of these data is not possible for two main reasons. Firstly, the beans used in the 1987 study were obtained from fruit harvested at a definite number of weeks after flowering and thus each sample was fairly uniform in maturity, whereas the immature beans used in the present study were obtained by hand-sorting of a commercial batch and are of a less precisely defined stage of

TABLE 3. THE CONTENT OF INDIVIDUAL CHLOROGENIC ACIDS AND CAFFEINE (% DRY BASIS) IN IMMATURE AND MATURE INDIAN ROBUSTA COFFEE BEANS.

Compound quantified	Indian robusta (unwashed)	
	Immature beans, n = 3	Mature beans, n = 3
3-CQA	0.446 ± 0.042	0.431 ± 0.042
4-CQA	0.597 ± 0.026	0.562 ± 0.022
5-CQA	4.507 ± 0.510	3.890 ± 0.301
CQA sub-total	5.568 ± 0.570	4.883 ± 0.332
Caffeic acid	0.073 ± 0.008	0.068 ± 0.005
5-*p*CoQA	0.065 ± 0.012	0.059 ± 0.001
4-FQA	0.080 ± 0.013	0.108 ± 0.002
5-FQA	0.663 ± 0.021	0.805 ± 0.037
FQA sub-total	0.743 ± 0.013	0.913 ± 0.038
Unknown 1	0.069 ± 0.001	0.082 ± 0.007
3,4-diCQA	0.622 ± 0.036	0.523 ± 0.031
3,5-diCQA	0.797 ± 0.109	0.652 ± 0.086
4,5-diCQA	0.610 ± 0.011	0.581 ± 0.029
diCQA sub-total	2.209 ± 0.157	1.756 ± 0.144
3C,4FQA + 3F,4CQA	0.155 ± 0.009	0.156 ± 0.018
3C,5FQA + 3F,5CQA	0.109 ± 0.007	0.113 ± 0.010
CFQA sub-total	0.264 ± 0.010	0.269 ± 0.022
Caffeoyl-tryptophan	0.672 ± 0.022	0.555 ± 0.110
Unknown 2	0.167 ± 0.018	0.146 ± 0.005
Total CGA	9.650 ± 0.702	8.731 ± 0.526
Caffeine	2.600 ± 0.021	2.400 ± 0.075

immaturity. Secondly, there is some evidence that seasonal and clonal factors influence the changes observed (Clifford and Kazi 1987). However, an increase in the CQA:diCQA ratio seems to be a general feature of the final five to six weeks of maturation, e.g., 3.3 to 4.2 for 'IC 182' and 3.2 to 5.7 for 'IC 503' (Clifford and Kazi 1987). The corresponding data for the two samples compared in the present study are mean ratios of 2.5:1 and 3.0:1, which suggest a similar trend, although the magnitude of this change is not statistically significant.

Acknowledgements

The authors are grateful to Government of India for the award of a National Overseas Scholarship to K.J.B. for studies leading to Ph.D. The authors also thank Consolidated Coffee Ltd., Pollibetta, Kodagu, Karnataka, India, for providing green coffee samples.

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Received 15 November 1993; revised 11 November 1994; accepted 25 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 109-114

Evaluation of Yield, Texture and Cooking Time of *Rasogolla*

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Volume expansion and temperature rise of *rasogolla* during cooking in plain water and sugar syrups of 45, 55, 60 and 65° Brix were studied for determining the required cooking time. It was observed that sugar concentration had negligible influence on volume expansion and temperature rise. Initial diam of *rasogolla* was 2.7 cm and it increased to 3.7 cm after 10 min cooking, thereby leading to volume expansion of 2.6. Initial centre temperature of *rasogolla* ranged from 25 to 30°C and it increased to 100-103°C after 5.5 to 6 min cooking time due to the elevation of boiling point by sugar. Textural parameters of *rasogolla* in a 55° Brix sugar syrup attained constant values after 20 min cooking. Prediction models for recovery of milk solids in *chhana* and yield of *rasogolla*, using fat content, of milk as a variable, were developed. Yield of *rasogolla* from milk of 4.1% fat content prepared in a 55° Brix sugar solution, was 0.287 kg/kg milk, which corresponded to 83% of the predicted yield of 0.345 kg/kg milk.

Keywords : *Chhana*, *Rasogolla*, Yield, Cooking time, Volume expansion, Temperature rise, Textural parameters.

Chhana, an indigenous milk product, is obtained by acid coagulation of hot milk and subsequent drainage of whey. Of late, methods have been developed for the preparation of *chhana* from wet casein (Kumar and Kapoor 1991) and also from soy milk (Chakraborty and Gangopadhyay 1990). It is used as a base in the preparation of a variety of sweetmeats, of which *rasogolla* is a very popular one (De 1980). The production of *rasogolla* is increasing at a rate of about 67% per year (Anon 1994).

Many workers (Singh and Ray 1977; Bhattacharya and Des Raj 1980; Sen 1988; Tarafdar et al. 1988) have described the preparation of *rasogolla*. *Chhana* is kneaded to a homogeneous and smooth dough, which is then made into balls and cooked in boiling sugar syrup (Sen 1988).

Cooking in sugar syrup is an important step, leading to volume expansion, temperature rise, weight increase and change in mouthfeel quality of *rasogolla*. These changes occur primarily as a result of changes in textural parameters during the cooking process (Tarafdar et al. 1988). The strength or concentration of sugar syrup primarily depends on the desired sweetness and shelf-life of *rasogolla* (Bhattacharya and Des Raj 1980). The reported values of strength of cooking sugar syrup to get good quality *rasogolla* varies widely. De (1980) recommended 30° Brix. Since addition of water to compensate for evaporation was not reported, the strength of syrup must probably have increased during the cooking process. Soni et al (1980) recommended as high as 80° Brix. However, majority of the workers suggested that the strength of sugar syrup during cooking should be maintained between 50 and 60° Brix (Goel 1970; Kundu and De 1972; Bhattacharya and Des Raj 1980).

In order to meet the growing demand of *rasogolla*, it is necessary to develop a continuous process for making *chhana* and *rasogolla*. Singh (1994), Gupta and Kohli (1988) and Aneja et al (1977) developed processes for continuous production of *chhana*. Development of a continuous process for *rasogolla* requires, cooking *chhana* balls within a boiling sugar syrup for a pre-determined time. The reported values of cooking time of *chhana* balls ranged from 20 to 30 min (Goel 1970; Kundu and De 1972; De 1980; Bhattacharya and Des Raj 1980; Chandan 1992). Most likely, their results were based on sensory evaluation of the *rasogolla*, as no objective assessment had been reported.

Yield of *rasogolla* per unit weight of milk is another important parameter from the commercial point of view and depends primarily on the recovery of milk solids in *chhana*, which in turn, is influenced by a number of factors, like heat treatment prior to acidification of the milk, coagulation temperature, acidity of the milk-acid mixture and residence time of the coagulum prior to separation (Jonkman and Das 1993). These authors and Singh (1994) also reported a higher recovery of milk solids by a high rate of heating and cooling, prior to coagulation of milk. A combination of a coagulation temperature of 70°C, acidity of 0.522% lactic acid and a long residence time was necessary for the maximum recovery of solids and yield of *chhana* from cow milk (Jonkman and Das 1993). A low residence

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time of 1 min is desirable for a continuous process. Many workers have described an increased recovery of milk solids in *chhana* with increasing fat content of milk (Kundu and De 1972; Jagtap and Shukla 1973; Bhattacharya and Des Raj 1980; Tambat et al. 1992). A prediction model for recovery of milk solids in *chhana* and yield of *rasogolla* thus, can be developed, using fat content of milk as a variable.

The present investigation was undertaken to find the time required for cooking of *chhana* balls under varying concentrations of sugar syrup, on the basis of change in diam, temperature and textural quality, along with the development of a predictive model for recovery of milk solids in *chhana*, based on 1 min residence time.

Materials and Methods

Type and composition of milk : Milk from one particular cross-bred ('Holstein' X 'Haryana') cow was collected in the evening from a local milkman and stored in a refrigerator overnight for use the next day.

Preparation of chhana : At a time, 400 g milk was heated to 95°C in a microwave oven and subsequently cooled to 70°C. The temperatures of the milk during heating and cooling were recorded at intervals of 30 sec. Citric acid solution (100 ml, 1.5%) was heated to 70°C, before adding to the milk. The mixture was stirred till the appearance of a clear whey. After 1 min residence time, the *chhana* was strained through a muslin cloth, pressed into a slab of 1 cm thickness and was stirred in ice-cold water (0-4°C) for 1 min to cool to room temperature. This step was undertaken in order to get a fast and homogeneous cooling of the *chhana*. It was then manually squeezed so as to obtain a moisture content between 54 and 57%.

Chemical analysis : Chhana (2 g) was diluted with 18 ml plain water. The fat contents in milk and diluted *chhana* were determined by Gerber method (ISI 1970). The titratable acidity was determined by the method recommended by AOAC (1975). The moisture contents of milk and *chhana* were determined by oven-drying at 100±5°C for 4, 5 and 8 h, respectively.

Kneading of chhana : *Chhana* was kneaded in a disc grinder. The grinder was coupled to a motor with a variable speed drive. Peripheral speed of the grinder for kneading of the *chhana* was 0.89 m/s, which makes good quality *rasogolla*, as reported by Tarafdar et al (1988).

Preparation of chhana *balls :* The kneaded *chhana* was divided into lumps of 10±0.5 g. These were made into balls by rolling in palms for 1 min. Care was taken to avoid cracks on the surface.

Preparation of sugar syrup : One kg each of 45,55,60 and 65° Brix sugar solutions was prepared by dissolving the required quantity of sugar in plain water. The syrups were clarified by boiling with 5 ml of milk, followed by straining through a muslin cloth. The strength of the clarified sugar syrups was controlled using a refractometer. The sugar solutions as well as plain water (0° Brix) were used for cooking of *chhana* balls.

Measurement of temperature rise and volume expansion : At a time, one *chhana* ball was dropped in the liquid. It was kept within the liquid by means of a strainer, so as to get a homogeneous heating of the ball. A thermocouple was placed at the centre of the ball. The variation of temperature with time was read from a temperature indicator. The centre temperature was noted at an interval of 0.5 min. The diam of the ball was measured using a Vernier caliper at an interval of 1 min. While cooking in boiling sugar syrup, 35 ml of boiling water was added every 5 min to compensate for the loss by evaporation. In this way, the sugar concentration was kept constant.

Measurement of textural changes : Since the reports on organoleptic studies by many workers (Goel 1970; Kundu and De 1972; Bhattacharya and Des Raj 1980) stated that sugar concentration should be maintained at 55° Brix during the cooking process to get good quality *rasogolla*, this concentration was used to measure textural changes and yield of *rasogolla*.

At a time, 5 *chhana* balls were dropped in a 55° Brix boiling sugar syrup. After 5, 10, 15, 20 and 25 min, one ball was taken out for textural measurement. An unboiled *chhana* ball was also used as a sample. Texture analyzer (Stevens, LFRA Textural Technologies Corpn., USA) was used. Cylinders of 1.3 cm diam were carefully cut out from the prepared *rasogolla* using a cork borer. From this, a piece of 1 cm height was cut with a razor blade and placed under the crosshead of the texture analyzer. A 0.5 mm/s crosshead speed and 2 mm compression depth were used. Force-deformation data as for first and second bites were recorded (6512 Linseis, USA) at a chart speed of 10 cm/min. From the graphs, different textural parameters were calculated by the method recommended by Peleg (1976).

Calculation of recovery of milk solids and yield of chhana : The actual recovery of milk solids (Y_a) was calculated (Jonkman and Das 1993) from the equation :

$$Y_a = \frac{S_c W_c - (100-S_c)\ W_c\ [s\ W_a/\{(100-s)\ W_a + (100-S_m)W_m\}]}{W_m S_m} \quad ..(1)$$

Where, W_c, W_a, W_m are, the weight (kg) of *chhana*, citric acid solution and milk, respectively; S_c and S_m are, the solids content (%) in *chhana* and milk, respectively; and s is the strength of citric acid solution (%).

The actual yield of *chhana* (Z) was calculated from the ratio W_c/W_m :

$$Z = W_c/W_m \quad .....(2)$$

Yield of rasogolla : The weight of *rasogolla*, that can be obtained from 1 kg milk, was calculated from the predictive value of recovery of milk solids in *chhana*/kg solids in milk, as per the regression equation for the recovery of milk solids Y_t(kg/kg solids in milk) for low fat cow milk having 2.65% fat, developed by Jonkman and Das (1993).

$$Y_t = 0.4492 - 0.0502\ X_1 + 0.5553\ X_3 + 0.5942 * 10^{-3} X_1 X_2 - 0.6808 * 10^{-2}\ X_2 X_3 + 0.2831 * 10^{-3} X_4^2 \quad .....(3)$$

Where, X_1 is the degree of whey protein denaturation due to the heat treatment prior to acidification; X_2 is the coagulation temperature (°C); X_3 is the acidity of milk acid mixture (% lactic acid); and X_4 is the residence time (min) of milk-acid mixture prior to separation of *chhana* from whey. The whey protein denaturation follows first order reaction kinetics, and if c_0 and c are the initial and final whey protein concentration, it can be shown that

$$X_1 = \log (c_0/c) = k^* \cdot t/2.303 \quad .....(4)$$

Where, k^* is the whey protein denaturation rate constant (sec^{-1}), and t is the time (sec) of heat treatment (Walstra and Jennes 1983; Burton 1988). The value of k^* varies with temperature, and decimal reduction time. From the data of Burton (1988) for α-lactoglobulin, the largest fraction of whey protein in milk, Jonkman and Das (1993) derived the following equations :

$$\log k^* = 39.22 - 14754/(T+273) \text{ for } 60 < T < 90°C \quad .....(5)$$

$$\log k^* = 3.43 - 1760/(T+273) \text{ for } 90 < T < 130°C \quad .....(6)$$

Using eqns. (5) and (6), a plot of k^* vs t was made from the T vs t data. From eqn. (4), it can be seen that the area under the k^* vs t plot represents 2.303 log (c_o/c).

The acidity of the milk-acid mixture, X_3, (% lactic acid) was calculated (Jonkman and Das 1993) from :

$$X_3 = [C_m + s(M_1/M_a)\ W_a/W_m]/[1 + W_a/W_m] \quad .....(7)$$

Where, C_m is the acidity of the milk (% lactic acid); s is the strength of citric acid solution; M_1 is the molecular weight of lactic acid (90 g/mole); and M_a is the equivalent molecular weight of citric acid (64 g/mole).

The value of Y_a for cow milk, having fat content varying between 2.7 and 4.5%, was obtained under the condition, $X_1 = 3.46 \pm 1.25$, $X_2 = 70°C$, $X_3 = 0.522\%$ lactic acid, and $X_4 = 1$ min.

Since eqn. (3) does not take into consideration the fat content, F(kg fat/kg milk), the ratio, R were calculated from :

$$R = (Y_a)_F/(Y_a)_{F=2.65} \quad .....(8)$$

Where $(Y_a)_F$ is the actual recovery of milk solids from milk having any fat content and $(Y_a)_{F=2.65}$ is the actual recovery from milk having 2.65% fat content.

A functional relationship of the type R = p+qF was developed. The theoretically predicted value for recovery of milk solids Y_t was then calculated from :

$$(Y_t)_F = (p+qF)\ (Y_t)_{F=2.65} \quad .....(9)$$

During cooking, sugar syrup enters into the *chhana* ball and the volume of the ball rises. The weight, W_r, of *rasogolla* that can be obtained from a kg of milk was calculated from :

$$W_r = S_m Y_t + \rho_s[(d'/d_o)^3 - 1]\ [S_m Y_t/\rho_c + \frac{m\ S_m\ Y_t}{(1-m)\ \rho_w}] \quad .....(10)$$

Where, S_m is the solid content in milk (kg/kg milk), ρ_s is the density of sugar syrup (kg/m³); d_0 is the diam of the *chhana* ball before cooking (m); and d' is the final diam of the *rasogolla* (m). A value of 3 for (d'/d_0) was obtained by Bhattacharya and Des Raj (1980) and Tarafdar et al (1988). ρ_c is the density of milk solids in *chhana* (kg/m³); m is the moisture content of *chhana* (kg/kg *chhana*); and ρ_w is the density of water (1000 kg/m³). In eqn. (10), the term $S_m\ Y_t/\rho_c$ is the volume of milk solids; and the term $m\ S_m Y_t/[(1-m)\rho_w]$ is the volume of water present in *chhana* ball before *rasogolla* making.

The value of ρ_c was calculated from :

$$\rho_c = \left[\frac{FP}{S_m Y_t \rho_f} + \frac{1 - FP/(S_m Y_t)}{\rho_{snf}}\right]^{-1} \quad .....(11)$$

Where, P is the fraction of original fat in milk that is recovered in *chhana*. Bhattacharya and Des Raj (1980) observed that the value of P was 0.83±0.02 for milk having 3 to 4% fat. ρ_f and ρ_{snf} (eqn. 11) are

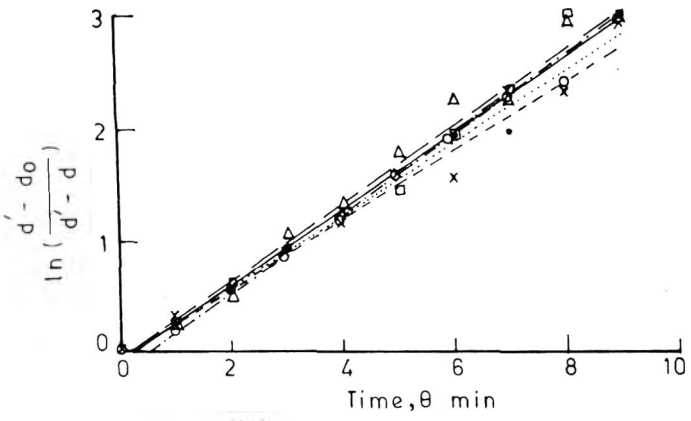

Fig. 1. Plot of $\ln \frac{d'-d_0}{d'-d}$ and time θ at different sugar concentrations. O—O : 0° Brix, X—X : 45° Brix, : Δ—Δ : 55° Brix, ●—● : 60° Brix, □—□ : 65° Brix

the densities of the fat and solids-non-fat in milk, respectively. In the present analysis, the values of ρ_f and ρ_{snf} were taken as 930 and 1614 kg/m³ (BS 1959). The value of ρ_s depends on the concentration of sugar syrup B and temperature T. It was calculated from :

$$\rho_s = (959.864 + 5.798\,B) - (0.405 + 3.59*10^{-3}B)\,T \quad .....(12)$$

The above equation is developed from the data given by Okade (1990), for use in the present study.

Results and Discussion

The total solid content in milk ranged from 11.5 to 12.6%. The fat content was 4.1% and the titratable acidity was 0.16% lactic acid. The average moisture and fat contents of *chhana* were 55 and 22%, respectively.

Volume expansion : Initial diam, d_0, of the balls was 2.7 cm, while final diameter d' after a 10 min cooking time was 3.7 cm for all the sugar solutions, thus, resulting in a volume expansion of $(d'/d_0)^3$ as 2.6. For the different sugar concentrations, B, a functional relationship of the type $\ln[(d'-d_0)/(d'-d)] = a\theta+b$, was developed, where d is the diam at any time θ; and a and b are constants. It was observed that the values of a and b were linearly related to the values of B with $a = 0.321 + 2.231*10^{-4}B$, and $b=-0.065+5.675*10^{-4}B$. Fig. 1 shows the plot of $\ln[(d'-d_0)/(d'-d)]$ and time, θ at different sugar concentrations, B. It was observed that the plots of $\ln[(d'-d_0)/(d'-d)]$ and θ at different values of B overlapped. Since the values of the coefficient of B are small, it may be inferred that the influence of sugar concentrations on volume expansion is negligible. From the values of $\ln[(d'-d_0)(d'-d)]$ and θ at the different sugar concentrations, a single relationship (eqn. 13) was developed.

$$\ln[(d'-d_0)/(d'-d)] = 0.331\ \theta - 0.066 \quad ..(13)$$

The time to reach 99% of the final diam was calculated from eqn. (13) and was found to be 10.2 min. This compares well with the actual time of 10 min.

Temperature rise : The initial centre temperatures of *chhana* balls were found to range from 25 to 30°C. It was further observed that the centre temperature of *chhana* balls reached its maximum within 5.5 to 6 min. This time increased slightly with the increase in concentration of sugar syrup. This was possibly due to the elevation of boiling point of the syrup, giving a higher maximum centre temperature. The elevations of boiling points calculated from Raoults law were 1.2°, 1.8°, 2.2° and 3°C for sugar concentrations of 45, 55, 60 and 65° Brix, respectively. For the different sugar concentrations, relationships of the type $\log [\ln\{(T'-T_0)/(T'-T)\}] = c \log\theta + d$ were developed, where T_0 and T' are the initial and the maximum centre temperatures, T is the centre temperature of *rasogolla* at any time; θ and c and d are constants. It was observed that the values of c and d were linearly related to the values of sugar concentration, B with $c=1.871-1.437*10^{-3}$ B and $d = -0.856 + 3.570*10^{-3}B$.

Fig. 2 shows the plot of $\log [\ln\{(T'-T_0)/(T'-T)\}]$ and log θ at the various sugar concentrations used. It was observed that the plots of $\log [\ln\{(T'-T_0)/(T'-T)\}]$ and log θ at various values of concentration B of sugar syrup overlapped.

Since the values of the coefficient of B are small, it may be concluded that the influence of

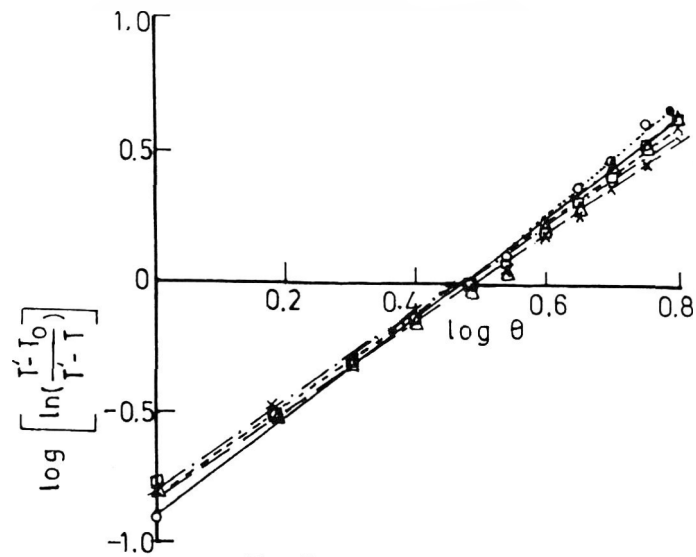

Fig. 2. Plot of $\log \ln\left[\frac{T'-T_0}{T'-T}\right]$ and log θ at different sugar concentrations. o—o : 0° Brix, X—X : 45° Brix, Δ—Δ : 55° Brix, ●—● : 60° Brix, □—□ : 65° Brix

TABLE 1. VARIATION IN TEXTURAL PARAMETERS+ OF *RASOGOLLA* WHEN COOKED IN SUGAR SYRUP CONTAINING 55% SUCROSE

Cooking time, min	Hardness, g	Cohesiveness,	Gumminess, g	Springiness, cm	Chewiness, g,cm
0	36.33	0.79	28.77	0.9	25.89
5	35.33	0.84	30.32	0.9	27.29
10	33.33	0.93*	31.00	0.9	27.90
15	33.33	0.94*	31.33	1.0	28.20
20	36.00	0.95	34.20	0.9	30.47
25	36.33	0.95	34.63	0.9	31.17
MR_1	28.00	0.82	23.01	0.9	20.70
MR_2	30.00	0.88	26.40	0.9	23.96

+ Average mean values obtained from three experiments.

* These values are the average of two values because a value of 1.10 at t=10 min and a value of 0.67 at t=15 min were found to be not reliable.

sugar concentration on rise of centre temperature was negligible. From the values of log $[\ln\{(T'-T_0)/(T'-T)\}]$ and log θ at the different sugar concentrations, a single functional relationship (eqn. 14) was developed.

$$\log [\ln\{(T'-T_0)/(T'-T)\}] = 1.804 \log\theta - 0.842 \quad \text{.....(14)}$$

The time to reach 99% of the maximum centre temperature was calculated from eqn (14) with the highest value of T' as 103°C (for 65° Brix sugar solution) and 25°C as value of initial temperature, T_0 and this was found to be 6.5 min. This compared well with the actual time of 6 min.

Textural change : Table 1 presents the variation of different textural parameters of *rasogolla* with cooking time together with the textural parameters of two different market samples of *rasogolla* (MR_1 and MR_2), procured from local shops.

It is observed (Table 1) that cohesiveness increased during the cooking process, probably due to settling of the casein network in the *rasogolla*. Springiness remained nearly constant, whereas hardness showed variation, which was probably due to a possible variation in the body of the *rasogolla* at the points of sampling. Gumminess and chewiness, which are both derived parameters, increased with time. Because hardness, cohesiveness and springiness are directly measured parameters, and they attained constant values after 20 min cooking time, it was concluded that cooking time of *rasogolla* should be around 20 min. Two market *rasogollas*, MR_1 and MR_2, have lower hardness and cohesiveness scores, possibly due to different methods adopted for their preparation.

Recovery of milk solids : Chhana was made from different samples of cow milk varying in fat content, F. Table 2 presents the actual yield of *chhana*, Z, and recovery of milk solids, Y_a. The Table also gives the values of R (eqn. 8) and the predicted values of the recovery of milk solids, Y_t (eqn. 9). Yield of *chhana* and recovery of milk solids increased with increasing fat content in the milk (Table 2). This finds support in results reported by Kundu and De (1972), Jagtap and Shukla (1973), Bhattacharya and Des Raj (1980) and Tambat et al (1992). The higher yield and recovery of milk solids with higher fat content might be due to a higher number of fat globules in the milk, which could trap larger amounts of milk proteins through their association with the fat globule membrane.

A functional relationship of the type R=p+q F was developed. Fig. 3 gives the plot of R and fat content, F, of milk. It was observed that the values

TABLE 2. VALUES OF YIELD OF *CHHANA*, Z, ACTUAL Y_a AND PREDICTED Y_t, R AND $(Y_a-Y_t)/Y_t$

Fat content of milk, F, %	Actual yield of *chhana*, Z, kg/kg milk	Recovery of milk solids kg/kg milk solids		R	$\frac{Y_a-Y_t}{Y_t}$
		actual, Y_a	predicted, Y_t		
2.65	0.118	0.479	0.471	1.000	0.017
3.50	0.136	0.525	0.517	1.096	0.015
4.10	0.150	0.556	0.551	1.161	0.009
4.50	0.160	0.587	0.573	1.225	0.024

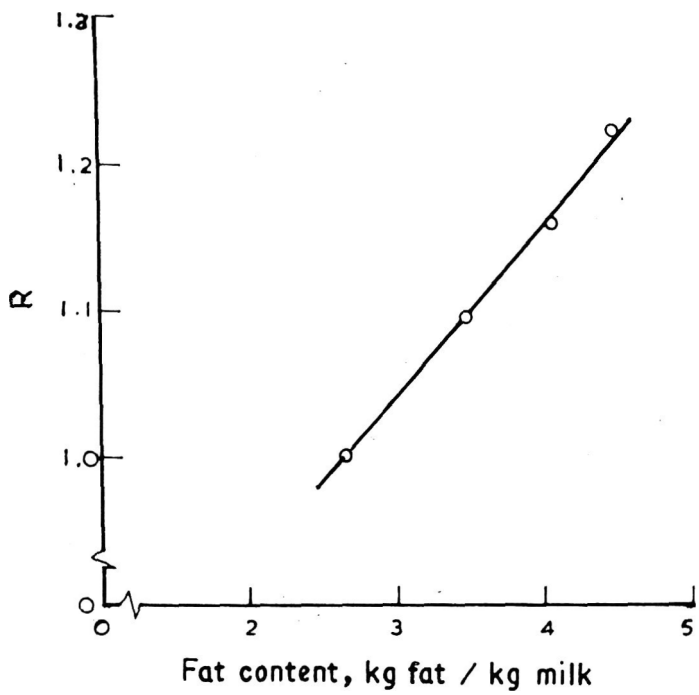

Fig. 3. Relationship between R (eqn. 8) and fat content, F of milk

of R and F were linearly related. The equation obtained was :

$$R = 0.681+0.119F \quad ..(15)$$

With the values of p and q, the predicted values of recovery of milk solids was calculated from eqn. 9. The ratio $(Y_a-Y_t)/Y_t$ was calculated for all the values of F and it may be seen that the actual recovery of milk solids, Y_a differed by not more than 2.4% of the predicted value, Y_t.

Yield of rasogolla : De and Ray (1954), Bhattacharya and Des Raj (1980) and Tambat et al (1992) observed that good quality *rasogolla* could be obtained from cow milk having about 4% fat. An experiment was undertaken to find out the yield of *rasogolla* from milk having 4.1% fat, while cooking *chhana* balls in a 55° Brix sugar syrup. In this case, the yield was found to be 0.287 kg *rasogolla*/kg milk. For calculation of the theoretical yield, average values obtained from experiments were taken for total solids content in milk, S_m (12.1%); moisture content in *chhana*, m (55%); recovery of fat in *chhana*, P (82.3%); and volume expansion d'^3/d_0^3 (2.6).

Using eqn 9, the recovery of milk solids was calculated as 0.551 kg/kg milk. The density of milk solids was calculated from eqn. 11 and was found to be 1178.3 kg/m^3. The density of a 55° Brix sugar solution at 30°C was calculated as 1260.7 kg/m^3 from eqn. 12. With the above data, the theoretical yield was calculated from eqn. (10) as 0.345 kg *rasogolla*/kg milk. The difference (0.345–0.287=0.058 kg) between actual and predicted yields could be due to the values taken for S_m, m, P and $(d'/d_0)^3$ in the experiment might have been different. Another factor responsible for the difference could be the fat loss out of *chhana* balls, while cooking in sugar syrup (Bhattacharya and Des Raj 1980).

Acknowledgement

The authors thank the foundation, Harold Quintus Bosz, The Netherlands, for financial support.

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Received 27 July 1994; revised 14 November 1994; accepted 25 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 115-118

Effect of Different Levels of Molasses and Salt on Acid Production and Volume of Fermenting Mass During Ensiling of Tropical Freshwater Fish Viscera

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Viscera from freshwater fish, constituting 5-11% of body weight, consists of (%) water 67, proteins 10, ether extracts 14, and minerals 3. Process of ensiling fish viscera after mixing individually with different levels of molasses (7.5, 10.0 and 12.5%, w/w) with (2 and 4%, w/w) or without salt was studied under microaerophilic condition at ambient (26±2°C) temperature. Data revealed that the optimum level of molasses was 10% of fish viscera, acid production being inadequate with 7.5% molasses, while it did not improve, but resulted in lower rise in fermenting mass with the use of 12.5% molasses. Salt lowered the swelling of fermenting mass, the efficiency being higher with the use of 4% salt, in addition to significantly ($p \leq 0.001$) reducing the rate of acid production during the first two days of fermentation. Subsequently, pHs of salted samples were markedly ($p \leq 0.001$) lower than those of non-salted samples.

Keywords : Fish viscera, Fermentation, Ensilage, Acidity, Fermenting mass volume, Molasses, Salt.

Total fish catch in India is reported to be 3,790,508 MT (FAO 1990), and 284 fish processing units are existing in the country (Anon 1992). Processing of fish in these organised industries and stray-dressing in market lead to generation of large quantity of fish viscera. The viscera which is discarded at present, causing environmental pollution, could be collected and suitably treated to preserve the nutrients for incorporation into animal diets.

Considerable interest has been witnessed in the preparation of fish silage by fermentation (James et al. 1977; Twiddy et al. 1987; Zuberi et al. 1993). Acid silaging of cod (marine fish) viscera using propionic and/or formic acids has also been reported (Raa and Gildberg 1976; Gildberg and Raa 1977). Acid silaging of poultry and fish offals is effective, but involves the use of expensive acids (Mahendrakar et al. 1991 a,b). Report on fermentative ensiling of tropical freshwater fish viscera has not yet been reported to the best of our knowledge. In order to develop fermentative ensiling process for tropical freshwater fish viscera, the influence of different levels of molasses as well as salt on acid production and changes in volume of fermentative mixture were studied. The results are reported in the present paper.

Materials and Methods

Freshwater fish (approx. 2 kg body weight each) viz., common carp (*Cyprinus carpio*), *catla* (*Catla catla*), *mrigal* (*Cirrhinus mrigala*) and *rohu* (*Labeo rohita*) were procured from local market and body components were weighed. Proximate composition of viscera from these fishes and mixed viscera obtained from local market was determined according to AOAC (1980) methods. Molasses, obtained from the nearby sugar factory, had a microbial load (log cfu/g) of total plate count 3.9, lactic acid bacteria 3.2, and spore count 2.9. Yeast, mould, coliform, faecal streptococcus and staphylococci were absent. The sample contained (%) moisture 27.2, proteins (N x 6.25) 3.9, ether extract 0.4, sulphated ash 15.4 and reducing sugars 46.3. It has a pH of 4.6 and Brix value of 81°. As per ISI (1958) standards, the molasses was found to be of grade 2.

Treatment : Viscera of mixed variety from freshwater fish was homogenized immediately for 1-2 min. Homogenate (5-10 kg each) was mixed individually with different levels (7.5,10.0 and 12.5%, w/w) of molasses. In another experiment, the homogenate was mixed with 10% (w/w) molasses along with different levels (0, 2 and 4%, w/w) of salt. The treated homogenate (2 kg) was transferred into 3 l beaker, covered with thin low density polyethylene (LDPE) film to create microaerophilic condition. A lid was placed over the beaker, and the mass was allowed to ferment at ambient temperature (26±2°C). Another aliquot of 1 kg quantity with initial height of 8 cm was used in studies on volume increase of fermenting mass.

Analytical measurements : The fermenting mass was stirred with glass rod daily before measuring the pH (Model 29, Radiometer pH meter, Copenhagen). In addition, known quantity of sample

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TABLE 1. WEIGHT OF BODY COMPONENTS AND PROXIMATE COMPOSITION OF VISCERA OF TROPICAL FRESH WATER FISH

	Common carp	*Catla*	*Mrigal*	*Rohu*
Body weight, kg	2.0 ± 0.20	1.6 ± 0.14	1.9 ± 0.21	1.9 ± 0.09
Fillets*	42.2 ± 1.80	36.9 ± 2.10	46.7 ± 1.66	47.5 ± 0.51
Bones*	15.2 ± 1.23	16.7 ± 1.84	10.5 ± 1.10	13.8 ± 0.77
Head with gills*	19.3 ± 2.45	26.9 ± 3.92	13.5 ± 2.27	16.9 ± 0.89
Skin with scales*	10.3 ± 0.83	9.6 ± 0.47	10.3 ± 0.55	9.9 ± 1.59
Fins*	3.6 ± 0.67	2.8 ± 0.16	3.1 ± 0.79	2.4 ± 0.51
Viscera*	4.7 ± 1.59	7.3 ± 1.02	10.8 ± 1.11	9.0 ± 2.64
Proteins**	10.3 ± 0.92	8.9 ± 0.68	12.0 ± 1.20	8.5 ± 0.82
Ether extract**	15.7 ± 3.21	12.0 ± 3.59	20.7 ± 2.31	18.6 ± 2.80
Ash**	2.8 ± 0.59	3.6 ± 0.67	3.1 ± 0.49	3.2 ± 0.71
Moisture**	66.8 ± 3.20	65.5 ± 2.89	60.3 ± 3.48	62.8 ± 1.80

* Values are % of body weight, ** values are % of the viscera weight. Each observation is the average of six fishes. Mixed viscera from market contained (%) proteins 9.63±1.88, ether extract 14.07±3.18, ash 3.33±0.87 and moisture 67.06±3.99.

was stirred with 10 volumes of distilled water, centrifuged at 4000 rpm for 15 min, and the centrifugate was titrated potentiometrically against 0.1 N NaOH solution to pH 7.0 for determining titrable acidity (AOAC 1980). During titration, the mixture was stirred continuously, using a magnetic stirrer. The acidity values were expressed as mg NaOH required to neutralize acid(s) in 1 g sample. For measuring the rise in volume of fermenting mass, the height of the material was measured periodically prior to stirring. Initial height of the sample was 8 cm.

Statistical analyses : The experiments were planned on a replicated (six replicates) factorial design having treatment of fish viscera (three treatments) as one factor and storage period as another. Analysis of variance technique, appropriate to the design (Steel and Torrie 1980) and Duncan's new multiple range test (Duncan 1960 were used to segregate the treatment means.

Results and Discussion

Body weight composition : Carp fish studied yielded 37-48% fillets and 10-17% bones, thereby containing 57-61% salable material, when the body weight of the fish was 1.5-2.0 kg. Remaining 39-43% portion comprised waste, which was rejected. Head with gills, comprising 14-27% of the fish weight, is some times sold due to its meat content. Fins and scales with skin, are the parts that are refractory to digestion by mild treatments like fermentative ensiling (Gildberg and Raa 1982). Viscera, consisting 5-11% of body weight, includes liver, swim bladder, intestine, blood and gonads, and can be subjected to ensiling. Viscera contained (%) protein 8.5-12.0, ether extract 12.0-20.7, minerals 2.8-3.6 and water 60.3-67.1 (Table 1).

Effect of molasses on volume of fermenting mass : Fermenting mass was found to swell with visible air packets during ensiling. Both treatment and fermentation period significantly ($p \leq 0.001$) influenced the degree of gas production and swelling, though the interaction between the two was not significant ($p \geq 0.05$). Greater variations ($p \leq 0.001$) in the results of the replicate experiments were observed in all the treatments. The results indicated that the greater the quantity of molasses in fermenting material, lesser was the degree of volume increase during the period up to 7 days

TABLE 2. VOLUME RISE OF FERMENTATION MIXTURE WITH DIFFERENT LEVELS OF MOLASSES AND SALT DURING FERMENTATION PERIOD

(Expressed as increased height in cm.)

Fermentation period, h	Levels of molasses (% of fish viscera) 7.5	10.0	12.5	Levels of salt (% of fish viscera) 0	2	4
4	5.4^{ax}(4.8-5.8)	4.8^{ay}(4.5-5.0)	4.2^{az}(3.8-4.6)	8.1^{ax}(4.5-11.2)	5.8^{ay}(3.8-7.3)	4.3^{ay}(1.0-6.6)
24	4.3^{bx}(3.8-4.8)	3.8^{by}(2.8-4.4)	3.3^{bz}(2.0-4.0)	9.2^{ax}(3.3-14.4)	4.7^{ay}(2.6-6.0)	2.9^{az}(1.0-4.0)
48	3.6^{cx}(2.8-4.0)	3.1^{cy}(2.4-3.7)	2.8^{cy}(2.0-3.4)	7.6^{ax}(3.0-13.2)	5.4^{ay}(2.1-9.1)	3.4^{ax}(1.6-6.2)
72	3.1^{dx}(3.0-3.4)	2.7^{dy}(2.4-2.9)	2.5^{dy}(2.2-3.2)	5.1^{bx}(2.4-7.0)	3.8^{axy}(1.3-5.8)	2.7^{aby}(1.3-4.0)
96	2.4^{ex}(1.8-2.9)	1.8^{ey}(1.3-2.4)	1.7^{ey}(1.4-2.2)	2.4^{cx}(1.2-5.6)	1.5^{bx}(0.4-4.7)	0.8^{bcx}(0.4-1.8)
120	1.4^{fx}(0.6-2.0)	0.9^{fy}(0.3-1.3)	0.7^{fy}(0.3-0.8)	0.3^{cdx}(0.2-2.9)	0.4^{bx}(0.0-1.4)	0.2^{cx}(0.0-0.8)
144	1.0^{gx}(0.5-1.3)	0.6^{fy}(0.2-1.0)	0.5^{gy}(0.0-0.6)	0.3^{dx}(0.0-1.0)	0.1^{bx}(0.0-0.2)	0^{cx}
168	0.5^{bx}(0.2-0.6)	0.2^{gx}(0.0-0.5)	0.2^{gx}(0.0±0.5)	-	-	-
	SEM (115df) ± 1.46			SEM (100df) ± 8.44		

Each value is a mean of six experiments. Numerals in the parentheses are the range of values. Means of the same column followed by different letters (a-h) and means of the same row followed by different letters (x,y,z) are significantly different ($p \leq 0.05$).

(Table 2). This could possibly be due to greater amount of acid produced with higher quantity of molasses, which was effective enough to suppress the gas producing heterofermentative microorganisms present in fish viscera. High increase in volume in first 4 h was observed in 7.5, 10.0 and 12.5% molasses-treated samples. Marginal ($p \geq 0.05$) differences between 10.0 and 12.5% molasses-treated samples, from 2 days onwards, were noticed, the values being markedly lower ($p \leq 0.001$) as compared to 7.5% molasses-treated samples. It is evident that optimum molasses level was 10%. While the level of 7.5% is inadequate, leading to higher activity of heterofermentative microorganisms as well as greater swelling of the mass, 12.5% level did not provide any marked additional advantage in suppressing the activity of these organisms. With 5% (w/w) molasses, the samples gave rise to a putrid odour within 24 h, thereby indicating inadequacy of molasses to effect good lactic acid fermentation. Zuberi et al (1993) tested the range of carbohydrate sources (e.g., liquid glucose, sucrose and molasses) and their combinations for fermentative ensiling of fish and reported that microbiologically fermented fish silage could be prepared within 3-4 days at 28-30°C by

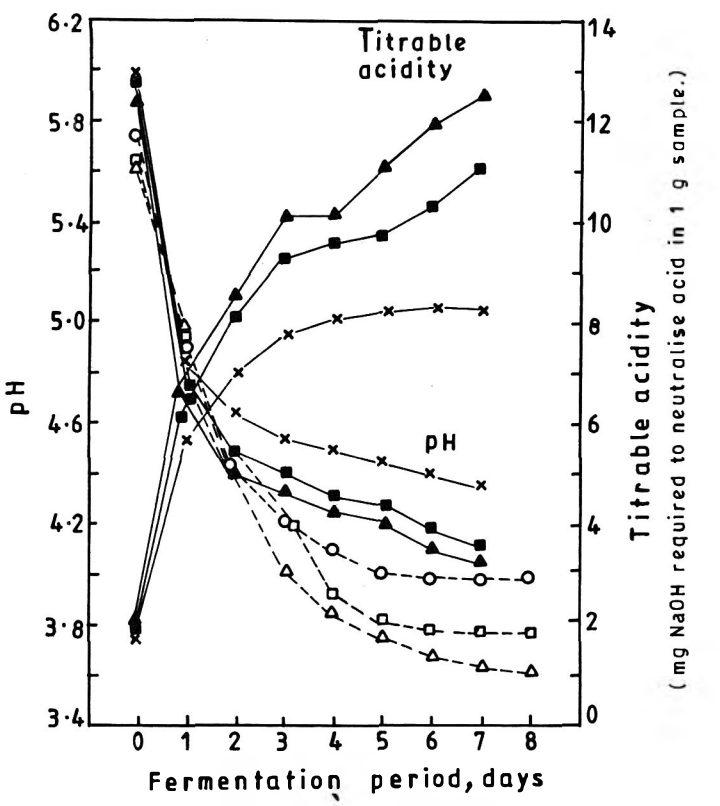

Fig. 1. pH and titrable acidity of fermentation mixture with different levels of molasses and salt during fermentation. Levels of molasses X—X, 7.5%; ■—■, 10.0%; ▲—▲, 12.5%; Levels of salts O—O, 0.0%; □—□, 2.0%; Δ—Δ, 4.0%. Each observation is a mean of six experiments.

adding carbohydrate sources up to 10%.

The degree of swelling at 7 days was in the range of 2-6% in all the treated samples (Table 2). Development of heterofermentative bacteria causing intensive gas production with consequent volume rise has been reported by Stanton and Yeoh (1977) in fermentative ensiling of trash fish.

Effect of molasses on pH and acidity : Enrichment of viscera with different levels of molasses led to slight lowering of the pH (Fig 1). Titrable acidity (TA) increased and pH decreased exponentially as a function of fermentation period, the correlation coefficient being 0.98 to 0.99 for treatments with 7.5 to 12.5% molasses. Although batch to batch (replicate) variations ($p \leq 0.001$) in pH and titrable acidity were noticed, the treatments (different levels of molasses) and fermentation period were found to have a significant ($p \leq 0.001$) influence on the acid production. However, there was no interaction ($p \geq 0.05$) between these two factors. Further, the rate of production of acid was considerably ($p \leq 0.001$) slower in 7.5% molasses-treated sample, whereas differences between 10.0 and 12.5% molasses- treated samples were marginal ($p \geq 0.05$). The microbiologically safe pH of about 4.2 (Raa and Gildberg 1982) was reached in 3-5 days in 10.0 and 12.5% molasses - treated samples, whereas the pH remained at 4.4 even on the 7th day in 7.5% molasses containing samples. These results indicate that a minimum of 10% molasses is required for effective fermentative ensiling of fish viscera. The fall in pH during fermentation of fish and broiler processing waste was also reported by some workers (Raa and Gildberg 1982; Russell et al. 1992).

Effect of salt on volume of fermenting mass : Treatment with salt and the fermentation period were found to significantly ($p \leq 0.001$) influence the production of gas, and consequent increase in volume of fermentating mass, the interaction between the two being significant ($p \leq 0.01$). Marked ($p \leq 0.01$) differences among replicates were also observed. Presence of salt lowered the volume rise (Fig. 1), 4% salt being more effective than the use of 2% salt. The degree of volume rise decreased during fermentation in all the samples, and no swelling was observed on the 7th and 8th days. Thus, the salt suppressed development of heterofermentative microorganisms, resulting in lower production of gas, as also been reported by Stanton and Yeoh (1977) in fermentative ensiling of fish. Inclusion of salt at 2 and 4% on wet weight basis in fish viscera

corresponds approximately to 6 to 12% on dry weight basis. Such a high concentration of salt, although has an industrial advantage of suppressing volume rise, restricts the utility of fermented silage product as an ingredient in animal diet. Nevertheless, in the current experiment, salt at these levels was added to see whether it has any desirable advantage in terms of faster production of acid during fermentation.

Effect of salt on pH values : Since the definite correlation between pH and titrable acidity was observed earlier, only pH of fermentating material was monitored. Salt treatment as well as fermentation period had a significant effect ($p \leq 0.001$) on production of acid, despite the marked ($p \leq 0.001$) differences in the results of the replicate experiments. There was also a significant ($p \leq 0.01$) interaction between salt treatment and fermentation period. Exponential fall in pH, as a function of fermentation period (correlation coefficient being in the range of 0.97-0.99), revealed that the rate of fall in pH was slightly lower in salted samples, initially up to 2 days, as compared to non-salted ones. Subsequently, markedly greater ($p \leq 0.001$) quantity of acid(s) (lower pH) was produced in salted samples, bringing down the pH to 3.7 and 3.6 in 2 and 4% salted samples, respectively. The initial delay in the production of acid and later greater quantity of acid(s) in salted samples could be due to the effect of salt on changes in microbial profile during fermentation.

From the microbial safety point of view, the pH of the viscera should, as quickly as possible, be brought down and maintained at 4.0-4.2, because the pathogenic and spoilage organisms are destroyed at this pH (Raa and Gildberg 1982). The silage pH below 4.0 makes the product more acidic, thereby necessitating neutralization prior to incorporation in the feed. In the current investigation, the presence of salt delayed acid production initially. However, greater quantities of acids were produced later on and the pH was lowered to below 4.0. Thus, inclusion of salt in fermenting material is disadvantageous in the ensiling of fish viscera.

Acknowledgement

This work was supported by a grant from the Department of Biotechnology, Ministry of Science and Technology, Government of India. JA is thankful for the award of fellowship. Authors thank Shri B.S. Ramesh for statistical analysis and Shri N.P. Dani for valuable suggestions.

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Received 2 August 1994; revised 10 December 1994; accepted 18 January 1995

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 119-121

Microbial Production of Organic Acids from Carrot Processing Waste

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Possible use of carrot processing solid waste, as a carbohydrate source, for production of citric and lactic acids in solid state fermentation was explored. On the basis of fermentable sugar consumed, the yields of citric acid and L (+) - lactic acid from carrot processing waste by fermentation with *Aspergillus niger* and *Rhizopus oryzae* were 36 and 55 %, respectively.

Keywords : *Aspergillus niger*, *Rhizopus oryzae*, Citric acid, Lactic acid, Carrot processing waste, Solid state fermentation.

Carrot processing industry in the United States utilizes about 280,000 tonnes of carrot each year and subsequently, generates approximately 150,000 tonnes of solid residuals (Rose et al. 1971). Because of high organic matter content, these waste materials pose a serious environmental pollution problem (Rose et al. 1971). In recent years, there has been an increased interest in the recovery of valuable by-products from food processing waste materials (Hang and Woodams 1986; Jewell and Cummings 1984). Organic acids such as citric and lactic acids are widely used in the food, beverages, pharmaceutical and other industries, and they also stimulate production of flavour compounds (Prescott and Dunn 1959; Kapoor et al. 1982; Dutta et al. 1972). These acids are generally produced commercially by submerged microbial fermentation of crude carbohydrates such as molasses, cheese whey, and starchy materials (Prescott and Dunn 1959). Many strains of *Aspergillus niger* are well known for their capacity to produce citric acid under suitable conditions (Kapoor et al. 1982; Banik 1975). By carefully selecting strains and improving conditions, about 80-85% of the weight of initial sugar can be converted into citric acid (Kiel et al. 1981). Citric acid has also been produced using bagasse with additives (Manonmani and Sreekantiah 1988). Sporulation of the inoculated fungi is deterimental for citric acid production (Shu and Johnson 1947). Methanol and ethanol at concentrations of 2.5-3% have been found to prevent sporulation (Moyer 1953). Lactic acid is generally produced by using lactic acid bacteria. Of late, technologies have been developed using whey and *Aspergillus oryzae* (Ozbas and Kutsal 1990). Such fermentations usually result in the formation of racemic or optically inactive lactic acid (Hang et al. 1989). Prescott and Dunn (1959) have reviewed the production of L(+) lactic acid by moulds. The objective of the present investigation was to determine the feasibility of using carrot processing solid waste, as a substrate for fungal production of citric and L(+) lactic acids, as such type of work has not been conducted earlier.

Samples of carrot processing solid waste were obtained from a nearby commercial plant and stored at -10°C, until needed. Before use, the waste was homogenized in a Waring blender for 2 min. Moisture, total sugars, crude fibre, total proteins and fat contents of the homogenized mixture were determined by the methods of AOAC (1975). The fungal cultures, *Aspergillus niger* NRRL 2270 and *Rhizopus oryzae* NRRL 395, used in this study, were provided by C. W. Hesseltine, Northern Regional Research Centre, USDA, Peoria, Illinois, USA. These moulds were maintained on potato-dextrose-agar slant. The spore inoculum was prepared, as described previously (Hang and Woodams 1986).

Citric acid production by solid state fermentation : Samples of homogenized carrot waste (100 g) were placed in one litre beakers, covered with aluminium foil and sterilized at 121°C for 15 min. Each beaker was inoculated with 10 million spores of *A. niger* and incubated at 30°C under stationary conditions for 24-96 h. Methanol was added to the waste at a concentration of 3% (v/w) before fermentation. The thickness of the waste material in the beaker was 2.5 cm.

Citric acid production by submerged fermentation : Samples of homogenized carrot waste (100 g) and 100 ml of distilled water were placed

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in 500 ml Erlenmeyer flasks and sterilized at 121°C for 15 min. Each flask was inoculated as above, and incubated at 30°C for 24-96 h on a New Brunswick rotary shaker, operated at 240 rpm. Methanol was added as above.

L(+) lactic acid production : Experimental procedures were the same as those for citric acid fermentation, except that *Rhizopus oryzae* spores were used as inoculum and $CaCO_3$ at a concentration of 2%, was added before fermentation.

Sugar was measured as glucose by the phenol-sulphuric acid method of Dubois et al (1956). Citric acid and L(+) lactic acid were analyzed by HPLC using a Bio-Rad Aminex HPX-87C column, as described earlier (Hang et al. 1989; Hammanci and Hang 1989).

Carrot processing waste is rich in sugars (approx. 9.0%). It has got about 89% moisture. Fig. 1 depicts the time course of citric acid production by *A. niger* NRRL 2270. At the end of 96 h, most of the sugars were consumed and approximately 1.4 and 2.9% citric acid was produced in submerged and solid state fermentations, respectively. Addition of methanol increased citric acid production from 1.1 to 1.4% and 2.3 to 2.9%, in submerged and solid state fermentations, respectively. The influence of methanol in increasing citric acid production appears to be a general phenomenon with strains of *A. niger* and the use of methanol has become a common practice (Prescott and Dunn 1959). Methanol is not assimilated by *A. niger*, but it prevents sporulation by affecting the permeability properties of the mould, thereby enabling greater excretion of citric acid (Kapoor et al. 1982). Solid state culture was viewed as an economically better medium than submerged culture because the initial sugar content of carrot waste in solid state culture was higher, and thus twice the amount of citric acid could be produced. However, carrot waste yield a lesser amount of citric acid (about 36%) than fruit pomace. The yield from apple pomace, for example, was greater than 88% (Hang and Woodam 1986). This difference is probably due to intrinsic differences in the composition of the waste materials. For example, carrot waste had a much greater moisture content than apple pomace, and its texture was thus too mushy to provide good fungal growth and acid production.

The production of L(+) lactic acid by *R. oryzae* NRRL 395 from carrot processing solid waste in submerged culture is shown in Fig. 2. At the end of 96 h, the sugar content was reduced from an initial value of 4.5% to less than 1%, and the amount of L(+) lactic acid produced was higher in the presence of neutralizing agent, $CaCO_3$. The yield was approximately 55%, based on the quantity of sugar consumed. This confirms our earlier finding

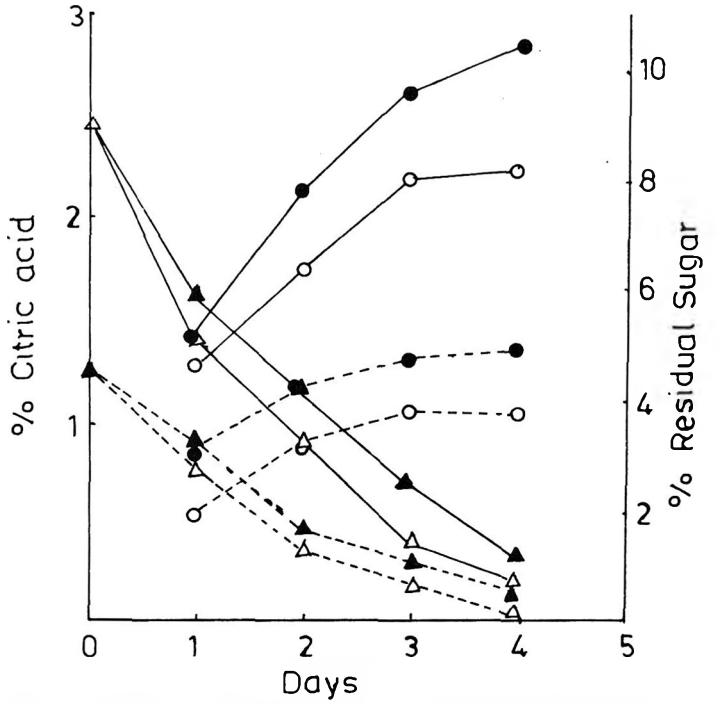

Fig. 1. Citric acid production from carrot waste by *Aspergillus niger*. ____ solid state fermentaiton ------- submerged fermentaiton; ● - citric acid with methanol; O- citric acid without methanol; Δ - residual sugar without methanol ▲ - residual sugar with methanol.

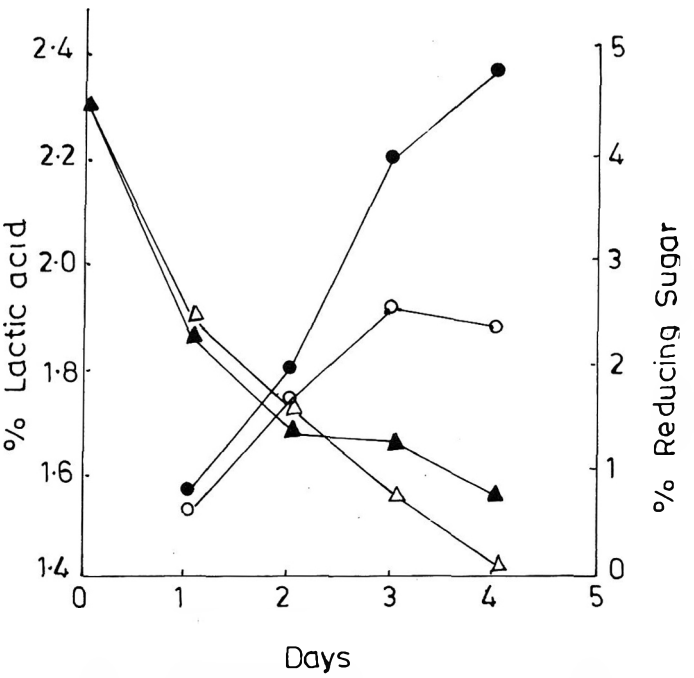

Fig. 2. Lactic acid production from carrot waste by *Rhizopus oryzae* in submerged culture. ● - lactic acid produced with $CaCO_3$; O- lactic acid produced without $CaCO_3$; ▲ - residual sugar without $CaCO_3$; Δ - residual sugar with $CaCO_3$.

that lactic acid production is more in the presence of $CaCO_3$ (Yu and Hang 1989). Attempts to produce L(+) lactic acid from carrot waste by solid state fermentation showed that only 1% or less L(+) lactic acid could be produced after 96 h and the fermented solid waste still contained more than 4% sugar concentration. This is probably because the waste material was too mushy, and thus did not have sufficient free air space, required for mould growth and acid production.

The data indicate that carrot processing solid waste could serve as a substrate for the production of organic acids by fungi. However, considering the low concentrations of citric and L(+) lactic acid produced, it might be economical, if carrot processing solid wastes were used in combination with other carbohydrate substrates.

The first author was supported by a training grant from Winrock International under INDO-USAID sub-project on Post-harvest Technology of Fruits and Vegetables. Technical assistance provided by E.E. Woodams is gratefully acknowledged.

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Received 18 January 1992; revised 7 July 1994; accepted 4 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 122-125

Quick-cooking *Dhal* of Pigeonpea as Influenced by Salt Solution and Enzyme Pre-treatments

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Quick-cooking *dhal* of pigeonpea (*Cajanus cajan* L.) was prepared by employing various salt solutions and enzyme treatments. Sodium carbonate (1%) and sodium bicarbonate (>1%) were effective in reducing the cooking time, but the product quality was affected. Pectinase treatment remarkably decreased the cooking time, as compared to other enzymes and salt solutions. General acceptability score of *dhal* was the highest (3.3) for pectinase-treated *dhal*, followed by the control (3.2), 1.0% solution of sodium bicarbonate (3.0) and salt-mixture (2.2).

Keywords : Pigeonpea, Quick-cooking *dhal*, Salt solutions, Salt mixture, Enzyme treatments.

Among food legumes, pigeonpea (*Cajanus cajan* L.) is an important source of protein in human diet in several semi-arid and tropical regions of the world. India accounts for over 80% of the world's pigeonpea production as well as consumption, and this crop is important to many other countries of Asia and Africa (ICRISAT 1985). In India, pigeonpea is mostly consumed after dehulling, in the form of *dhal* (decorticated split cotyledon), after cooking it in water to a desirable softness. In some African countries, the whole seeds are also consumed after boiling (Singh and Eggum 1984). Of all the food crops, legumes provide a significant portion of protein needs in the vegetarian diets in many developing countries (Singh and Singh 1992). In addition, these are valuable sources of minerals and vitamins, particularly the B-group vitamins, in the daily diets of the population, especially of low-income groups (Aykroyd and Doughty 1964). The most serious drawback in the utilization of grain legumes, is their long-cooking time. Even though dehusking and splitting into *dhal* reduce the cooking time considerably, the cooking process is time consuming. Also, the storage under adverse conditions of high temperature and high humidity renders the grain legumes susceptible to a hardening phenomenon, known as hard-to-cook (HTC) defect (Paredes-Lopez et al. 1991). Pre-soaking in water or soaking solution at 25°C has been recommended to facilitate the cooking step (Chavan et al. 1983). Special soaking solutions containing inorganic salts have also been employed for quick-cooking of legume formulations (Rockland et al. 1979).

An understanding of the role of chemical constituents in influencing the cooking time, cooking quality and chemical composition of pigeonpea genotypes have been the subject of several studies in the past, as the quality traits vary with different cultivars (Sharma et al. 1977; Narasimha and Desikachar 1978; Singh et al. 1984). Bhuibhar et al (1991) studied the effect of drying time and temperature on the cooking time of instant *dhal*. The present study was undertaken to compare the effect of salt solutions and enzyme-treatment on the cooking quality and sensory properties of the quick-cooking pigeonpea *dhal*.

Two cultivars, 'C 11' and 'BDN 1', commonly grown in the Central and Peninsular India, were grown during 1989 rainy season in deep vertisols at ICRISAT. After harvest, seed samples were stored in plastic bags in a cold room at 5°C, until used. Sample of *dhal* was also obtained in 1990 from a local market and stored similarly. The market sample was similar in size, shape, and appearance to those of 'C 11' and 'BDN 1'. All the chemicals used in the present study were of AR grade and purchased locally. Enzymes were obtained from Sigma Chemical. Co., St. Louis, USA.

Decortication and pre-treatments : Whole seed samples were processed into *dhal* (decorticated dry split cotyledons) by using a tangential abrasive dehulling device (TADD), as described by Singh et al (1992). *Dhal* samples were pre-treated individually with salt solutions and enzyme preparations. Salt solutions (1% w/v) used individually were those of sodium chloride, sodium carbonate, sodium bicarbonate, and sodium tripolyphosphate. The salt-mix solution contained 2.5% sodium chloride, 1.0% sodium tripholyphosphate, 0.25% sodium carbonate and 0.75% sodium bicarbonate. *Dhal* samples were soaked for 4 h in each solution at room temperature. After soaking, the excess solution was discarded

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and samples were dried in an oven at 50°C for 16 h.

Five enzymes were selected, based on their role in the hydrolysis of proteins (protease and papain), carbohydrates (amylase), pectic substances (pectinase), and phytic acid (phytase). Solution of each crude enzyme preparation (1%) in 0.1 M phosphate solution was employed at different conditions as follows : Protease (pH 7.5, temperature 37°C), papain (pH 6.2, temperature 25°C), pectinase (pH 4.0, temperature 25°C), phytase (pH 5.2, temperature 55°C), and amylase (pH 6.9, temperature 25°C). These conditions for different enzyme activities were selected, as described in the manual published by Sigma Chemical Co., St. Louis, USA. The processing of the *dhals* after enzyme treatment, was the same as that of the salt-treated samples.

Determination of cooking time : A block digester (Model 20 DB, Tecator, Hoganas, Sweden) was used for ensuring uniform and constant temperature during boiling. About 100 ml distilled water was brought to the boiling point in a 250 ml digestion tube, and then, a 20 g seed sample was added. Boiling was continued and the boiled samples (4-5 cotyledons/split *dhals*) were drawn with the help of scupla at 1 min intervals for softness testing by pressing between the fingers and thumb, as described by Singh et al (1984). The time taken to achieve the desirable softness was recorded as the cooking time of the sample.

Sensory and statistical analysis : Properties such as colour, texture, flavour, taste and general acceptability were evaluated by eight panel members, as described by Singh et al (1993). Freshly boiled samples (15 min) were served for sensory evaluation. The following rating scale was used : 1= poor, 2= fair, 3 = good, and 4=excellent. Standard error was determined by one-way analysis of variance (Snedecor and Cochran 1967).

The cooking time of pigeonpea *dhal* was significantly ($P<0.01$) reduced by salt solution treatments (Table 1). Results indicated that sodium carbonate solution was the most effective in reducing the cooking time, and this was followed by salt-mix and sodium bicarbonate solutions. The treatment effects did not differ significantly, when the results of salt-mix and sodium bicarbonate were compared. Soaking legumes in salt solution was found beneficial in reducing the cooking time in many other cases. A considerable improvement in cooking quality of horsegram by pre-soaking in salt solution was reported by Kadam et al (1981).

TABLE 1. EFFECT OF DIFFERENT SALT SOLUTIONS AND ENZYME TREATMENTS ON COOKING TIME OF *DHAL* OF PIGEONPEA GENOTYPES[a]

Treatment	Solution pH	Cooking time, min		
		'C 11'	'BDN 1'	Market sample
Control	6.0	26	25	25
		Salt treatments		
Sodium chloride, 1.0%	6.1	20	18	19
Sodium carbonate,				
1.0%	11.3	12	12	10
1.5%	8.7	12	11	12
2.0%	8.7	9	9	10
6.0%	9.0	5	6	6
Sodium bi-carbonate, 1.0%	8.6	15	12	15
Sodium tripoly-phosphate, 1.0%	9.1	20	20	18
Salt mix[b]	9.1	14	15	12
		Enzyme treatments		
Protease	7.5	18	18	16
Papain	6.2	20	21	20
Pectinase	4.0	12	12	12
Phytase	5.2	33	35	55
Amylase	6.9	18	18	16
SEM±	-	0.4	0.6	0.5

[a] Values are mean of two independent determinations; [b] see text.

Soaking of legume (pigeonpea, chickpea, mung bean, *urd* bean, and lentil) *dhals* in salt solution (1.5% sodium bicarbonate, 0.5% sodium carbonate, and 0.75% citric acid at pH 7.0) was found to be more effective in reducing cooking time than that by water (Chavan et al. 1983). Paredes-Lopez et al (1991) reported that the adverse effects of hard-to-cook condition in common beans were practically eliminated by soaking seeds in salt solution, consisting of 1% sodium chloride and 0.75 sodium bicarbonate.

Effect of soaking pigeonpea in sodium carbonate solution was more pronounced than soaking in sodium bicarbonate solution, obviously due to the pepitising action at high pH (Rockland et al. 1979). But, soaking in the sodium carbonate solution changed the *dhal* colour considerably, making it unacceptable to the consumer. Therefore, sodium bicarbonate solution was used in further studies instead of sodium carbonate. As shown in Table 1, the cooking time decreased with a increase in concentration of sodium bicarbonate solution. However, higher concentrations of sodium bicarbonate adversely affected the sensory scores and general acceptability (Table 2). Scores of such

TABLE 2. SENSORY EVALUATION OF QUICK-COOKING *DHAL* OF PIGEONPEA PREPARED BY DIFFERENT TREATMENTS

Genotype	Treatment	Sensory score				General acceptability
		Colour	Texture	Flavour	Taste	
'C 11'	Water	3.9	3.3	3.2	3.1	3.3
	Pectinase, 1%	3.8	3.4	3.0	3.3	3.2
	Sodium bicarbonate, 1%	3.1	3.0	3.0	2.8	2.8
	Sodium bicarbonate, 2%	2.9	2.3	2.8	2.8	2.5
	Salt mixture	3.2	2.8	2.2	2.1	2.0
	SEM ±	0.21	0.26	0.22	0.23	0.24
'BDN 1'	Water	3.6	3.2	3.6	3.3	3.2
	Pectinase, 1%	3.7	3.9	3.1	3.3	3.2
	Sodium bicarbonate, 1%	3.2	3.2	3.2	3.0	3.0
	Sodium bicarbonate, 2%	2.6	2.9	2.8	2.6	2.9
	Salt mixture	2.6	3.4	2.6	2.4	2.3
	SEM ±	0.19	0.20	0.18	0.19	0.17
Market sample	Water	3.6	3.3	3.2	3.0	3.1
	Pectinase 1%	3.4	3.3	3.6	3.3	3.4
	Sodium bicarbonate, 1%	3.2	3.3	3.4	3.2	3.2
	Sodium bicarbonate, 2%	2.2	2.6	2.5	2.4	2.8
	Salt mixture	2.2	3.3	2.4	2.3	2.3
	SEM ±	0.18	0.24	0.22	0.21	0.23

Results are averages of scores given by nine panel members.

organoleptic properties as colour, texture, taste, flavour and general acceptability decreased, when the sodium bicarbonate concentration was increased to 2% and more (Table 2). The carbonate or bicarbonate not only acts as an alkaline agent and buffer, but also acts as a protein dissociating, solubilizing or tenderizing agent (Rockland et al. 1979). Good results were obtained with a mixture of sodium carbonate and sodium bicarbonate and the preferred form of the hydrating medium contained these components in concentrations of about 0.25% sodium chloride and 0.75% sodium bicarbonate (Rockland et al. 1979).

The effects of different enzyme solutions in imparting quick-cooking characteristics to *dhal* are summarized in Table 1. Pectinase treatment seemed to remarkably decrease the cooking time, as compared to other enzyme treatments and the control. Treatment with phytase increased the cooking time by nearly 35%. Phytic acid, which chelates divalent cations (Ca, Mg) (Muller 1967), might have been reduced due to hydrolysis by phytase treatment, thereby increasing the cooking time. Bean seeds with reduced levels of phytic acid have been reported to take longer time to cook (Kon and Sanshuk 1981). Pectic substances in combination with divalent ions, calcium, and magnesium, have long been known to influence the cooking time of grain legumes (Muller 1967; Rockland et al. 1979, Paredes-Lopez et al. 1991). Pectinase treatment might have resulted in degradation of pectic substances, thereby reducing their ability to complex Ca and Mg (Muller 1967). Also, this may facilitate cell wall dissolution during the cooking process, thereby reducing the cooking time (Paredes-Lopez et al. 1991).

Data on organoleptic properties such as colour, texture, flavour, taste and general acceptability of the quick-cooking *dhal* prepared by different pre-treatments, including enzymes and sodium bicarbonate are presented in Table 2. The average score on general acceptability was the highest (3.3) for pectinase-treated *dhal* and this was followed by the control (3.2), sodium bicarbonate (3.0) and the salt mixture (2.2). This trend was observed in both the genotypes and the market sample. The lowest score for salt mixture-treated *dhal* was probably due to sodium carbonate, which generally imparts a dark brown colour to the product, because of its high alkaline pH.

Although the results are based on the analysis of a limited number of pigeonpea cultivars, it is evident that sodium bicarbonate solution and pectinase treatment are effective in reducing the cooking time of pigeonpea *dhal*. Further, pectinase treatment also improved the general acceptability of the quick-cooking *dhal* of pigeonpea.

Authors thank Dr. K.B. Saxena for the supply

of seed materials. Technical assistance of G. Venkateswarlu and B. Hanmanth Rao is gratefully acknowledged.

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Received 16 August 1993; revised 6 June 1994; accepted 4 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 126-128

Effect of Lactic Acid, Ginger Extract and Sodium Chloride on Quality and Shelf-life of Refrigerated Buffalo Meat

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Meat cuts sprayed with 2% solution of lactic acid + 20% sodium chloride or ginger extract + 20% sodium chloride solution showed increased shelf-life, when compared to control, at chill temperature (4±1°C). The shelf-life of unwrapped meat cuts was comparatively higher than that of the wrapped cuts. Bacteria, such as *staphylococci, micrococci, lactobacilli* and *bacilli* were recorded at chill temperature, besides psychrotrops, which were present predominantly. Colour, odour and other sensory parameters of treated meat cuts were acceptable to trained panelists.

Keywords : Lactic acid, Ginger extract, Sodium chloride, Shelf-life, Quality buffalo meat.

Decontamination of meat carcasses with organic acids is gaining importance in recent years (Dickson and Anderson 1992). Lactic acid, being a natural constituent of many foods, is often used for controlling the microbial growth and extending the shelf-life of foods (Smulders et al. 1986; Singh et al. 1989). Recently, the bactericidal effects of lactic acid were assessed on artificially inoculated beef (Gordon and Bryan 1992).

Spices are generally used in foods as flavouring agents and many of these have been found to have some antimicrobial activity (Davidson et al. 1983). Ginger rhizome has been shown to have antioxidant property and it also contains a powerful proteolytic enzyme, which can be useful in tenderizing tough meat (Lee et al. 1986). In an earlier *In vitro* study, lactic acid and sodium chloride solution were shown to posses antimicrobial property against some of the spoilage and pathogenic bacteria of meat (Syed Ziauddin et al. 1993). The present investigation was undertaken to study the use of lactic acid, ginger extract and sodium chloride in extending the shelf-life of buffalo meat at chill temperature (4±1°C).

Shoulder and leg cuts (triangle in shape, 5-6 kg each) of buffalo carcasses were procured soon after slaughter from the local market, as variety meats are known to vary in composition (Kondaiah et al. 1986). Twenty per cent lactic acid (90% pure, Merck, v/v), 20% sodium chloride (w/v) and 2% lactic acid + 20% sodium chloride solutions were prepared in distilled water. Ginger extract was prepared by blending 100 g 'Mysore variety' ginger cubes in 100 ml chilled distilled water in a Waring blender for 1-2 min. The pulpy material after blending was squeezed through muslin cloth to obtain the extract. The meat cuts were weighed and sprayed with 2% lactic acid v/v, 20% sodium chloride solutions singly or a mixture of 2% lactic acid + 20% sodium chloride solution, at the rate of 20 ml per kg of meat. Similarly, the meat cuts were sprayed with ginger extract alone or a mixture of ginger extract + 20% sodium chloride solution. The treated meat cuts as such or after wrapping in polythene bags (200 gauge), along with the untreated (control) samples, were stored at chill temperature (4±1°C) and a relative humidity of 85-95%. Six replicates were used for each treatment.

The quality of meat was assessed by determining the total microbial counts by swab technique, off-odour development and change in colour as well as odour of meat as per the methods used by Gill and Penney (1985). Microorganisms were enumerated by standard plate count technique and psychrotrophs were determined after incubating for 10 days at 4±1°C (Buchanan and Gibbons 1974). *Staphylococci* were grown on Baird-Parkar medium, while MRS agar (Difco) containing 0.02% sodium azide was used for growing *lactobacilli* (Buchanan and Gibbons 1974). The bacterial counts are expressed as log of colony forming units (cfu) per g sample. The sensory evaluation of meat, cooked at 121°C for 30 min, was carried out by 10 trained panelists, on a 10-point Hedonic scale, using small pieces of cooked meat. The results were subjected to analysis of variance technique (Steel and Torrie 1980) and Duncan's Multiple range test (Duncan 1960).

Microbial count and shelf-life of meat : The microbial growth was very slow during the first three days of storage (Table 1), which can be attributed to adoptation of mesophilic microbes to new environment of chill temperature. In all the cases, the microbial count at the start of spoilage, the point at which the meat exhibited off-odours,

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TABLE 1. MICROBIAL COUNT (log cfu/g) IN MEAT CUTS STORED AT 4±1°C (RH 85–95%)

	Storage period, days											
	0		2		3		5		6		7	
	W	N	W	N	W	N	W	N	W	N	W	N
20% sodium chloride	5.1	4.9	5.0	4.5	4.8	4.0	5.0	4.6	5.2	5.0	7.6	7.5
2% lactic acid	5.2	4.9	5.0	4.4	4.0	3.5	4.6	4.2	4.8	4.8	7.6	7.7
Ginger extract	4.7	4.4	4.2	4.0	4.7	4.6	4.9	4.6	5.1	4.7	7.6	7.8
Ginger extract + 20% sodium chloride	5.0	4.8	4.7	4.2	4.8	4.0	4.8	4.2	5.1	4.8	5.6	5.2
Untreated (control)	5.0	4.8	4.6	4.4	5.5	4.9	5.1	5.2	7.8	6.0	ND	7.7

W : Wrapped cuts; N: Non-wrapped cuts; ND : Not done. The values are mean of six replications, P<0.05. The values were 7.5, 7.6 log cfu/g at 9 and 11 days storage in case of ginger extract + 20% sodium chloride-treated samples stored in wrapped and unwrapped samples. The value in case of samples treated with 2% lactic acid + 20% sodium chloride was 7.4 at 9 days in case of wrapped sample, while 5.6 and 7.5 Log cfu/g at 9 and 11 days in case of unwrapped samples. In case of all other treatments, the meat got spoiled at 9, 10 and 11 days storage.

varied between 7.0 and 8.0 log cfu/g meat (Table 1). *Pseudomonas* was the predominant, followed by *staphylococci, micrococci, bacilli* and *lactobacilli* in both control and treated meat cuts (Table 2). The predominance of *Pseudomonas* species in beef stored at chilled temperature has also been recorded by earlier workers (Gill and Newton 1982; Brown 1982). The shelf-life periods for wrapped and non-wrapped cuts (control) were 5 and 6 days, respectively (Table 3). Sodium chloride treatment extended the shelf-life by one day, both for wrapped and un-wrapped meat cuts. Meat cuts treated with ginger extract also showed the same period of shelf-life. However, meat cuts treated with solutions containing ginger extract plus sodium chloride, and lactic acid plus sodium chloride showed a further extension of shelf-life, in both wrapped and non-wrapped conditions, to 8 and 10 days, respectively.

Sensory evaluation : The colour and odour scores of treated uncooked cuts are presented in Table 3. It was observed that all the treated samples were acceptable to panelists. The treatment with 2% lactic acid did not discolour the meat cuts, an observation, which is in agreement with that made by Smulders et al (1986) in beef carcass treated with 1-2% (v/v) lactic acid. However, highly significant (P<0.001) difference was observed between the wrapped and unwrapped meat cuts, with regard to colour and odour. Similar was the result in case of meat treated with ginger extract + 20% sodium chloride solution.

Sensory data on meat cuts treated with 2% lactic acid + 20% sodium chloride or ginger extract + 20% sodium chloride after storing for 10 days in unwrapped condition as well as after cooling are presented in Table 4. There were no significant (P<0.05) differences in colour, taste and aroma between the treated and untreated (fresh) meat samples. However, significant (P<0.05) differences were observed in texture and juiciness, which were more in samples treated with ginger extract. The meat was also superior in overall quality and this observation is in agreement with the findings of Lee et al (1986). Thus, this study indicated that treatment with 2% lactic acid or ginger extract,

TABLE 2. PER CENT COMPOSITION OF BACTERIA, ISOLATED AT THE START OF SPOILAGE OF CONTROL AND TREATED MEAT CUTS AT 4±1°C (RH 85-95%)

Type of bacteria	Treatment		
	Control (untreated) at 5 days	2% lactic acid+ 20% sodium chloride at 10 days	Ginger extract+ 20% sodium chloride at 10 days
Pseudomonas sp.	90	62	76
Micrococcus sp.	3	14	17
Staphylococcus sp.	4	3	5
Bacillus sp.	1	1	2
Lactobacillus sp.	ND	20	ND

ND : Not detected

TABLE 3. EFFECT OF LACTIC ACID AND GINGER EXTRACT ON COLOUR, ODOUR AND SHELF-LIFE OF MEAT CUTS STORED AT 4±1°C

Treatment	Colour		Odour		Shelf-life, days	
	W	N	W	N	W	N
Control	2.5	1.8	2.5	1.8	5	6
2% lactic acid+ 20% sodium chloride	2.7	1.8	2.5	2.25	8	10
100% ginger extract + 20% sodium chloride	2.7	1.9	2.4	2.1	8	10
Level of significance	**		**		**	

** Significant at P<0.01, W: Wrapped cuts, N : Non-wrapped cuts; Colour and odour scores : 1 : excellent; 2 : very good; 3:good; 4: acceptable; 5 : unacceptable.

TABLE 4. SENSORY EVALUATION OF CONTROL AND TREATED MEAT CUTS STORED AT 4±1°C IN UNWRAPPED STATE

Treatment	Colour and appearance	Texture and consistency	Juici-ness	Taste	Aroma	Overall quality
Control (fresh)	6.9	6.9	6.5	7.0	6.8	6.6
2% lactic acid + 20% sodium chloride	7.0	7.4	7.0	7.1	6.7	6.3
Ginger extract + 20% sodium chloride	6.1	8.5	7.5	6.9	7.2	7.0
Level of significance	NS	•	•	NS	NS	NS

• Significant at $P<0.05$, NS : Not significant ($P>0.05$)

along with 20% sodium chloride, could extend the shelf-life of meat cuts at 4±1°C by inhibiting the microbial growth and without any significant change in sensory properties of meat.

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Received 6 December 1993; revised 10 June 1994; accepted 7 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 129-131

Electro-chemical Studies on Tinplate Corrosion in Organic Acids

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Corrosion behaviour of lacquered and unlacquered tinplate was characterized, using electro-chemical (direct current polarization and polarization resistance) methods, and the results compared with those obtained from the established weight loss methods. The test media used were citric and acetic acids. Trace amount of nitrate was found to increase the rate of corrosion of tinplate. The results from direct current electro-chemical methods showed the same general trend as the weight loss methods, suggesting that the electro-chemical methods could be used to predict the shelf-life of canned foods.

Keywords : Tinplate, Corrosion, Shelf-life, Electro-chemical methods, Polarization, Comparison with weight loss methods.

Factors that affect internal corrosion of food cans include the properties of tinplate, the nature of food process, and the processing as well as storage conditions (Saguy et al. 1973). Corrosion of a metal can be regarded as a single electrode on which coupled cathodic and anodic reactions occur (Lorenz and Mansfield 1981). The electro-chemical reactions that take place in corrosion involve electrons (Mannheim and Passey 1982). Tin occupies a higher position in the electro-chemical series than iron (Popova et al. 1990), and consequently, might be expected to form the cathode with iron being dissolved. However, in acidic solutions, e.g., fruit juices, a reversal of potential occurs with tin becoming anodic to iron, thereby dissolving the latter (Albu-Yaron and Feignin 1992; Gouramma et al. 1981; Mahadeviah et al. 1971, 1976). Corrosion of food cans must not occur, as high levels of iron can cause unacceptable changes in colour, taste and texture of the food product (Semel and Saguy 1974). Even more are the toxic effects caused by the high tin levels in humans (Mannheim and Passey 1982).

The criteria for corrosion rate measurements of electrolytic tinplate have been mainly based on the amount of dissolved tin or iron or % weight loss or models thereof. The amount of metal dissolved in the food can be determined by titrimetric, atomic absorption or colorimetric methods (Saguy et al. 1973; Linder and Giessman 1972). However, all these methods have the disadvantage that they require relatively long exposure periods. Popova et al (1990) have recently shown that electro-chemical methods could be used for corrosion monitoring of tinplate in citrate solutions. In another study, Albu-Yaron et al (1979) were able to show a correlation between results from potentiokinetic polarization technique and storage tests during localized tinplate corrosion in organic acids.

In this study, the feasibility of using electro-chemical methods to predict the behaviour of tinplate in model solutions of citric and acetic acids has been investigated, along with the effect of trace amounts of nitrate.

The specimens for the weight loss experiments were pieces of electrolytic tinplate, 20 mm wide and 40 mm long, cut from a large piece of commercial tinplate. Both the plain and lacquered tinplates were protected on the sides and the back by a self-curing elastomer (araldite). Before use, the specimens were degreased with acetone and stored in a desiccator. The solutions used were 1, 5, and 10% (w/v) citric and acetic acids (Sigma Chemical Co. St. Louis, U.S.A.) individually. The specimens were weighed before and after immersing in the acid solutions. They were then cleaned with distilled water, dried using a hair drier and weighed. For the polarization studies, three electrode arrangements, consisting of a platinum counter electrode, a saturated calomel electrode and a working electrode, were used in conjunction with a Heathcote Potentiostat (Lorenz and Mansfield 1981). In order to deaerate the solutions, nitrogen was bubbled through for 3 h, before starting the experiments. The electrodes were immersed in solution for 60 min to allow the rest potential to reach a steady state, before taking measurements. Using a scan rate of 20 mV/min, the electrode was anodically polarized. The working electrode was then allowed to return to rest potential, before

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obtaining the cathodic polarization curve. For the polarization resistance measurements, the electrode was polarised to an overpotential of 10 mV, using a sweep rate of 20 mV/min. The current was then reversed, and the cathodic portion of the curve was obtained. The specimens for the potential time curves were prepared in the same manner, as those for the polarization curves. The electrodes were then dipped in the solution and the electrode potential readings were taken with respect to saturated calomel electrode on a daily basis.

The weight loss results show that the corrosion rate is greater for plain tinplate than that for lacquered tinplate, and that metal dissolution is greater at higher acid concentrations (Table 1). Typical polarization curves (semi-log plots) for plain tinplate show that the corrosion rates increased with an increase in acid concentration (Fig. 1). The same trend was obtained with lacquered tinplate. The cathodic portion revealed the presence of a kink at an overpotential of -400 mV in case of plain tinplate only, and these were more pronounced in citric acid solutions. Typical polarization curves for lacquered tinplate are characterized by the absence of kinks. The kinks observed in the anodic Tafel lines are probably due to the formation of pits at local weak points. How the kinks came to be present in the cathodic curve with plain tinplate is more difficult to explain. These are probably due to a limiting current density in that region. The plots of potential versus current around the rest potential were linear. The polarization resistance, Rp is given by the relationship.

$Rp = (\Delta E/\Delta i)$ where ΔE and Δi represent change in potential and current densities, respectively.

The rate of corrosion is given by the Stern-Geary equation (Lorenz and Mansfield 1981)

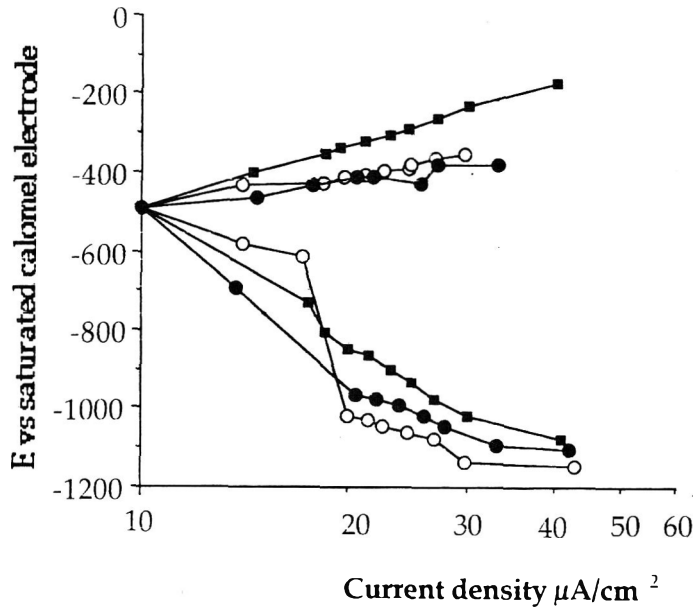

Fig. 1. Polarization curve (semi-log plots) for plain tinplate in acetic acid. —■—: 1% acetic acid, —●—: 5% acetic acid, —o—: 10% acetic acid.

$i_{corr} = (B/R_p)$

where B = constant in mV/decade.

Typical results from such measurements are shown in Table 1. The polarization resistance decreased with an increase in concentration of the acid solution. This indicates that the ease of transfer of electrons across the electrode-electrolyte interface increases with an increase in acid concentration. Both weight loss and electro-chemical methods show that lacquered tinplate is more resistant to attack by organic acids than plain tinplate. The differences in the corrosion rates by the different carboxylic acids have been attributed to the differences in stability constants of the tin complexes formed (Mahadeviah et al. 1976). The differences can also be explained in terms of the strength of the acid. Since cathodic reactions

TABLE 1. CORROSION CURRENT DENSITIES FROM TAFEL EXTRAPOLATION, POLARIZATION RESISTANCE, WEIGHT LOSS DATA AND EFFECT OF 20 PPM NITRATE ON PLAIN TINPLATE

System	i_{corr} μA/cm²		Weight loss mg/day		Effect of 20 ppm nitrate on plain tinplate i_{corr} μA/cm²	
	Plain tinplate	Lacquered tinplate	Plain tinplate	Lacquered tinpate	Tafel extrapolation	Polarization resistance
Acetic acid						
1%	18.4 ± 1.1	9.4 ± 1.5	2.30 ± 0.25	0.60 ± 0.14	30.5 ± 2.1	28.0 ± 2.0
5%	43.7 ± 3.8	24.2 ± 1.8	2.50 ± 0.30	0.69 ± 0.11	46.5 ± 2.2	42.0 ± 2.9
10%	53.9 ± 1.7	25.6 ± 1.9	3.90 ± 0.40	0.70 ± 0.14	53.0 ± 2.8	56.5 ± 2.5
Citric acid						
1%	23.8 ± 1.1	10.2 ± 1.5	3.10 ± 0.21	0.64 ± 0.12	39.0 ± 2.9	39.5 ± 3.5
5%	48.2 ± 1.5	26.2 ± 1.9	3.90 ± 0.21	1.20 ± 0.11	52.5 ± 3.5	50.0 ± 3.0
10%	54.1 ± 2.5	33.3 ± 2.1	4.90 ± 0.40	1.20 ± 0.30	62.5±3.7	63.5 ± 3.5

The values are means of two measurements. The ± value denotes the standard deviation.

involve hydrogen ions, the stronger is the acid, the higher will be the concentration of hydrogen ions, present at a given concentration and consequently, high corrosion rates occur. Thus, citric acid is expected to be more aggressive than acetic acid (Semel and Saguy 1974). However, the use of a single carboxylic acid represents a crude simplification of the environment inside the can. The corrosion current densities obtained by the polarization resistance method are comparable to those obtained by extrapolation from polarization curves (Lorenz and Mansfield 1981).

The electrode potential for lacquered tinplate drifted in the anodic direction, while that of plain tinplate drifted in the cathodic direction. Lacquered tinplate showed higher potentials in 1% acetic acid than in 1% citric acid. The trend was reverse for plain tinplate, where higher potentials were recorded in citric acid solutions than in acetic acid solutions. The drift towards the anodic direction is probably due to accumulation of corrosion products at discontinuities of the lacquer at the electrode surface. The accumulation of corrosion product, e.g., oxides, salts of acids reduces the rate of metal dissolution (Abu-Yaron et al. 1979)

Addition of sodium nitrate did not change the general shape of the curves. However, the corrosion current density values for each acid concentration increased upon addition of nitrate (Table 1). Similar results were obtained using dissolved iron and tin as criteria (Saguy et al. 1973; Albu-Yaron and Semel 1976). These workers proposed nitrate reduction as the mechanism for the observed accelerated corrosion rate. Present results show that the direct current electro-chemical methods give results, which have the same general trend as those obtained by the established weight loss method, in spite of the different units used. Therefore, the electro-chemical methods can be used to predict the shelf-life of cans. The advantage would be the relatively short time required to obtain results.

The work was supported by University of Zimbabwe Research Board grant. Thanks are due to Bobby for typing the manuscript.

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Received 23 November 1993; revised 13 June 1994; accepted 7 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 132-134

Effect of Fermentation Period and Temperature on Antinutrients and *In vitro* Digestibility of Starch and Protein of *Wadi* - An Indigenous Fermented Legume Product

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Fresh batter of greengram *dhal* contained high amounts of phytic acid (897.4 mg/100 g) and polyphenols (982 mg/100 g). Indigenous fermentation at 35°C for 18 h reduced the levels of these anti-nutrients to approximately half. *In vitro* digestibility of starch and proteins also improved significantly ($P<0.05$) with increase in the temperature and period of fermentation. A significant ($P<0.01$) and negative correlation was found between the contents of anti-nutrients and *in vitro* digestibility.

Keywords : Greengram *dhal*, *Wadi*, Indigenous fermentation, Phytic acid, Polyphenols, Protein digestibility, Starch digestibility, *In vitro* studies.

The importance of food legumes, especially in the diets of the population of developing nations, is well established (Goyal 1991). Legumes not only add to the variety in human diet, but also serve as an economical source of supplementary proteins for a large human population in developing countries like India (Bishnoi 1991). Legumes are also recognized as a major source of carbohydrates and other important nutrients (Bishnoi 1991). Phytic acid, widely distributed in legumes, including greengram inhibits proteases and amylases (Deshpande and Cheryan 1984) and hence, may adversely affect the digestibility of starch and proteins. Polyphenols may also lower the digestibility of dietary proteins (Hernandez et al. 1991) and starch (Thompson and Yoon 1984) in plant foods. Removal of these anti-nutrients by any of the processing methods is, therefore, necessary for effective utilization of food legumes. Hence appropriate processing for legume is essential, owing to its high contents of toxins, antinutrients and the indigestible nature of many raw legumes (Gupta 1987). The most common processing methods include soaking, dehulling, ordinary or pressure cooking, sprouting and fermentation (Bishnoi 1991).

Fermentation is probably one of the oldest methods of processing legumes (Goyal 1991). In the present study, an effort has been made to find out the changes in the contents of phytic acid and polyphenols as well as *in vitro* digestibility of starch and proteins of *wadi* - a fermented greengram *dhal* product. Greengrams are also widely used for *Punjabi warri* fermentation (Soni and Sandhu 1990) and microflora associated with *warri* fermentation has been documented (Sandhu and Soni 1989). Dehulled greengram or blackgram cotyledons are the raw materials of *wadi*. *Wadis*, somewhat like Japanese *miso*, are spicy, hollow, brittle, friable balls of 5-8 cm diam, and are very popular in northern India. *Wadis* are used in preparing spicy vegetable dishes.

Preparation of wadis : Greengram *dhal* (*Vigna radiata*), procured from local market in a single lot, was cleaned of dust, stones, wrinkled seeds and foreign materials. Dehulled greengram cotyledons (200 g) were soaked in distilled water (250 ml) for 12 h at 30°C. The soaked *dhal* was ground coarsely in an electric grinder. The soaking water was not discarded, as it was just sufficient to be used for grinding. The batter was kept as such for natural fermentation at 25, 30 and 35°C in an incubator for 12 and 18 h. At the end of fermentation period, salt (2 g/100 g *dhal*) and black pepper powder (0.65 g/100 g *dhal*) were added to the fermented slurry. Small portions of the fermented legume slurry were taken, shaped manually into the form of round balls (*wadis*), and put on the polythene sheets for drying at 60°C for 36 h to a constant weight. The coarsely ground fresh batter, containing the above spices and processed as above, but without any fermentation, served as control.

Chemical analysis : The dried *wadis* were finely ground in an electric grinder (Cyclotec M/s Tecator, Hoganas, Sweden) for use in chemical analysis. Phytic acid content was determined by the method of Davies and Reid (1979). The polyphenolic compounds were extracted from the defatted sample by refluxing for 4 h with 50 ml methanol containing 1% HCl, and estimated as tannic acid equivalent

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according to Folin-Denis procedure (Swain and Hills 1959). *In vitro* starch digestibility was determined by employing pancreatic amylase, and then measuring maltose liberated by using dinitrosalicylic acid reagent (Singh et al. 1982). *In vitro* protein digestibility was carried out by the method of Akeson and Stahmann (1964), as modified by Singh and Jambunathan (1981).

Statistical analysis : The data were subjected to analysis of variance in a completely randomized design and correlation coefficients were derived according to standard statistical methods (Panse and Sukhatme 1961).

Phytic acid : Fresh, unfermented slurry of greengram *dhal* had 897.4 mg phytic acid/100 g, which was reduced significantly ($P<0.05$) in the products fermented at 25, 30 and 35°C for varying periods (Table 1). Higher the temperature and longer the period of fermentation, greater was the extent of phytic acid reduction. Fermentation at 35°C for 18 h reduced the phytate content to approximately half. The hydrolysis of phytic acid may be due to phytase naturally present in greengram *dhal*, the activity of which may be influenced by pH changes occurring during fermentation. Alternatively, it may be due to phytase produced by naturally occurring microorganisms that ferment the slurry, as reported earlier (Daniels and Fisher 1981; Lopez et al. 1983). Optimum temperature for phytase activity from plants and microbial sources has been known to range between 35 and 45°C (Grewal 1992). This may account for greater reduction in phytic acid content at 35°C than at 30 or 25°C. Decrease in phytic acid content during fermentation has been reported in other fermented foods, such as *tempeh* (Sutardi and Buckle 1985) and soy *rabadi* (Grewal 1992).

Polyphenols : The polyphenolic content of the unfermented legume batter was 982 mg/100 g and it was reduced significantly (23 to 53%) after fermentation (Table 1). The contents of polyphenols were reduced to approximately half after fermentation at 35°C for 18 h. This effect may be due to the activity of polyphenol oxidase present in the legume or fermenting microflora (Grewal 1992). A decrease in polyphenolic contents has also been reported in various fermented foods, based on pearl millet (Dhankher and Chauhan 1987; Khetarpaul and Chauhan 1990). Contrary to these findings, some workers (Goyal 1991; Grewal 1992) reported an increase in polyphenolic contents of the fermented rice-defatted soy flour blends and soy-*rabadi*.

In vitro *starch digestibility :* Indigenous *wadi* fermentation improved the starch digestibility of the legume significantly ($P<0.05$), the extent of improvement being 52.7 to 85.4% at different fermentation temperatures and periods (Table 1). It enhanced significantly with increase in the temperature and period of fermentation. Maximum improvement occurred, when the *wadi* batter was fermented at 35°C for 18 h. Improvement in starch digestibility during fermentation may be due to breakdown of starch to oligosaccharides by fermenting microflora (Cronk et al. 1977). Reduction in phytate content during fermentation (Table 1) may also account for improvement in its starch digestibility, as a significantly ($P<0.01$) negative correlation (0.9756) was obtained between the phytic acid and *in vitro* starch digestibility. Earlier workers have also reported an enhancement in the digestibility of starch through fermentation in case of soybean (Boralkar and Reddy 1985; Grewal 1992) and cereal-legume blends like rice and defatted soy flour (Goyal 1991).

In vitro *protein digestibility :* It improved with a rise in the temperature and prolongation of the period of fermentation (Table 1). Protein digestibility of *wadi* batter fermented at 35°C was significantly ($P<0.05$) higher than that at 30 or 25°C. Similarly, batter fermented at 30°C had significantly more protein digestibility than that at 25°C. Protein digestibility improved gradually and significantly, as fermentation progressed at all the temperatures for 12 and 18 h. Both temperature and time of fermentation have a cumulative effect on improvement of protein digestibility. Maximum enhancement occurred, when the legume slurry was fermented at 35°C for 18 h, the increase in protein digestibility being about 41% in the fermented batter, over the control value. Proteolytic enzymes (Wang and Hesseltine 1970; Steinkraus et al. 1965) produced during fermentation may be responsible for increased protein digestibility. An increase in the amino nitrogen by fermentation signifies partial breakdown of protein to peptides and amino acids, thereby improving protein digestibility (Kao and Robinson 1978). Phytic acid, known to inhibit the proteolytic enzymes (Tan et al. 1984; Knuckles et al. 1985), is considerably reduced during *wadi* fermentation (Table 1), and may be partly responsible for increase in protein digestibility. A significant ($P<0.01$) and negative correlation (0.9659) has been found between phytic acid and protein digestibility. Increased protein digestibility has been reported in various fermented products including *tempeh* and

TABLE 1. EFFECT OF TEMPERATURE AND PERIOD OF FERMENTATION ON PHYTIC ACID, POLYPHENOLS, *IN VITRO* STARCH AND PROTEIN DIGESTIBILITIES OF *WADIS* PREPARED FROM GREENGRAM *DHAL* (ON DRY MATTER BASIS)

Temperature, °C	Period of fermentation, h	Phytic acid, mg/100g	Polyphenols, mg/100g	Starch digestibility, mg maltose released/ g meal	Protein digestibility, %
	0 (control)	897.4 ± 0.09	982.0 ± 0.25	37.6 ± 0.09	61.2 ± 0.25
25	12	706.6 ± 0.09 (-21.3)	711.0 ± 0.08 (-27.6)	57.4 ± 0.07 (+52.7)	70.0 ± 0.57 (+14.4)
	18	692.5 ± 0.06 (-22.8)	684.3 ± 0.23 (-30.4)	59.7 ± 0.10 (+58.8)	71.7 ± 0.65 (+17.2)
30	12	580.27± 0.14 (-35.3)	560.2 ± 0.07 (-43.0)	62.8 ± 0.10 (+67.0)	78.2 ± 0.46 (+27.8)
	18	561.1 ± 0.03 (-37.5)	521.9 ± 0.09 (-46.8)	64.2 ± 0.09 (+70.7)	80.9 ± 0.58 (+31.2)
35	12	503.2 ± 0.11 (-44.0)	503.1 ± 0.04 (-48.8)	67.6 ± 0.07 (+79.6)	84.1 ± 0.34 (+37.4)
	18	489.0 ± 0.07 (-45.5)	458.0 ± 0.37 (-53.4)	69.7 ± 0.06 (+85.4)	86.3 ± 0.07 (+41.0)
	SEM[a]	0.16	0.12	0.28	0.14
	CD (P<0.05)[b]	0.47	0.35	0.83	0.41

Values are means ± SD of four independent determinations; Figures in parentheses indicate % decrease or increase over the control values; [a] SEM denotes standard error of mean; [b] Critical difference at 5% level. Difference within/between the fermentation time and temperature exceeding this value is significant.

miso (Kao and Robinson 1978), fermented soybean (Boralkar and Reddy 1985) and fermented rice-defatted soy flour blend products (Goyal 1991).

Overall, this indigenous method of *wadi* fermentation is highly useful and at the same time, not expensive for improving the nutritive value of legumes. Hence, this indigenous technology may be encouraged at industry scale.

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Received 27 October 1993; revised 8 June 1994; accepted 7 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 135-137

Occurrence of *Salmonella infantis* and *S. newport* in Market Prawns

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Five hundred samples of market prawns, 60 frozen and 40 iced prawn samples from processing plants and 50 fish samples from local market were screened for salmonellae. *Salmonella infantis* and *S. newport* were isolated from four samples and one sample of market prawn, respectively. None of the other seafood samples was found to contain salmonellae. *S. infantis* from Indian seafoods is reported for the first time. Rapid detection method involving Rappaport-Vassiliadis semi-solid modification medium was found to be better than conventional method for isolation of salmonellae from seafoods.

Keywords : *Salmonella infantis*, *Salmonella newport*, Prawn samples, Market fish, Rapid detection.

Salmonellosis accounts for majority of food-borne infections in countries, where a good system of reporting and investigating food-borne diseases exists (Robert 1980). Salmonella as an agent of food-borne disease is known all over the world and the animal foods are still the major source of human salmonellosis (Bachhil and Jaiswal 1988; Narasimha Rao 1983). When such is the situation in developed countries, the problem of salmonellosis must be more acute in developing countries, where there are still some lacunae in awareness as well as good environmental hygiene. Different salmonella species have been reported from seafoods in India (Kulsherestha et al. 1985; Iyer and Shrivastava 1989; Narkar and Bandekar 1990; Nambiar and Iyer 1991; Thampuran and Gopa Kumar 1991). All the isolations of salmonellae from seafoods in India have so far been from West Coast. The present study is an attempt to assess the potential health hazards due to salmonella in seafoods from East Coast region.

Five hundred samples of market prawns, 60 frozen and 40 iced prawn samples from processing plants and 50 fish samples from local retail trade of Kakinada town were collected for this study. Samples were collected aseptically in sterile containers, and were brought in the ice box for immediate analysis in the laboratory. In case of frozen prawns, samples were taken from blocks into the sterile containers, using sterile poker in aseptic conditions. The fish samples comprised mainly of sciaenids, mackerels and sardines.

Twenty five g edible meat from samples of raw fish, raw and iced prawns was collected aseptically and triturated thoroughly with 225 ml buffered peptone water (ICMSF 1978) in alcohol sterilized pestle and mortar. The suspension was incubated at 34°C for 24 h. In case of frozen prawn samples, the same quantity of meat (25 g) was triturated thoroughly with 225 ml of lactose broth (USFDA 1984), and the suspension was incubated at 37°C for 24 h. Cultures of salmonellae were isolated from these media by conventional and rapid detection methods.

In the conventional method, 1 ml of the cultured medium was inoculated into five tubes, containing 10 ml each of tetrathionate and selenite cystine broths (USFDA 1984). Tetrathionate broth tubes were incubated at 37°C for 24 h, while selenite cystine broth tubes were incubated at 42°C for 24 h. Growth from each of these broth media was surface-streaked on separate pre-poured plates of bismuth sulphite agar (USFDA 1984), salmonella-shigella agar (Difco Manual 1977) and brilliant green agar (Speck 1976). All the plates were incubated at 37°C for 48 h. Suspected colonies, i.e., brown, black with or without metallic sheen from bismuth sulphite agar; opaque, transparent uncoloured colonies with smooth surface, and some black centered colonies from salmonella-shigella agar; and pink white opaque colonies surrounded by brilliant red colour from brilliant green agar were picked up, and streaked on pre-poured MacConkey agar (USFDA 1984) plates. From MacConkey agar, transparent and colourless colonies were taken on to nutrient agar (USFDA 1984) for further identification.

In the rapid detection method, the medium used was *Salmonella* rapid test elective medium (SRTEM, OXOID code FT 201). This medium consists of (g/l), tryptone 10, sodium chloride 5, disodium hydrogen phosphate 9, potassium

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di-hydrogen phosphate 1.5, casein 5, malachite green 0.0025 and 7.2±0.2 pH. Inoculation of the autoclaved medium was done as described above. This was incubated at 35°C for 24 h, before spot inoculation by 3 drops on Rapport-Vassiliadis (MSRV) medium semi-solid modification in petri dishes (De Smedt et al. 1986). This medium contains novobiocin, which makes it a highly selective medium, and takes advantage of the ability of salmonellae to move through this semi-solid medium (De Smedt et al. 1986). The plates were incubated at 42°C for 20 to 24 h. Suspected colonies from the terminal point of motility were picked on to nutrient agar slants for further identification (De Smedt and Bolderdijk 1987).

The slant cultures on nutrient agar slopes, obtained as above, were subjected to morphological, biochemical, fermentation and serotyping tests (Buchanan and Gibbons 1974).

In the present study, it was found that rapid detection method enabled picking up of *Salmonella* colonies more efficiently than the other method. In the rapid detection method, all the suspected colonies were totally confirmed, as against confirmation of only one in fourteen of the suspected colonies in case of conventional media. The distribution of *Salmonella* cultures among the seafoods analyzed is shown in Table 1.

Out of the five isolates of salmonellae, four were identified as *S. infantis* and one as *S. newport* on the basis of morphological, biochemical and fermentation reactions, followed by serotyping. The isolation of *S. infantis* from seafoods appears to be the first documented report from India.

Both the serotypes, *S. infantis* and *S. newport*, isolated from *Paeneus indicus* in the present study, are of public health importance in view of their pathogenicity to man, and the observation by Cohen and Tauxe (1986) that antibiotic resistant salmonellae originate from foods of animal origin. This becomes more relevant, as shrimp farming is rapidly expanding in India. Besides, the present study indicates the occurrence of salmonellae in market prawns in very few numbers. The application of good hygienic processing practices in local seafood processing plants has shown the absence of any *Salmonella*. However, there is a need for monitoring of seafoods for this potential health hazard.

TABLE 1. DISTRIBUTION OF *SALMONELLA* CULTURES AMONG SEAFOODS

Sample	Number	Source	Identified species
Fresh prawns	500	Local outlets	*S. newport* (1) *S. infantis* (4)
Fresh fish	50	Local outlets	Nil
Frozen prawns, block frozen, peeled devined	60	Local seafood processing plants	Nil
Iced prawns, peeled undevined	40	Local seafood processing plants	Nil

Numbers in parenthesis indicate the samples positive for the species.

Authors are thankful to Dr. K. Gopa Kumar, Director, C.I.F.T., Kochi, for permission to publish this paper. Technical assistance provided by Mr. B. Ramaiah, Mr. P. Radha Krishna and Mr. N. Ramesh Singh is acknowledged. For serological identification of the isolates, authors are thankful to Director, Central Research Institute, Kasauli (H.P.), India.

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Received 18 December 1993; revised 8 June 1994; accepted 7 August 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 138-140

Monitoring of Pesticide Residues in Temperate Horticulture Produce in India

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In 1990-92, 91 apple, 72 tomato and 8 capsicum samples were analyzed for ethylene bis-dithiocarbamate and 37 samples of apple (0.024-6.724 ppm), 44 samples of tomato (0.028-7.890 ppm), were found contaminated. Out of these, 9, 8 and 4 samples of apple, tomato and capsicum, respectively, exceeded the maximum residue limit (3 ppm carbon disulphide). None of the 26 apple samples had detectable ethylenethiourea residues (>1 ppm) while 7 samples were found contaminated with parathion methyl (0.024–0.159 ppm). In okra, none of the 17 samples, had detectable pesticide residues. In 1988, 4 apple samples out of 32 samples were found contaminated with low levels of carbendazim (<0.5 ppm) residues, while none of the 18 samples had detectable organochlorine residues. High ethylene bis-dithiocarbamate residues in apple, tomato and capsicum samples are of concern.

Keywords : Maximum residue limit, Pesticides, Apple, Tomato, Capsicum, Okra.

In Himachal Pradesh, fruits and vegetables were grown in 1,93,490 ha in 1990, and these were sprayed with 97,500 kg of pesticides including 65,000 kg of mancozeb (Personal communication). These pesticides were used mainly against apple scab (*Venturia inaequalis* L.) and other rotting pathogens. Indian Council of Agricultural Research started pesticide residue screening/monitoring programme in 1988. Under this project, the residues of mancozeb, ethylene bis-dithiocarbamate (EBDC), organochlorine and organophosphorus insecticides in horticultural crops were determined, and results are presented in the present communication.

Fruit and vegetable samples (approx. 1 kg) were collected from Shimla, Solan, Sirmour, Kullu, Kinnaur, Bilaspur and Mandi districts of the State from June through September, 1988-92. Samples were processed within 48 h of collection. The organochlorine pesticide residues were studied as per Jonansson (1978). The technique involved extraction with benzene-hexane mixture, and cleanup by florisil column chromatography. Analysis was done on Hewlett Packard 5890 A, gas chromatograph (GC), fitted with a capillary column (HP-5, 50% phenyl methyl silicone), and Ni^{63} electron capture detector. GC parameters were: oven 220°C, injection 225°C and detector 325°C. Injection was split 95:5. Quantification was done using 3392A integrator. Cleaned sample extract equivalent to 25 mg was injected into GC with minimum detectability of 0.02 ppm for 2,2-bis(*p*-chlorophenyl)-1,1,1-trichloroethane (DDT) and its analogues and 0.01 ppm for hexachlorocyclohexane (HCH) isomers and captafol. The retention times of the organochlorine insecticides, alpha-HCH, beta-HCH, gamma-HCH, delta-HCH, 1-chloro-2, 2-bis (*p*-chlorophenyl) ethylene (DDMU), captafol, 1, 1-dichloro-2, 2-bis(*p*-chlorophenyl) ethylene (DDE), 2, 2-bis (*p*-chlorophenyl)-1, 1-dichloroethane (TDE), *op*-DDT and *pp*-DDT were 7.30, 7.84, 8.41, 8.61, 21.28, 22.15, 26.60, 33.12, 35.53 and 43.15 min, respectively. The residues of organochlorines were further confirmed by TLC (Johansson 1978).

The extract left after GC injection was dried by blowing air on warm extract. The residue left was dissolved in 2 ml acetonitrile and extract equivalent to 25 mg was spotted on silica plate, containing silver nitrate. Plates were developed, air-dried and exposed to long UV. The minimum detectability was 0.04 ppm for DDT and its analogues, 0.01 ppm for HCH isomers and captafol. Carbendazim residues were semi-quantified by TLC (Prakash et al. 1979). Silica plates were developed with hexane : ether mixture, air dried, exposed to chlorine vapours, and then sprayed with ortho-tolidine potassium iodide mixture. Carbendazim appeared as blue spot with sensitivity of 50 ng and detectability of 0.5 ppm. Ethylene bisdithiocarbamate (EBDC) residues were analyzed as per Keppel (1971) on acid hydrolysis. There was a complete recovery of EBDC residues in fruit spiked at 10 ppm. Recoveries at lower concentration could not be studied, because of organometallic nature of compounds, which limit their solubilities. However, quantitative recoveries were obtained, when samples were spiked at 0.25 ppm with carbon disulphide in ethanol. Apple, tomato and capsicum fruits in ripe, unripe and over-ripe states did not show any absorbance. Ethylenethiourea (ETU) residues were

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TABLE 1. MONITORING OF ORGANOCHLORINES (OC), CARBENDAZIM, ETHYLENE-BIS-DITHIOCARBAMATES (EBDC), ETHYLENETHIOUREA (ETU) AND METHYL PARATHION (MP) IN HIMACHAL PRADESH

Crop	Year	No. of samples analyzed	No. of samples contaminated				
			OC	Carbendazim	EBDC	ETU	MP
Apple	1988	32	0	4	-	-	-
	1988	18	1	-	-	-	-
	1990	50	-	-	15 (3)	-	-
	1991	15	-	-	12 (2)	-	-
	1992	26	-	-	10 (4)	0	7
Tomato	1990	50	-	-	28 (6)	-	-
	1992	22	-	-	16 (2)	0	-
Capsicum	1992	8	-	-	6 (4)	-	-
Okra	1992	17	-	-	-	-	-

Figures in parentheses denote samples exceeding MRL

extracted in methanol:water (2:1) mixture as per Krause (1991) and semi-quantified on TLC with Grote's reagent as per Onley and Yip (1971), with blue spot (R_f value 0.23) having detectability of 1 ppm. Parathion methyl residues were extracted in acetone, their extracts were cleaned on florisil column and analyzed at a retention time of 2.71 min on GC (Hewlett Packard 5890A), fitted with nitrogen phosphorus detector (NPD), and with the following parameters : oven 185°C, injection 220°C, detector 300°C and flexible methyl silicone column (HB-1), with a carrier gas flow rate of 25 ml, hydrogen 1 ml and air 80 ml/min.

In a four year study from 1988-1992, a total of 232 samples of apple, tomato, capsicum and okra were screened for residues of various pesticides in the produce, which was ready for marketing (Table 1). Out of 32 samples, four were found contaminated with low levels of carbendazim residues. The residues were 5 times less than the recommended maximum residue limit (MRL) of 5 ppm in India (Parmar et al. 1988).

None of the 18 apple samples analyzed had any detectable organo-chlorine insecticide residues, either by TLC or GC. One, out of 18 samples, showed captafol fungicide residues (0.222 ppm), well below the MRL of 5 ppm in India (Parmar et al. 1988). The residues of captafol were confirmed on TLC, when co-chromatographed with captafol standard (R_f=0.23) using hexane : ether mixture (9:1 v/v). Earlier, low levels of organochlorine pesticide residues (4-7 ppb) were detected in apple (Kaphalia et al. 1990).

From 1990-92, 91 apple samples were analyzed for ethylene bis-dithiocarbamate (EBDC) fungicide, ethylenethiourea (ETU) and parathion methyl residues. A total of 37 samples were found contaminated with EBDC residues, ranging from 0.024–6.724 mg/kg and 9 samples were above the MRL of 3 mg/kg CS_2 (Parmar et al. 1988). Twenty six apple samples were analyzed for parathion methyl and ETU (a suspected carcinogenic metabolite of EBDC fungicide) by TLC. None of these samples had detectable ETU residues (>1 mg/kg), but parathion methyl residues were detected in 7 samples (0.024-0.159 mg/kg). A better technique like HPLC for detecting ETU residue is required, as the MRL for it is as low as 0.01 mg/kg (Lentza 1990).

During 1990-92, 72 tomato samples were analyzed for EBDC residues, out of which 44 samples were found contaminated with EBDC residues, ranging from 0.028-7.890 mg/kg and 8 were found to exceed the MRL (3 mg/kg CS_2). Out of 8 capsicum samples analyzed, 6 were found contaminated with EBDC residues, ranging from 1.671-12.812 mg/kg and 4 exceeded the MRL. In okra, none of the 18 samples had detectable organophosphorus pesticide residues. These studies indicate that horticultural produce in Himachal Pradesh is safe for humans.

The above studies were funded by I.C.A.R., New Delhi, under All India Co-ordinated Research Project on Pesticide Residues.

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Received 6 January 1993; revised 5 September 1994; accepted 27 September 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 141-143

Single Cell Proteins from Chemically Pre-treated Groundnut Pod Shells Using *Pleurotus* sp.

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Pleurotus sp. (IARI No. 2572) was grown on groundnut pod shells, pre-treated with sulphuric acid, sodium hydroxide and sodium chlorite. All the pre-treatments were effective in yielding a protein-rich biomass. Highest protein productivity was found in the fermentation medium, which apart from mild acid pre-treated substrate, also contained pre-treatment liquor.

Keywords : *Pleurotus* sp., Single cell protein, Pre-treatment, Groundnut pod shells.

Microbial conversion of lignocellulose in protein-rich biomass has been extensively worked out in the recent past (Rhodes and Broderick 1989; Kannan et al. 1991; Singh and Kalra 1978; Garg et al. 1985). Groundnut is a major cash crop of India. Its production is about 7.066 million tonnes per year (Anon 1994). Groundnut pod shells are good sources of cellulosic materials and therefore, could be a good substrate for the production of single cell proteins (SCP).

The digestibility of cellulose and hemicellulose is considerably reduced due to their association with lignin (Fan et al. 1981). However, digestibility can be increased by physical or chemical pre-treatments of substrate (Mirrill et al. 1976). The present communication deals with the microbial conversion of groundnut pod shells into protein-rich biomass for animal consumption, using *Pleurotus* sp., one of the most efficient lignin degrading edible fungi (Bisaria et al. 1983).

Microorganism and medium : Pleurotus sp. (IARI No. 2572), obtained from the Department of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi, India, was maintained on potato dextrose agar (PDA) medium. Groundnut pod shells, obtained from local oil mills, were air-dried and ground to different mesh sizes. Mineral medium (Ander and Eriksson 1976), used for fermentation, contained (g/l) ammonium phosphate 2.0, potassium phosphate 0.6, dipotassium hydrogen phosphate 0.4, magnesium sulphate 0.5, calcium chloride 0.074, ferric citrate 0.012, zinc sulphate 0.006, manganese sulphate 0.005, cobalt chloride 0.001, copper sulphate 0.001, thiamine hydrochloride 0.001 in one litre of distilled water. The pH of the medium was 6.0. The concentration of groundnut pod shells in the medium as the source of lignocellulose was 1%.

Pre-treatment : In case of alkali treatment, weighed amounts of groundnut pod shells were taken, and sodium hydroxide (1, 5 and 10%, w/v) was added at 1:5 solid to liquid ratio. The flasks were autoclaved at 120°C for 1 h. Acid pre-treatment of substrate was done in three different ways using (i) 1% sulphuric acid at 120°C for 1 h. Substrate was not washed, but neutralized with ammonium hydroxide to pH 6.0; (ii) 1% sulphuric acid at room temperature (30°C) as well as at 120°C for 1 h; and (iii) 10% sulphuric acid at 70°C for 1 h. In case of treatment with sodium chlorite, the substrate was treated with 24% sodium chlorite at 70°C for 1 h. After each treatment, the sample was washed, dried and powdered.

Fermentation : Mineral medium (50 ml) was taken in 150 ml Erlenmayer flask along with 0.5 g substrate. If pre-treatment liquor was retained in the substrate, the mineral medium was directly added after neutralization of the substrate. The pH of the medium was adjusted to 6.0. Sterilized medium was inoculated with 7 days old inoculum and incubated at 30°C for 15 days. The mycelial biomass along with the residual substrate was recovered by filtration on Whatman No. 1 filter paper, washed thrice with water, and dried at 80°C to a constant weight. The dried biomass was analyzed for crude protein content.

Analytical procedures : Groundnut pod shells were analyzed in duplicate for ash, fat and moisture (AOAC 1980), holocellulose, α-cellulose, hemicellulose, soluble carbohydrates and lignin (Allen 1974). Protein content was estimated by micro-Kjeldahl method after multiplying the total nitrogen by 6.25 (Jackson 1958). Statistical analysis was carried out by analysis of variance and the Studentized Range Test (Snedecor and Cochran 1967).

TABLE 1. EFFECT OF PRE-TREATMENTS ON THE PRODUCTION OF BIOMASS AND PROTEIN YIELD BY *PLEUROTUS* SP. GROWN ON GROUNDNUT POD SHELLS

Pre-treatment method	Dry wt. of mycelium & unutilized substrate, mg (mean ± SD)	Increase in dry wt. after pre-treatment, folds	Protein*, mg/g of dry fermented mass	Total proteins/ 1 ml medium, mg (mean ± SD)**
Control,				
No pre-treatment	394 ± 12.72[a]	-	50.00	0.394 ± 0.03[a]
Sulphuric acid				
1% H_2SO_4, room temp., 1 h.	525 ± 9.19[b]	1.33	156.20	1.64 ± 0.17[bc]
1% H_2SO_4, 120°C, 1 h & neutralized with NH_4OH	866 ± 12.72[c]	2.19	331.26	5.73 ± 0.38[d]
1% H_2SO_4, 120°C, 1 h	503 ± 4.94[b]	1.27	62.48	0.628 ± 0.04[ab]
10% H_2SO_4, 70°C, 1 h	517 ± 9.19[b]	1.31	68.72	0.710 ± 0.04[abc]
Sodium hydroxide (120°C, 1 h)				
1% NaOH	845 ± 6.36[c]	2.14	56.24	0.950 ± 0.10[abc]
5% NaOH	520 ± 10.60[b]	1.31	168.73	1.75 ± 0.22[c]
10% NaOH	548 ± 17.47[b]	1.39	62.50	0.685 ± 0.18[abc]
Sodium chlorite				
24% $NaClO_2$, 70°C, 1h	508 ± 10.60[b]	1.28	87.50	0.889 ± 0.08[abc]
LSD (P<0.05)	35.26			0.707

* Total N x 6.25, ** 4 replicates; values with different alphabets in a column show significant differences at p<0.05

Groundnut pod shells contained (%) 3.90±0.56 ash, 8.40±0.183 moisture, 1.0±0.038 soluble sugars, 1.87±0.113 proteins, 58.82±2.107 holocellulose, 30.92±5.458 α-cellulose, 15.60±0.735 hemicellulose, 35.70±6.222 lignin and 2.70±0.084 fat. Since part of the hemicellulose remains in the solution, 'hemi' plus 'α' celluloses do not equal holocellulose, when final results are compared (Allen 1974).

Data indicated that the pre-treatment considerably increased the production of biomass (Table 1). Analysis of variance showed significant variations due to treatments on production of biomass ($F=207.33$, $p<0.001$) and total protein production ($F=39.63$, $p<0.001$). Studentized Range Test indicated significant differences between control and all treatments with respect to biomass and protein production ($p<0.05$). Variations in biomass and protein production due to different pre-treatments show their extent of bearing of these treatments (Table 1). Maximum increase in biomass (2.19-folds) and highest protein production were found in the medium, which apart from substrate (treated with 1% sulphuric acid at 120°C in an autoclave), also included the pre-treatment liquor.

The highest protein production in this medium can be attributed to the presence of soluble carbohydrates, and partially hydrolyzed cellulose in the liquor, and their utilization by microorganisms (Han and Callihan 1974). In addition, neutralization of substrate with ammonium hydroxide provides extra nitrogen for increased protein production. Pre-treatment with 5% sodium hydroxide was most effective for protein production, among all the other alkali treatments. Mild alkali treatment of substrate has also been found effective by El-Shawarby et al (1987). Since alkali treatment removes most of the hemicelluloses from substrate, and causes net loss of carbon (Moo-Young et al. 1978), there appears a possibility of higher protein production using alkali pre-treated substrate along with liquor. Pre-treatment with sodium chlorite was not as effective as alkali pre-treatment.

The author is thankful to Prof. K.M. Vyas for laboratory facilities, and to CSIR for financial assistance.

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Received 31 December 1993; revised 5 September 1994; accepted 12 October 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 144-146

Utilization of Cowpea Flour (*Vigna catjung*) in the Preparation of *Sandige*

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Possibility of preparing *sandige* (penitype) by incorporating 50 to 90% cowpea flour in to rice flour was investigated. Physical and sensory qualities of the blends of cowpea *sandige* were similar to rice flour *sandige*. The acceptability scores were significantly higher in *sandige* made from cowpea-rice flour blend, when compared to the traditional product. *Sandige* with 16.5% protein content could be obtained using equal proportion of cowpea and rice flours.

Keywords : Cowpea flour, *Sandige*, Physical characteristics, Sensory quality, Proximate composition.

Sandige (also known as curls), a cookie-like product with irregular shape and brittle texture, is a popular food adjunct in the South Indian diet. *Sandige* is consumed after frying, along with the entree's. Traditionally, *sandige* is prepared from cereal flours, viz., rice, ragi, puffed rice and sago (Manay and Shadaksharaswamy 1987). In recent years, use of lesser known and cheaper pulses for the preparation of *sandige* is being explored (Hemalatha 1992). Cowpea is one such legume, the food uses of which is being explored (Okaka and Potter 1977; McWaters and Frank 1980; McWaters et al. 1992). Nutritionally, cowpea is similar to other pulses (Gopalan et al. 1989; Bakr and Gawish 1991; Bakr and Gawish 1992; Emefu et al. 1992) and is relatively cheaper. It has a protein content ranging from 20-25%, and has no known anti-nutritional factors (Venkataraman et al. 1976). Onwuka (1983) studied its cooking quality characteristics. Cowpea has been successfully used in making *Wadians* (Thakur 1989) and *papads* (Bhagirathi et al. 1992). In the present study, the possibility of utilizing cowpea in the preparation of *sandige* has been explored.

Good quality cowpea (*Vigna catjung*), common salt, refined groundnut oil, and milled rice were procured in bulk from local market. These were cleaned for dust particles and grits, dehulled in a paddy huller, milled in a commercial flour mill into flour, passed through 60 mesh (British standard), and stored in air tight containers at room temperature (~28°C), until used. For the preparation of *sandige*, 100 parts cowpea flour or rice flour with 6 parts of common salt were mixed, and stirred into 350 ml hot water (75°C) for 10 min to a dough consistency. Dough was also prepared individually with blends of cowpea and rice flours in the ratio of 90:10, 80:20, 70:30, 60:40 and 50:50. The doughs were then made into *sandige* by passing through a mould (*chakli*) with holes of 2 mm dia, sun-dried to a moisture level of < 6%, and packed in 120 gauge polypropylene bags.

Sandige prepared from cowpea flour, rice flour and the blends (50:50, 60:40, 70:30) were deep-fried in groundnut oil at 190°C for 2 min, and served to a semi-trained panel of 22 members for sensory evaluation. Quality description for desirable and undesirable aspects in individual quality attributes of fried *sandige*, viz., colour, appearance, texture, aroma, taste and after -taste was finalised in a few preliminary evaluations for panel training and uniform understanding of quality. Desirable qualities were off-white/creamish colour, puffed/ uniform appearance, crisp (soft/firm)texture, fried (pulse/cereal) aroma, balanced taste and after-taste. Light/dark brown, burnt colour, unpuffed/ oily appearance, brittle/hard/gritty texture, raw/ beany/off-aroma, salty/bitter/off-taste and bitter/ lingering after-taste were undesirable. The samples were assigned ranks for each attribute. The overall quality was additionally rated by the panelists on a 5-point quality rating scale. The ranked data were analyzed by Kramer's rank sum method (Kramer et al. 1974). The overall quality scores were subjected to analysis of variance, and means separated by Duncan's new multiple range test (Harter 1960). Proximate composition of the best blend of raw *sandige*, cowpea flour and rice flour was determined by AOAC (1984) methods.

The optimum water requirement for the preparation of dough was similar for all the samples. All the doughs were soft to handfeel. The easy dough making characteristic of cowpea flour may be attributed to its high hydration properties (Okaka and Potter 1977).

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TABLE1. SENSORY QUALITY OF FRIED *SANDIGE*

Quality attributes	Cowpea flour (C) : Rice flour (R)				
	$C_{100}R_0$	$C_{70}R_{30}$	$C_{60}R_{40}$	$C_{50}R_{50}$	C_0R_{100}
Rank sum					
Colour	** 106 I	* 78 I	64	** 44 S	* 38 S
Appearance	** 100 I	* 81 I	64	** 46 S	** 29 S
Texture	** 87 I	77	63	** 42 S	61
Aroma	** 87 I	81 I	66	55	** 41 S
Taste	** 87 I	71	65	** 48 S	59
After taste	** 87 I	82 I	63	**40 S	58
Overall quality	91 I	78 I	64	38 S	59
Mean score					
Overall quality	2.6^a	3.2^b	3.6^{bc}	4.6^d	3.9^c
± SEM			0.19 (84 df)		

* P≤ 0.05, ** P≤0.01, I = Inferior, S= Superior. Any two mean scores bearing different superscripts in rows differ significantly (P≤0.05); Limits for quality grade mean scores : 2.6-3.5 = Fair, 3.6-4.5= good,4.6 = very good

The physical characteristics of unfried and fried *sandige* samples were assessed. Unfried samples $C_{100}R_0$ (cowpea flour 100, rice flour 0) and $C_{90}R_{10}$ were light brown, in contrast to darker colour of $C_{80}R_{20}$, dull white colour of $C_{70}R_{30}$, dull and creamish colour of $C_{60}R_{40}$, $C_{50}R_{50}$ and C_0R_{100}. In texture, all the samples were brittle. Fried samples $C_{100}R_0$, $C_{90}R_{10}$ were light brown, in contrast to dull white colour of $C_{80}R_{20}$, $C_{70}R_{30}$, creamish colour of $C_{60}R_{40}$, $C_{50}R_{50}$ and white colour of C_0R_{100}. Except for $C_{100}R_0$, all the samples had puffed appearance. All the samples were crisp in texture and balanced in taste.

The sensory quality ratings by the 22 trained panelists are given in Table 1. The ratings of cowpea : rice flour blends were comparable to those of control (rice flour). Sample $C_{50}R_{50}$ showed significantly superior texture, taste and overall quality.

The proximate composition of cowpea flour, rice flour and the blend ($C_{50}R_{50}$) is given in Table 2.

TABLE 2. PROXIMATE COMPOSITION OF COWPEA, RICE FLOURS AND RAW *SANDIGE*

Composition*, %	Cowpea flour	Rice flour	*Sandige*	
			$C_{50}R_{50}$	C_0R_{100}
Moisture	7.0	6.0	2.9	2.7
Proteins	24.2	5.6	16.5	6.2
Fat	1.1	1.1	3.9	3.7
Total ash	1.4	1.0	4.1	3.5
Carbohydrates by difference	66.3	86.3	72.6	83.7
Dietary fibre (NDF)	9.1	7.6	NA	NA

* on dry basis, NA : Not analyzed, Mean of 3 replicates

The incorporation of cowpea flour into rice flour resulted in a 3-fold increase in the protein content of *sandige* ($C_{50}R_{50}$).

The results show that blend of equal proportion of cowpea and rice flour ($C_{50}R_{50}$) yields a desirable product, and show potential for commercializing the dehydrated products. Since cowpea has a high protein content, the use of cowpea flour with cereal flour increases the protein content of the product without increasing the cost.

Sincere thanks are expressed to Mr. S. Dhanaraj, for the statistical analysis of the data.

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Received 7 December 1993; revised 6 September 1994; accepted 12 October 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 147-149

Formulation and Preparation of Cowpea (*Vigna catjung*) *Papad*

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Potential of cowpea (*Vigna catjung*) for *papad* making was studied with respect to the effects of levels of water, carbonate and salt on the quality of *papad*. For obtaining a quality product, the requirement in parts for water, salt and carbonate were 45, 6.5 and 1.5,respectively, for every 100 parts of cowpea flour. Cowpea *papads* showed excellent quality upto a storage period of 4 months.

Keywords : *Papad*, Cowpea flour, Physical characteristics, Quality variables, Proximate composition, Sensory quality.

A large section of population consumes *papads* along with entree's (Saxena et al. 1989). Traditionally, blackgram (*Phaseolus mungo* L.) *dhal* is used to prepare *papads*. Recently, rarely known and cheaper *dhals* are being used for making *papads* (Saxena et al. 1989). Protein content in cowpea ranges from 20-25%, and no antinutritional factor is present (Mustafa et al. 1986; Uzogala and Ofofa 1992). Nutritional and cooking qualities have been studied by various workers (Onwuka 1983; Emefu et al. 1992; Bakr and Gawish 1991, 1992). The suitability of cowpea flour in the preparation of *papad* has been reported earlier (Bhagirathi et al. 1992). The present study was undertaken to optimize different factors to obtain commercial quality *papads* from cowpea flour.

Good quality cowpea (*Vigna catjung*), purchased from local market, was cleaned, dehulled (manually) and milled in a flour mill. The flour was passed through a 60 mesh sieve, and stored at room temperature (~28°C). Common salt, spices (cumin seeds, black pepper, asafoetida), and refined groundnut oil were purchased locally. Chemically pure (LR grade, BDH), alkaline additives - sodium carbonate and bicarbonate (2:1) were used.

Dough was prepared by mixing 100 parts of cowpea flour with weighed amounts of coarsely hand-pounded spices (cumin seeds 1.5 g, black pepper 2.5 g, asafoetida 0.2 g) and oil (3.0 g). The mixture was kneaded manually noting the time to obtain a homogeneous soft dough. Dough was also prepared by using varying levels of salt (1,3,5,7,0 parts), sodium carbonate + bicarbonate mixture (0,1,1.5,2 parts) and water (30,35,40,45,50,55,60 ml) for every 100 part of flour. After allowing 30 min for dough development, the dough of all the variables were divided into balls (10 g) and pressed into thin discs (0.8 mm thickness and 12 cm diam) using a mechanical press (Chapatimatic, Local make, Mysore). The *papads* from each variable were oven-dried at 50°C to < 6% moisture level and packed in 120 gauge polypropylene bags.

The physical characteristics of the raw *papads*, viz., rolling property, diameter of the *papad*, handfeel and % expansion after frying, were assessed by ISI (1972) methods. All the variables, after frying *papad* in refined groundnut oil for 10-15 sec (190±5°C), were evaluated for sensory quality in four replicates for colour, texture, shape, taste and overall quality by a descriptive procedure (Bhagirathi et al. 1992). Proximate composition of the cowpea flour and the *papads* from optimized process were determined by AOAC (1975) methods. *Papads* were also stored for a period of 4 months in air tight plastic containers to study their shelf-life.

Water decides the plasticity of the dough in *papad* preparation, as it is essential for rolling. Less than 40 parts of water made a tough dough, and caused considerable resistance to press the dough into *papad* of desirable thickness. Dough containing 50 or more parts of water was sticky. Soft and easy to roll/press dough could be obtained with 40-45 ml of water per 100 g flour (Table 1). The varying levels of water did not affect the colour, shape of the raw or the quality of the fried *papad*. However, it affected the diametrical expansion of fried *papad*, which was lower at water levels below 45 parts.

Common salt at 5-7/g 100 g flour improved the taste and gave a soft and easy rolling property (Table 1). At lower levels (1-2 g/100 g flour), the dough was tough, and offered considerable resistance to rolling. Salt levels beyond 7 parts imparted an undesirable salty taste to the fried *papad*, though it did not affect the quality of raw *papad*. Common

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TABLE 1. EFFECT OF VARYING LEVELS OF WATER, CARBONATE AND COMMON SALT ON THE DOUGH CHARACTERISTICS AND QUALITY OF COWPEA *PAPADS*

Variable parts/ 100 parts flour	Attributes*								
	Dough and raw *papad*				Fried *papad*				
	Kneading time, min	Handfeel	Rolling property	Appearance shape and colour	Diametrical expansion, %	Colour	Texture	Aroma	Taste
Water content									
30	10-15	e	c	a, b	27.0	a	a	b	b
35	10-15	e	c	a, b	28.0	a	a	a	a
40	7-10	d	a	a, b	31.0	a	a	a	a
45	6-7	a	a	a, a	31.5	a	a	a	a
50	3	b	b	b, b	30.0	b	b	a	a
55	3	c	b	b,b	30.0	b	b	b	b
Common salt									
1	10	e	e	c, c	24.0	b	d	b	b
2	10	d	d	c, c	28.0	a	c	a	a
5	6-7	a	a	a,a	30.0	a	a	a	a
7	6-7	a	a	a, a	31.5	a	a	a	a
9	6-7	a	a	a, a	30.0	b	b	c	c
** Carbonate									
0	All the doughs containing varying levels of carbonate were easy to roll, soft and needed 6-7 min kneading time				22.0	b	d	b	d
0.5					22.0	a	e	a	a
1.0					28.0	a	a	a	a
1.5					31.5	a	a	a	a
2.0					32.0	a	c	a	a

* Scripts a, b, c are indicative of attributes as described below

Dough and raw *papad*			Fried *papad*			
Handfeel	Rolling property	Appearance	Colour	Texture	Aroma	Taste
Soft - a	Easy to press - a	(Shape)	Cream - a	Crunchy - a	Typical - a	Balanced - a
Sticky - b	Easy to press, but needs more oil to hold shape - b	Uniform - a Not uniform - b	Dull cream - b	Moderately crunchy - b	Fairly typical - b	Fairly balanced - b
Very sticky - c	Needs more pressure - c	Cracks in the		Moderately	Not	Salty - c
Tough - d	Difficult to press - d	edges - c		hard - c	typical - c	Not
Very tough - e	Very difficult to press - e	(Colour)		Hard -d		balanced - d
		Cream - a				
		Light cream - b				
		Light brown - c				

** 2 :1 mixture of carbonate and bicarbonate

salt at 6.5 g/100 g flour could give a dough of easy rolling characteristics and *papad* with good expansion upon frying.

Carbonates are also essential for good expansion in fried *papads*. Different levels of carbonate, while keeping the water content (45 ml) and salt (6.5 g) constant, did not alter the rolling property and the handfeel. Carbonates are stated to improve colour brightness, mellow the beany flavour and impart crisp and brittle texture to the fried *papad* (Shurpalekar et al. 1972). The fried *papads* containing carbonates < 0.5 or >1.5 g were harder in texture (Table 1).

Moisture content of the *papad* (Table 2) was within the limits recommended by ISI (1972) for avoiding microbial spoilage. Physical and sensory characteristics of both raw and fried cowpea *papads*

TABLE 2. PROXIMATE COMPOSITION OF COWPEA FLOUR AND RAW *PAPAD*

* Component, %	Flour	*Papad*
Moisture	4.5	2.50
Proteins, (Nx6.25)	23.2	25.70
Fat	1.8	4.60
Total ash	3.6	9.20
Carbohydrates by difference	66.9	58.00
% Fat absorbed on frying	-	0.35

* Except for carbohydrates, all values are means of two replicates on dry basis

remained unchanged during storage period of four months.

In conclusion, it may be stated that a water content of 45 ml, salt 6.5 g and carbonate 1.5 g for 100 g flour are optimum to get a good quality *papad* from the cowpea.

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Received 7 December 1993; revised 29 August 1994; accepted 12 October 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 150-152

Some Moisture Dependent Physical Properties of *Kabuli Chana* (*Cicer arietinum* L.)

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Moisture dependence of some physical properties of *kabuli chana* were studied in the range of 9.05-30% d.b. The sphericity and roundness were found to be 72% and 67%, respectively, at 9.05% d.b. with the mean values of major, medium and minor axes as 9.72, 9.62 and 7.43 mm. One thousand grain mass, coefficient of friction for different surfaces and angle of repose varied between 364.39-421.37 g, 0.246-0.648 and 19.54°-29.10°, respectively, with increasing moisture content. The respective range of bulk density, true density, porosity and single grain volume were between 840-774 kg/m^3, 1319-1253 kg/m^3, 36.30-37.97% and 310-380 mm^3 for increasing moisture levels.

Keywords : Physical properties, *Kabuli chana*, Moisture content.

Chickpea, one of the most important pulse grains, is widely cultivated in India, particularly in North-Western parts as *desi chana* and *kabuli chana*. The latter has large grains with smooth cream coloured testas and is mostly used for culinary purposes (Smartt 1990). Several studies have been done on the nutritive value and water activity. Effect of insect infestation on the nutritive value on this widely consumed legumes has also been studied (Narayana Rao and Rajagopal Rao 1976; Arya 1981). Physical properties must be known in order to design processes and equipment for various post-harvest operations such as cleaning, grading, pneumatic conveying and drying. Earlier work (Dutta et al. 1988) reported some important physical properties of *chana*, but specific information pertaining to *kabuli chana* is lacking. The present study was undertaken to investigate spatial dimensions, sphericity, roundness and shape of *kabuli chana* at a moisture content of 9.05% d.b. also. The moisture dependence of different properties was studied.

The grain stock 'L-550' was cleaned and moisture content of grain sample was determined by placing it in a hot air oven at 100°C for 72 h (Hall 1957). Grain samples of desired moisture contents were obtained by adding calculated amounts of distilled water, followed by equilibration at 5°C for a week (Dutta et al. 1988). One hundred grains at a moisture content of 9.05% d.b. were randomly selected in order to determine their major, medium and minor axes, respectively, as per the method of Dutta et al (1988). Sphericity and roundness of 25 randomly selected grains at a moisture content of 9.05% d.b. were calculated as per the method of Mohsenin (1970), along their length, width and thickness (Fig. 1). The above experiment was repeated after neglecting the protruding portion (root) of the grain (Dutta et al. 1988). All other properties were determined in the moisture range of 9.05-30% d.b. One thousand grain mass was determined for one thousand randomly selected grains. Coefficient of friction with respect to three structural surfaces namely, mild steel, plywood with wood grains parallel to the direction of slide, and galvanized iron sheet was determined according to the method of Stepannoff (1969). Grains were allowed to form heap on a circular platform, fixed inside a wooden box, and dynamic/emptying angle of repose was calculated, as described by Mohsenin (1970). Bulk density was determined as per ISI (1967) method by filling a cylindrical kettle of 500 ml capacity from a height of 150 mm and weighing the contents. Liquid displacement technique using rectified toluene having specific gravity of 0.866 was employed for determination of true volume and thereby density

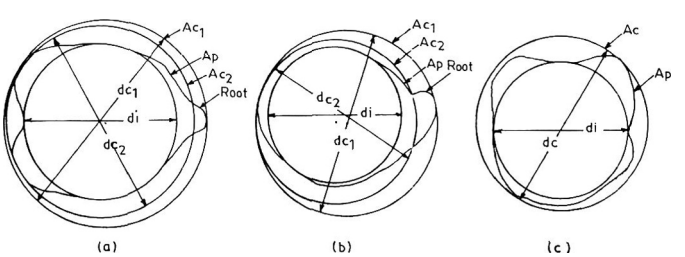

Fig. 1. Projected view of *kabuli chana* in three mutual perpendicular positions (a) Along the length (b) Along the width (c) Along the thickness

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TABLE 1. SPATIAL DIMENSIONS OF *KABULI CHANA* (MOISTURE CONTENT 9.05% d.b.)

	Major axis, mm	Medium axis, mm	Minor axis, mm
Maximum	11.74 ± 0.38	9.90 ± 0.56	8.96 ± 0.35
Minimum	7.62 ± 0.37	6.16 ± 0.16	6.00 ± 0.23
Mean	9.72 ± 0.83	7.62 ± 0.65	7.43 ± 0.58

(Mohsenin (1970). Porosity was calculated as per formula given by Mohsenin 1970). True volume of grain at 9.05% d.b. moisture content was compared with the volumes of sphere, prolate and oblate spheroids (Mohsenin 1970).

Mean values of major, medium and minor axes of grain were found to be 9.72, 7.62 and 7.43 mm, respectively (Table 1). As shown in Table 2, mean values of sphericity, with and without root, were found to be in the range of 72-80% and 78-79%, respectively. The respective values of roundness were in the range of 67-83% and 79-80%. Similar results for sphericity and roundness have also been reported earlier (Dutta et al. 1988). One thousand grain mass increased linearly with increase in grain moisture content (Table 3). Coefficient of friction exhibited a positive correlation (0.970-0.985) with moisture content (Table 3). The increase in coefficient of friction for plywood compared to other structural surfaces, may be attributed to roughness of plywood. The results for coefficient of friction (Table 4) were found to be in agreement with earlier reported studies (Shephard and Bhardwaj 1986; Dutta et al. 1988). Angle of repose showed a positive correlation with the moisture content (Table 3) and increased from 19.54° to 29.10° (Table 4). The increase in angle of repose with increasing levels of moisture content (Fig. 2) was found to be lower than that reported earlier (Dutta et al. 1988).

Bulk and true densities exhibited negative correlations with moisture content (Table 3), and both decreased with increasing levels of moisture content (Fig. 2), which was found to be in agreement with earlier reports (Brusewitz 1975; Shephard and Bhardwaj 1986; Dutta et al. 1988). Porosity % of *kabuli chana* increased with increase in moisture content (Table 3). The trend was found to be very much similar to that reported for other grains

TABLE 2. SPHERICITY AND ROUNDNESS OF *KABULI CHANA* (MOISTURE CONTENT 9.05% d.b.)*

Position	With root		Without root	
	Sphericity	Roundness	Sphericity	Roundness
Along the length	0.7204 ± 0.0312	0.6784 ± 0.0409	0.7850± 0.0388	0.7907 ± 0.0500
Along the width	0.7222 ± 0.0343	0.6754 ± 0.0485	0.7927± 0.0447	0.8010 ± 0.0532
Along the thickness	0.8071 ± 0.0361	0.8282 ± 0.0462	NA	NA

* Mean of twenty five values; NA : Not applicable.

TABLE 3. REGRESSION EQUATIONS SHOWING THE EFFECT OF INCREASING MOISTURE LEVELS ON VARIOUS PHYSICAL PROPERTIES OF *KABULI CHANA*

Physical property	Regression equation	R
One thousand grain mass	$Y = 345.4 + 2.806\ X$	0.957
Coefficient of friction		
i) Mild steel	$Y = 0.166 + 0.0126\ X$	0.977
ii) Galvanized iron	$Y = 0.376 + 0.0056\ X$	0.970
iii) Plywood	$Y = 0.098 + 0.0196\ X$	
Angle of repose	$Y = 12.71 + 0.8269\ X - 0.0087X^2$	0.997
Bulk density	$Y = 887.6 - 5.844\ X + 0.0721X^2$	-0.990
True density	$Y = 1357 - 4.380\ X + 0.0290\ X^2$	-0.990
Porosity, %	$Y = 34.52 + 0.233\ X - 0.0040\ X^2$	0.998
Grain volume	$Y = 249.40 + 7.511\ X - 0.1153\ X^2$	0.987

X = Moisture content, % d.b., Y = Physical property.

TABLE 4. VARIATION OF COEFFICIENT OF EXTERNAL FRICTION AND ANGLE OF REPOSE WITH MOISTURE CONTENT

Moisture content, % d.b.	Coefficient of external friction*			Angle of repose*
	Mild steel	Galvanized iron	Plywood	
9.05	0.2969 ± 0.0158	0.4164 ± 0.0081	0.2466 ± 0.0134	19.54 ± 0.45
15.00	0.3377 ± 0.0113	0.4532 ± 0.0101	0.3630 ± 0.0091	23.15 ± 0.51
20.00	0.3506 ± 0.0194	0.4778 ± 0.0043	0.4725 ± 0.0150	26.00 ± 0.24
25.00	0.4446 ± 0.0214	0.5187 ± 0.0069	0.5418 ± 0.0097	27.94 ± 0.52
30.00	0.5490 ± 0.0202	0.5255 ± 0.0094	0.6480 ± 0.0141	29.10 ± 0.43

*Mean of five values

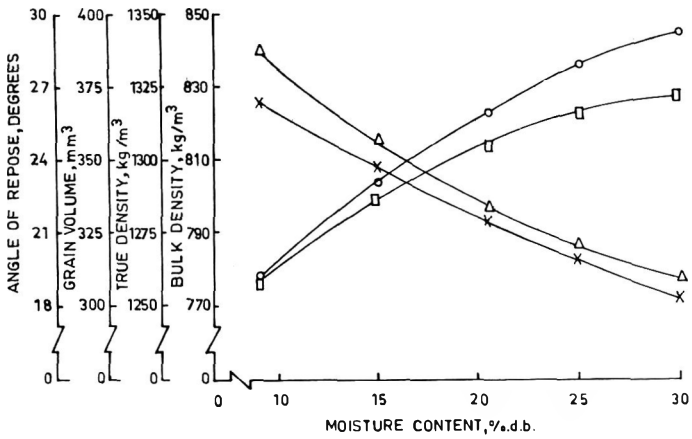

Fig. 2. Variation of physical properties of *kabuli chana* with moisture content. —Δ— : Bulk density, —X— : True density, —□— : Grain volume, —o— : Angle of repose

(Brusewitz 1975; Shephard and Bhardwaj 1986). Grain volume also showed positive correlation with moisture content (Table 3). It was also found that the rate of increase of grain volume with the increasing moisture levels was higher in the beginning (Fig. 2). This is in agreement with an earlier report (Dutta et al. 1988). Comparison of grain volume with the volume of sphere, prolate and oblate spheroids revealed that the grain volume was 9.67%, 0.148% higher and 21.96% percent lower, respectively, than the volume of sphere, prolate and oblate spheroids. Therefore, the grain closely resembles a prolate spheroid.

The results indicate that one thousand grain mass, coefficient of friction, angle of repose, porosity and grain volume exhibit an increasing trend, whereas, bulk and true densities decrease with increasing moisture levels.

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Received 9 November 1993; revised 23 August 1994; accepted 12 October 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 153-155

Influence of Organic Acids on Flavour Perception of Malaysian and Ghanaian Cocoa Beans

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As the concentrations of oxalic, lactic and acetic acids were increased, the intensity scores for acidic flavour and overall preference decreased. Samples from Ghanaian and Malaysian beans showed significant decreases ($p<0.05$) in both flavour scores at 1.0% lactic acid, and 1.04% oxalic acid, respectively. Samples from Malaysian beans showed significant decrease ($p<0.05$) in acidic and overall flavour preference at 1.15% and 0.85% acetic acid, respectively. Overall, oxalic acid was more preferred ($p<0.05$) in Malaysian beans, in contrast to lactic acid in the Ghanaian beans, while acetic acid did not show any significant difference ($p<0.05$).

Keywords : Cocoa beans, Organic acids, Acidic flavour, Overall flavour preference, Sensory evaluation, Cocoa liquor.

Organic acids in cocoa beans are produced during fermentation process by either microbial activity, or indigenous tissue respiration (Jinap and Dimick 1990). These acids prevent germination, solubilize polyphenols, aid in diffusing the content of the storage cells into surrounding parenchyma tissue, and prevent the bean from attack by putrefactive bacteria (Ziegleder and Biehl 1988). During fermentation, the acids are absorbed into the beans, thereby creating an acidic environment for enzymatic reactions, leading to the production of flavour precursors such as peptides, amino acids and sugars. These flavour precursors react with each other during roasting process to produce flavour components (Jinap and Dimick 1991). Holm (1991) reported that oxalic acid could improve cocoa flavour in Malaysian cocoa beans. Acids could also mask the overall chocolate flavour in cocoa beans (Lopez and McDonald 1981).

However, high concentrations of residual acids cause the beans to be excessively acidic in flavour. For example, the residual lactic and acetic acids have been associated with highly acidic beans (Duncan et al. 1989). This communication describes the influence of different concentrations of lactic, acetic and oxalic acids on acidic flavour intensity and overall preference of Malaysian cocoa bean samples, as compared to those from Ghana.

Cocoa samples : Cocoa beans were subjected to pod storage treatment (10 days), shallow-box fermentation, and sun-drying according to the method described by FAMA (1990). Two trials were carried out between September and October, 1992. Two weeks old fermented and dried Ghanaian cocoa beans were obtained from McRobertson, Singapore, and immediately processed similarly upon receipt, for comparative purposes. All the samples were analyzed in triplicate, for cut test (DelBoca 1962), fermentation index (Gourieva and Tserevitinov 1979), pH, titratable acidity and organic acids (Jinap and Dimick 1990).

The cut test indicated that beans from both the countries were well fermented, and there were no significant differences ($p<0.05$) in fermentation index values (Table 1). However, the pH and titratable acidity values were significantly different ($P<0.05$) with respect to lactic and acetic acids, the beans from Ghana being more acidic. Concentrations of other acids in both the beans were almost equal. Therefore, the levels of acetic and lactic acids in Ghanaian samples were adjusted equal to the values in Malaysian beans, by addition of the respective acids.

Liquor preparation : Samples (2 kg) were roasted in an oven (Memmert, Germany) at 150°C for 30

TABLE 1. pH, TITRATABLE ACIDITY, FERMENTATION INDEX AND ACID CONCENTRATION OF COCOA SAMPLE[a]

Parameter	Fermented beans from	
	Malaysia	Ghana
pH	5.40[a]	5.37[b]
Titratable acidity, meq NaOH/100 g	0.070[b]	0.074[a]
Fermentation index	1.265[a]	1.174[a]
Oxalic acid, %	0.14[a]	0.14[a]
Citric acid, %	0.62[a]	0.62[a]
Malic acid,%	0.21[a]	0.24[a]
Succinic acid, %	0.51[a]	0.58[a]
Lactic acid, %	0.09[b]	0.19[a]
Acetic acid, %	0.42[b]	0.56[a]

[a]Mean values having a common letter within the same row are not significantly different ($p>0.05$)

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min, and treated, as described by Jinap and Dimick (1991). Liquor samples were prepared according to Cacoa De Zaan (1992). Respective acids were added in order to achieve 0.14, 0.44, 0.74 and 1.04% oxalic; 0.20, 0.60, 1.00 and 1.40% lactic; and 0.85, 1.15, 1.45 and 1.75% acetic acid concentrations. The materials were mixed in mortar and mills (15 min) (Pascall Engineering, U.K.) and refined in triple roll refiner (Pascall Engineering, U.K.). Before evaluation, warm water (40°C) was added to the sample, and homogenized in Polytron PT 1200 (Kinematics, USA) for 1 min. Twenty panelists who have passed the screening (Watts et al. 1989) were imparted formal training for taste panelling of cocoa liquor, containing known concentration of acid, to familiarize them with acidic flavour notes. Round table discussions were also held. During the actual sample tasting, the panelists rated the acidic flavour, using an intensity scale of 1 to 7 - a score of I rated as not detectable, while score of 7 signified very pronounced acidic flavour attributes. The panelists then rated the samples in terms of preference using a 7-point Hedonic scale, as described above. The samples were kept in water bath (45°C, 30 min), prior to evaluation. Maximum of five liquor samples were evaluated in each session. Warm water was used for rinsing the mouth in between sample tasting. The data were analyzed using statistical analysis system (SAS Institute Inc., Cary, NY).

TABLE 2. EFFECT OF OXALIC, LACTIC AND ACETIC ACID CONCENTRATIONS ON ACIDIC FLAVOUR AND OVERALL PREFERENCE SCORE*

Concentration, %	Acidic flavour of beans from		Overall preference of beans from	
	Ghana	Malaysia	Ghana	Malaysia
Oxalic acid				
0.14	4.71[a]	4.31[a]	4.72[a]	4.65[a]
0.44	4.82[a]	4.34[a]	4.68[a]	4.61[a]
0.74	4.36[a]	4.16[a]	4.00[a]	4.93[a]
1.04	3.21[b]	3.14[b]	3.14[b]	4.01[b]
Lactic acid				
0.20	5.62[a]	5.55[a]	5.57[a]	5.51[a]
0.40	5.59[a]	5.49[a]	5.50[a]	5.48[a]
0.60	5.46[a]	5.18[b]	5.45[a]	5.16[b]
1.00	5.00[b]	5.06[b]	5.01[b]	5.11[b]
1.40	4.47[c]	4.00[c]	4.35[b]	4.03[c]
Acetic acid				
0.55	5.44[a]	5.50[a]	4.28[a]	5.19[a]
0.85	5.29[a]	5.45[a]	5.19[a]	4.75[b]
1.15	5.17[a]	5.00[b]	4.96[a]	4.71[b]
1.45	4.71[b]	4.76[b]	4.29[b]	3.76[c]
1.75	4.29[b]	3.57[c]	3.81[c]	2.76[d]

* Mean values having a common letter for each flavour acid within the same column are not significantly different ($p>0.05$).

The results showed that the perception for both acidic flavour and overall preference decreased, as acid concentrations in the samples increased (Table 2). However, the perception of these flavours, as affected by different concentrations, was not the same for both Ghanaian and Malaysian samples. Increasing concentration of oxalic acid up to 0.74% did not change the acidic flavour, and overall preference scores for samples from Ghana and Malaysia. However, the flavour scores decreased significantly ($p<0.05$), when the oxalic acid concentration was increased to 1.04%. Since usual concentrations of oxalic acid in cocoa beans is in much lower range, i.e., 0.04-0.44% (Jinap and Dimick 1990) and 0.24-0.43% (Weissberger et al. 1971), these findings indicate that oxalic acid at concentrations normally present in cocoa beans has low influence on acidic flavour and overall preference of chocolates made therefrom.

In case of samples from Malaysian beans, the panelists could detect a significant ($p<0.05$) decrease in both acidic flavour and overall preference scores, when the concentration of lactic acid was increased to 0.60%, whereas the concentration was 1% for samples from Malaysian beans were within the normal range of the acid found in cocoa beans, i.e., 0.21-0.98% (Jinap and Dimick 1990) and 0.11-0.71% (Weissberger et al. 1971).

Only after the concentration of acetic acid reached 1.45%, it significantly ($p<0.05$) influenced the perception of flavours in samples from beans of Ghana. In samples from Malaysian beans, the scores for overall preference were significantly decreased, as the concentration of acetic acid increased to 0.85%, in contrast to the concentration of 1.15% for the acidic flavour. These findings confirm earlier reports that acetic acid has high influence on acidic and chocolate flavour perceptions (Lopez 1983). The acidic flavour and overall preference in Malaysian beans were realized at the concentrations found in the commercial fermentation, i.e., 0.3-1.2% (Jinap and Dimick 1990) and 0.8-1.5% (Lopez 1983). These findings indicate that the significant ($p<0.05$) changes in the perception of acidic flavour and overall preference in Malaysian cocoa beans occurred at lower concentrations of acetic and lactic acids, as compared to those in the beans from Ghana.

The preference scores of acidic flavour for

TABLE 3. ACIDIC FLAVOUR AND OVERALL PREFERENCE SCORES* OF BEANS FROM GHANA AND MALAYSIA

Acid	Acidic flavour of beans from		Overall preference of beans from	
	Ghana	Malaysia	Ghana	Malaysia
Oxalic	4.13[b]	4.67[a]	3.94[b]	4.75[a]
Lactic	4.94[a]	4.55[b]	4.93[a]	4.48[b]
Acetic	4.54[a]	4.64[a]	4.25[a]	4.29[a]

* Mean values having a common letter for each flavour within the same row are not significantly different ($p>0.05$).

samples from the beans from both the countries, after adjusting to equal acid concentration, are shown in Table 3. The flavour perception of acetic acid was not significantly different ($p>0.05$) between the two samples. However, oxalic acid was more preferred in Malaysian cocoa beans ($p<0.05$), as compared to that in the Ghanaian. Moreover, the lactic acid in Malaysian cocoa beans was significantly ($p<0.05$) less preferred. This indicates that lactic acid would be more deterimental to the acidic and overall preference of Malaysian, as compared to the Ghanaian beans.

It is possible that other components, such as polyphenols and alkaloids, which constitute the bitter and astringent components in cocoa beans (Ziegleder and Biehl 1988) have intensified the acidic taste of the Malaysian beans. Polyphenols and alkaloids are shown to be affected by varieties or clones (Clapperton et al. 1992). It is also possible that lactic acid is present in Ghanaian cocoa in salt and bound forms, which would suppress the acidic flavour. The cocoa acids could bind to fat, proteins, alkyl pyrazines and polyphenols (Holm 1991; Clapperton et al. 1992). Holm (1991) has also indicated that acids could react with the pyrazines to form 2,3-dimethyl, 2,3,5-trimethyl and tetramethylpyrazine, which are detrimental to flavour development.

The data indicate that the production of lactic acid during fermentation, especially in Malaysian cocoa beans, should be controlled. This is because the acid is non-volatile, and therefore, it will not decrease significantly during further processing. Pod storage (7-10 days), before fermentation, and proper aeration during fermentation could be effective in order to decrease the level of lactic acid in the final product.

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Received 1 November 1993; revised 14 September 1994; accepted 12 October 1994.

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 156-158

Effect of Polyphosphate Chilling and Packaging on the Quality of Fried Quail Stored in Refrigerator

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Effect of chilling quail carcasses in 0 (control) or 5% sodium tripolyphosphate solution for 16 h at 5 ± 1°C, prior to battering and deep-fat-frying (170±2°C for 4 min), on the keeping quality of the product stored in high density polyethylene (330 G) or low density polyethylene (250 G) pouches under refrigerated condition (5±1°C) for 4 weeks was evaluated. The yield of fried quail from sodium tripolyphosphate-treated carcasses was significantly ($P<0.01$) higher (91.8%) than that of control (81.4%). The loss in weight of the product was lower in phosphate-treated than in control, as well as in HDPE-packed than in LDPE-packed samples. Sodium tripolyphosphate treatment raised muscle pH by 0.3 unit, yielded more tender product, as revealed by lower shear force value, and retarded lipid oxidation during storage. The mean bacterial and fungal counts were fairly low (log 3.4/g and 3.0/g, respectively) during storage. Control samples became organoleptically unacceptable after 2 weeks, while phosphate-treated group remained acceptable throughout 4 weeks storage, regardless of packaging materials.

Keywords : Fried quail, Polyphosphate, Packaging, Refrigeration, Quality

Processed quail products offer potential economic benefits to producers, processors and consumers alike. Quails, because of their small body size, could be conveniently fried as whole carcasses, and the product could find an important place in fast food outlets. However, the rapid development of oxidative rancidity in such pre-cooked meat product during refrigerated storage is a major problem, related to its storage stability (Tims and Watts 1958; Harris and Lindsay 1972). Lactic acid and potassium sorbate have been used to increase the shelf-life of quail (Singh et al. 1989) and some studies have been done on the suitability of packaging materials (Singh and Panda 1989). Polyphosphates, apart from their multiple functions in meat system, are reported to protect cooked meat against lipid autooxidation (Tims and Watts 1958; Sato and Hegarty 1971). As the information on the processing and storage quality of fried quail is lacking, except a report by Prabhakar Reddy et al (1991), an attempt was made to evaluate the effects of chilling quail carcasses in polyphosphate solution, and placing in the flexible packaging on the stability of deep-fat-fried quail under refrigerated storage.

Five weeks old meat type Japanese quails (*Coturnix coturnix japonica*), procured from the experimental quail farm of the Institute, were utilized. The birds were kept off feed overnight, conventionally dressed, and the eviscerated carcasses were soaked in 0 (control) or 5% sodium tripolyphosphate solution (1:2 w/v) for 16 h at 5±1°C. Following draining, the whole carcasses were pre-cooked under steam (1 kg/cm^2 for 4 min), battered for 4 h in a pre-standardised batter mix (Panda et al. 1993) and deep-fat-fried to an internal temperature of 80±2°C for 4 min in refined vegetable oil pre-heated to 170±2°C. After draining off excess oil, the finished product was packed individually in either high density polyethylene (HDPE, 330G) or low density polyethylene (LDPE, 250 G) pouches, and stored in a refrigerator (5±1°C).

The yield of the fried quail was expressed as % marinated carcass weight, while the loss in weight of the product was calculated by the difference between initial and stored weights. Five replications per treatment were used for these measurements. Ten g meat samples, in triplicate, were blended with 50 ml distilled water for determining pH of the meat homogenate. Force required to shear 1.27 cm diam cores of breast meat sample across the fibres was recorded in triplicate, using shear press (Warner-Bratzler model 13806 Chatillon, Kansas, USA). The thiobarbituric acid (TBA) values and free fatty acid (FFA) contents of meat were measured in triplicate, as per the methods of Tarladgis et al (1960) and IUPAC (1979), respectively. Standard methods prescribed by Speck (1976) were followed for microbial counts. The product was subjected to sensory evaluation for appearance, flavour, texture, juiciness and overall acceptability, using a 7-point Hedonic scale by five experienced panelists. Data were analyzed as a three-factor analysis of variance, involving chilling, packaging material and storage period (Snedecor and Cochran 1967).

The yield of the fried quail prepared from carcasses soaked in sodium tripolyphosphate (STPP)

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TABLE 1. EFFECT OF POLYPHOSPHATE CHILLING AND PACKAGING ON PHYSICO-CHEMICAL AND SENSORY QUALITY OF REFRIGERATED FRIED QUAIL

Treatments	Weight loss, %	pH	Shear force, lb	TBA value, mg malonalde-hyde/kg	FFA, % oleic acid	Overall accepta-bility score*
Chilling						
Control	2.22 ± 0.13[a]	6.27 ± 0.30[a]	4.05 ± 0.11[a]	0.98 ± 0.09[a]	4.43 ± 0.05[a]	4.53 ± 0.16[a]
STPP	1.48 ± 0.09[b]	6.57 ± 0.05[b]	3.63 ± 0.11[b]	0.60 ± 0.07[b]	4.75 ± 0.02[b]	5.63 ± 0.13[b]
Packaging materials						
HDPE	1.51 ± 0.08[a]	6.42 ± 0.05[a]	3.43 ± 0.12[a]	0.53 ± 0.03[a]	4.44 ± 0.06[a]	5.23 ± 0.18[a]
LDPE	2.19 ± 0.14[b]	6.43 ± 0.06[b]	4.01 ± 0.12[b]	0.80 ± 0.09[a]	4.74 ± 0.02[b]	4.93 ± 0.16[a]
Storage period, days						
0	NA	6.44 ± 0.10[a]	2.70 ± 0.54[a]	0.33 ± 0.03[a]	4.61 ± 0.06[a]	6.25 ± 0.18[a]
7	1.11 ± 0.11[a]	6.40 ± 0.08[a]	3.21 ± 0.12[b]	0.54 ± 0.07[b]	4.63 ± 0.14[a]	5.65 ± 0.17[b]
14	1.73 ± 0.14[b]	6.43 ± 0.08[a]	3.65 ± 0.08[c]	0.76 ± 0.07[c]	4.57 ± 0.08[a]	5.20 ± 0.17[b]
21	2.13 ± 0.15[bc]	6.42 ± 0.09[a]	4.46 ± 0.11[d]	1.03 ± 0.10[d]	4.55 ± 0.07[a]	4.40 ± 0.21[c]
28	2.42 ± 0.16[c]	6.35 ± 0.02[a]	5.20 ± 0.13[e]	1.29 ± 0.09[e]	4.60 ± 0.07[a]	4.10 ± 0.30[c]

* 7 = Like very much, 1 = Dislike very much; NA = Not applicable; ± SEM

Figures bearing same superscripts within each treatment (chilling, packaging and storage period) did not differ significantly (P<0.01).

solution was significantly (P<0.01) higher (91.8%), as compared to that of control samples (81.4%). This could be attributed to the functional role of STPP in increasing the water retention capacity of muscle proteins (Farr and May 1970; Sofos 1985) during thermal treatment.

The influence of polyphosphate and packaging materials on the physico-chemical and sensory qualities of fried quail during storage is presented in Table 1. Although, a progressive increase in weight loss occurred with storage time, the product pre-treated with polyphosphate exhibited significantly (P<0.01) less loss, than the control samples. Similarly, HDPE-packed samples had significantly less weight loss, than those packed in LDPE pouches, which might have resulted from comparatively higher water-vapour barrier property of the former (Saccharow and Griffin 1970). A significant (P<0.01) increase in weight loss was found to be associated with a simultaneous increase in shear force value during storage. However, polyphosphate treatment produced a more tender product, as evident from lower shear values. Similarly, better protection exhibited by HDPE pouches against dehydration could account for comparatively lower shear values of the product packed in it.

As expected, soaking of carcasses in STPP solution brought about a significant (P<0.01) increase in the pH of meat by about 0.3 unit, over that of control. However, the same was unaffected by the packaging materials, and varied within a narrow range during storage. Thus, the elevated pH and antioxidant property of polyphosphate (Tims and Watts 1958; Sato and Hegarty 1971) retarded lipid autooxidation, as evident from lower TBA values in treated samples throughout storage. Of the two packing materials, HDPE, because of its relatively higher oxygen barrier property, appeared to retard oxidative changes during storage. Approximately 3-fold increase in FFA content of cooked meat (4.4%), over raw meat (1.3%), could be attributed to the thermal hydrolysis, catalyzed by the destruction of cellular structure of meat during cooking (Igene and Pearson 1979). However, no appreciable changes in FFA content of meat were noted during subsequent storage.

Taste panel results revealed that pre-cooking of carcasses, prior to batter application and deep-fat-frying, caused partial shrinkage resulting in better adhesion of batter coating, and improved appearance of the finished product. This confirms the observations of Hanson and Fletcher (1963) and Cunningham and Suderman (1981) for fried chickens. Although, sensory quality tended to decline with increase in the length of storage (Table 1), product prepared from polyphosphate - treated carcasses was consistently preferred over the control, possibly due to improved tenderness, and less alteration in the flavour of meat during storage. Packaging materials had, however, no significant influence on the sensory attributes of the product. Polyphosphate-treated fried quail remained fairly acceptable throughout the 4 weeks,

in contrast to an acceptable shelf-life of 2 weeks for control, regardless of packaging materials.

The initial aerobic plate count, psychrotrophic count, and yeast and mould count of eviscerated carcasses were log 3.0, 2.8 and 1.3/g, respectively. These counts decreased slightly during chilling, but showed an increase after battering of carcasses. This might be due to microflora of the batter ingredients (Cunningham 1989) suggesting the necessity for microbiological quality control of such ingredients. Irrespective of packaging materials, product from treated carcasses had slightly lower counts than those of control, which might be due to the anti-microbial activity of polyphosphate (Sofos 1986). Similarly, dehydrated batter coating-skin complex, and reduced water activity of meat, following deep-fat-frying might have restricted the multiplication of aerobic bacteria and fungi, which showed mean counts of log 3.4/g and log 3.0/g, respectively on the 28th day of refrigerated storage.

From the foregoing account, it is apparent that the major factor responsible for the limited (2 weeks) shelf-life of fried quail was oxidative deterioration, associated off-flavour development. These could be minimised by polyphosphate treatment.

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Received July 10, 1993; revised September 23, 1994; accepted October 17, 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 159-161

Effect of Pre-harvest Spray of Growth Regulators on the Pectin Methyl Esterase Activity of *Ber* Fruit During Cold Storage

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Effect of pre-harvest spray of ethephon, succinic acid, 2, 2-dimethylhydrazide (SADH); morphactin and 2, 3,5-triiodobenzoic acid (TIBA) on pectin methyl esterase (PME) activity of *ber* fruits during cold storage showed increase in activity with the advancement of storage period. TIBA and SADH treatments resulted in significantly higher activities than morphactin and ethephon treatments. The PME activity was higher in fruits stored in polythene bags than those stored in paper bags. Little or no spoilage occurred, till 20 days of storage in both the packagings. The spoilage in different treatments increased with the progress in storage period. Ethephon treatment markedly reduced the spoilage during storage. Fruits stored in paper bags maintained better condition, and their spoilage percentage was almost half of that in the fruits stored in polythene bags. TIBA treatments, which resulted in higher spoilage rate, also showed increased PME activity.

Keywords : *Ber* fruit, Pre-harvest spray, Pectin methyl esterase, Growth regulators, Cold storage, Storage in paper and polythene bags.

Cultivation of 'Umran' variety of *ber* (*Zizyphus mauritiana* Lamk.) has received a significant impetus, as a commercial crop in Punjab, Haryana and Rajasthan, because of its potential for high yields and excellent economic returns to the growers (Bal 1979). 'Umran' is the leading commercial cultivar of *ber*, which ripens late during the first fortnight of April. Harvesting and post-harvest handling of *ber* fruit are the important factors in successful cultivation of this crop. The fruit of this late cultivar can be made to ripen earlier, and uniformly with pre-harvest sprayings of growth regulators at colour-break stage, thereby avoiding the difficult operation of picking the *ber* in 4-5 lots (Bal et al. 1988).

The storage life of *ber* fruits can be extended upto 30 days by cold storage in perforated polythene bags, after treating with 6% wax emulsion (Jawanda et al. 1980). Studies have been carried out on the dehydration of *ber* fruits (Khurdiya 1980a). Preparation of beverage from *ber* (*Zizyphus mauritiana* Lam) has also been documented (Khurdiya 1980b). However, information on cold storage life of *ber* fruits with special reference to pre-harvest spray of growth regulators is not available. Hence, the present study was undertaken.

The investigations were conducted on fourteen years old trees of *ber* cultivar 'Umran'. The fruits were harvested at optimum maturity (March 6, 1989; March 3, 1990) from the trees given pre-harvested sprays of ethephon (300, 400, 500 ppm), SADH (1000, 2000, 3000 ppm), morphactin and TIBA (10, 25,50 ppm), and stored in the commercial cold storage (0-3.3°C, RH 85-90%). Two kg fruits were packed (three replications) in polythene and paper bags of size 35 x 25cm. The polythene bags of 100 gauge thickness were used. Both the bags were punched once at each 2.5 to 3.0 cm square area with 30 perforations in order to facilitate gaseous exchange. The bags were sealed with stapler and placed in ventilated wooden boxes. The fruit samples were taken out after 20, 30 and 40 days for PME analysis. Spoilage of the fruit was judged visually for calculating % spoilage.

Preparation of extract : For the enzyme extraction, the fruit samples were stored immediately after harvest in a freezer at 0°C. Two g peeled fruit (without seed) was subsequently ground in a chilled mortar with 10 ml of phosphate buffer (pH 6.5, 0.1 M). Polyvinylpyrolidine (1 g) was added along with the buffer to avoid inactivation of the enzyme by the phenolic constituents of the *ber* fruit. The extracts were centrifuged at 10,000 rpm for 10 min in a refrigerated centrifuge at 0°C, and analyzed immediately.

Pectin methyl esterase assay : Method of Dingle et al (1953) was followed by measuring the increase in acidity after hydrolysis of pectin by the enzyme preparation. The PME activity was calculated as milli-equivalent of methoxyl groups, liberated/h/mg protein by 1 ml of the enzyme preparation under the specified conditions of the assay. The method of Lowry et al (1951) was followed for estimation of total soluble proteins, using bovine serum albumin as standard.

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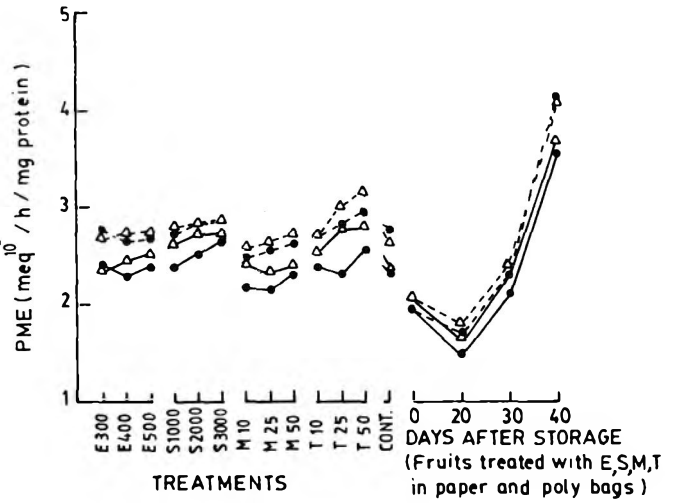

Fig. 1. Pectin methyl esterase of *ber* during cold storage —— : paper bags, --------- polythene bags, Δ : 1989, ●; 1990. E:Ethephon, S: Succinic acid, 2,2-dimethyl hydroxide, T: 2,3,5-Triiodobenzoic acid, M: Morphactin, CONT : control.

PME activity upto 20 days of cold storage was found to be slightly reduced. On next sampling (30 days), the enzyme activity showed significant increase. The rate of increase of PME activity was further maintained after 40 days of cold storage in both paper and polythene packings (Fig. 1). Increases in enzyme activities in *ber* fruits during storage at 10°C h have also been reported by Panwar (1981). Similar trend in the activity of PME was also noticed in 'Patharnakh' pear (*Pyrus pyrifolia*) fruits (Randhawa et al. 1987). TIBA and SADH treatments resulted in significantly more activities of PME than those with morphactin and ethephon treatments in both the packings. The highest activity was recorded with 25, 50 ppm TIBA and 2000 ppm SADH after 40 days of cold storage. The enzyme activity was the lowest in the fruits, sprayed with 10-25 ppm morphactin, and 300-400 ppm ethephon in paper bags. Likewise, morphactin treatments and ethephon (400-500 ppm) proved significantly effective in lowering the PME activities of fruits in polythene bags. In general, the enzyme activities were significantly higher in the fruits stored in polythene bags than those in the paper bags. Such changes in PME activities in fruits stored in paper bags lead to reduced degradative metabolism, and is thus helpful in extending the shelf-life of fruits.

It has been observed that % spoilage increased with increase in PME. There was little or no spoilage of *ber* fruits upto 20 days of storage in both paper and polythene bags under all the treatments. The condition of fruits upto 30 days of cold storage was good, but deterioration took place, thereafter, in both the packings in most of the treatments (Table 1). Continuous biochemical changes in fruits after harvest lead to fruit softening and spoilage, and hence deterioration in fruit quality. Fruit softening involves the hydrolysis of cellulose and pectin in the cell wall (Singh et al. 1979) by pectinase (Mason et al. 1975), and cellulase (Abeles 1963). Ethephon treatments markedly reduced the spoilage during storage in

TABLE 1. EFFECT OF PRE-HARVEST SPRAY OF GROWTH REGULATORS ON SPOILAGE OF *BER* FRUITS IN COLD STORAGE

Growth regulators	Concentration, (ppm)	Spoilage, %											
		Days after storage in 1989 season						Days after storage in 1990 season					
		Paper bags			Polythene bags			Paper bags			Polythene bags		
		20	30	40	20	30	40	20	30	40	20	30	40
Ethephon	300	-	2.2	5.3	-	1.2	16.3	-	1.8	4.5	-	-	23.1
	400	-	2.3	6.5	-	3.0	18.3	-	1.9	7.1	1.2	3.8	18.2
	500	-	2.9	6.4	-	2.8	22.3	-	3.3	5.1	-	2.8	16.7
SADH	1000	-	3.8	12.7	-	3.3	22.6	1.5	5.6	20.7	1.8	3.7	25.1
	2000	-	4.3	17.2	-	5.2	27.3	1.5	5.5	21.3	1.8	6.6	28.3
	3000	2.1	5.6	15.7	-	6.2	32.9	1.8	6.3	23.1	1.8	7.4	31.6
Morphactin	10	-	2.1	8.7	-	3.8	21.1	-	1.6	9.1	-	4.3	26.3
	25	-	1.9	9.4	-	4.3	28.2	-	-	9.9	-	5.7	35.4
	50	-	2.3	9.3	-	6.1	30.7	-	1.2	8.3	-	6.5	18.2
TIBA	10	-	1.7	8.2	-	5.2	36.8	-	2.3	7.7	-	4.1	49.2
	25	-	2.2	11.8	-	4.3	30.3	-	2.3	16.7	-	3.4	38.5
	50	-	2.4	14.3	-	6.4	28.6	1.8	3.3	17.8	-	7.7	39.5
Control			3.9	11.9	-	8.2	29.7	-	4.5	12.8	-	9.2	36.5

- : Negative

both the packings. TIBA treatments, which resulted in higher spoilage rate, also showed increased PME activity.

Thus, it may be concluded that the shelf-life of pre-harvest growth regulator-sprayed fruits in the cold storage can be extended upto 30 days in paper and polythene bags. However, the shelf-life can be enhanced upto 40 days effectively by spraying ethephon 400-500 ppm at colour-break stage and storing the fruits in paper bags.

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Received 20 April 1993; revised 12 October 1994; accepted 17 October 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 162-165

Functional Properties of Rapeseed Protein Isolates

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Functional properties of water and salt-soluble proteins of *Brassica campestris* var. 'toria' were measured. Water and fat absorption capacities of rapeseed meal were 2.220 g/g meal and 1.5 g/g meal, respectively, while the isoelectric points of both the protein isolates (RPI-1 and RPI-2) were in acidic range (pH 5-6). Solubility of RPI-1 was more than that of RPI-2, while sulphate and nitrate ions reduced the protein solubility. Foaming and emulsifying properties of RPI-1 were better than those of RPI-2.

Keywords : *Brassica campestris* var. 'toria', Emulsification, Foaming, Protein isolates, Salt effects, Solubility.

In order to find its use in food, a protein should possess several desirable functional properties (Kinsella 1982). Interactions of proteins with other components of food, like water and lipids, are also important to find their acceptability in foods (Johnson 1970). Several groups have made studies on the functional properties of protein isolates of *Brassica napus*, i.e., rapeseed of foreign origin (Sosulski et al. 1976; Naczk et al. 1985; Dev and Mukherjee 1986). However, 'toria', an Indian rapeseed, which is extensively grown in India for its oil content, remains untouched as far as its protein characterization is concerned, although some studies were done by a few Indian workers on oils and seeds (Uppal et al. 1984; Sindhu Kanya et al. 1993; Krishnamurthy et al. 1983). In the present study, some of the functional properties of rapeseed proteins are undertaken, and these are compared with proteins of other species of *Brassica* of Indian as well as foreign origin.

Pure line seeds of rapeseed (*Brassica campestris* var. 'toria') were obtained from the Punjab Agricultural University, Ludhiana. Defatted meal was prepared by treating rapeseeds with hexane for 6 times, every time changing the solvent, and finally evaporating the solvent at room temperature. The meal was finely powdered, and passed through a 80 mesh sieve. Extraction of proteins from defatted seed was carried out by stirring 30 ml distilled water with 5 g material for 1 h, before centrifugation at 7000 rpm for 15 min at 4°C. Supernatants of such three extractions were pooled, and precipitated at 100% saturation of $(NH_4)_2SO_4$ (protein isolate-1). Residue was further extracted thrice with 8% NaCl as above, and the pooled supernatant was precipitated with 50% saturation of $(NH_4)SO_4$ (protein isolate-2). Precipitated protein isolates 1 and 2 were dissolved in water and NaCl, respectively, and dialyzed against distilled water at 4°C for 48 h.

Water and fat absorption capacities were determined according to the procedure employed by Sosulski (1962) and Sosulski et al (1976), respectively. Isoelectric points were calculated on the basis of flocculation, and nitrogen solubility methods (Dua et al. 1993). Effect of pH on the protein solubility was studied by keeping the protein solution at these specific conditions for 30 min. Effect of various salts on protein solubility was evaluated, using different concentrations of salts (0.1-1.0M). The protein content of the supernatant was estimated by the method of Lowry et al (1951). Foam capacity (FC) was measured by the method of Lawhon et al (1972), while foam stability (FS) was studied by the method of Ahmed and Schmidt (1979). Emulsifying activity (EA) and emulsion stability (ES) were estimated by the procedures given by Yasumatsu et al (1972).

Water absorption capacity (WAC) of rapeseed meal was 2.220 g/g meal, whereas fat absorption capacity (FAC) was 1.5 g/g meal. Rapeseed meal

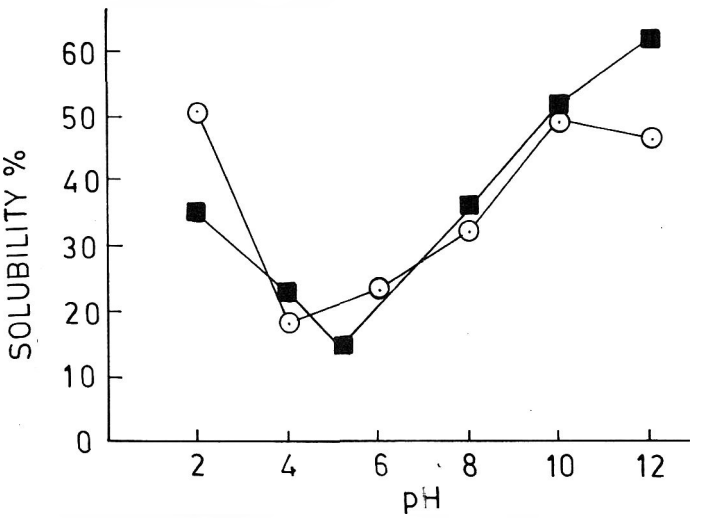

Fig. 1. Effect of pH on the solubility of RPI-1 (—O—O—) and RPI-2 (—■—■—).

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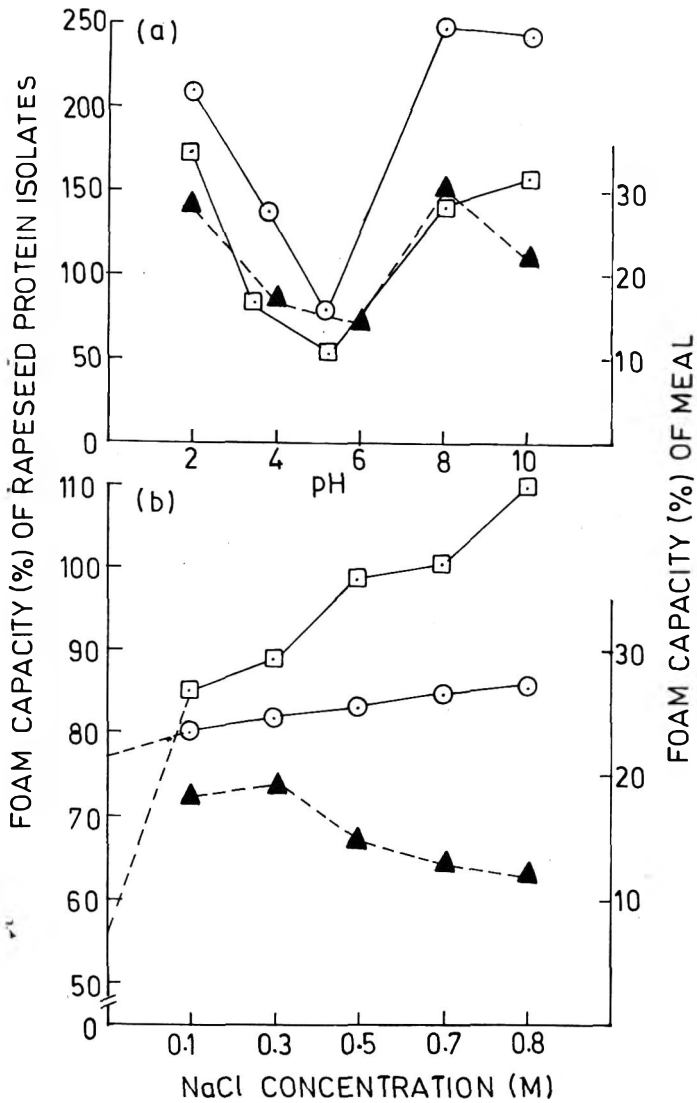

Fig. 2. Effect of pH (a) and NaCl (b) on % foaming capacity. RPI-1: (—O—O—), RPI-2 : (—□—□—) and Rapeseed meal : (—▲—▲—)

showed better FAC than *B. napus* (1.3 g/g meal), and equal to soybean meal (1.51 g/g meal), Dev and Mukherjee 1986), thereby suggesting that rapeseed meal proteins are more lipophilic than *B. napus*.

The isoelectric points of rapeseed protein isolates 1 and 2 (RPI-1 and RPI-2) were found to be in the acidic range (pH 5-6). The protein solubilities of these isolates were maximum at extreme pH values (pH 2 and 12) and minimum around isoelectric point (Fig. 1). Similar types of changes were observed in foam capacities for both the isolates and rapeseed meal (Fig. 2). These values are more than those for soybean meal and isolates (Sosulski et al. 1976), but are comparable with other *Brassica* spp. (Dev and Mukherjee 1986). Emulsifying properties also showed a similar type of 'V' shaped curve with EA minimum at their isoelectric points (Fig. 3).

The high solubilities at extreme pH values suggest that electrostatic repulsive interactions between molecules are greater than hydrophobic interactions on the molecules (Shen 1976), and hence the protein remains in the solution. The proportion of protein solubilized is directly related to foam capacity and emulsifying activity (Shen 1975). Previous reports have also indicated that EA of protein products from rapeseed and other sources compared well with the amount of protein solubilized (Yasumatsu et al. 1972; Volkert and Klein 1979). ES values of rapeseed isolates, however, were

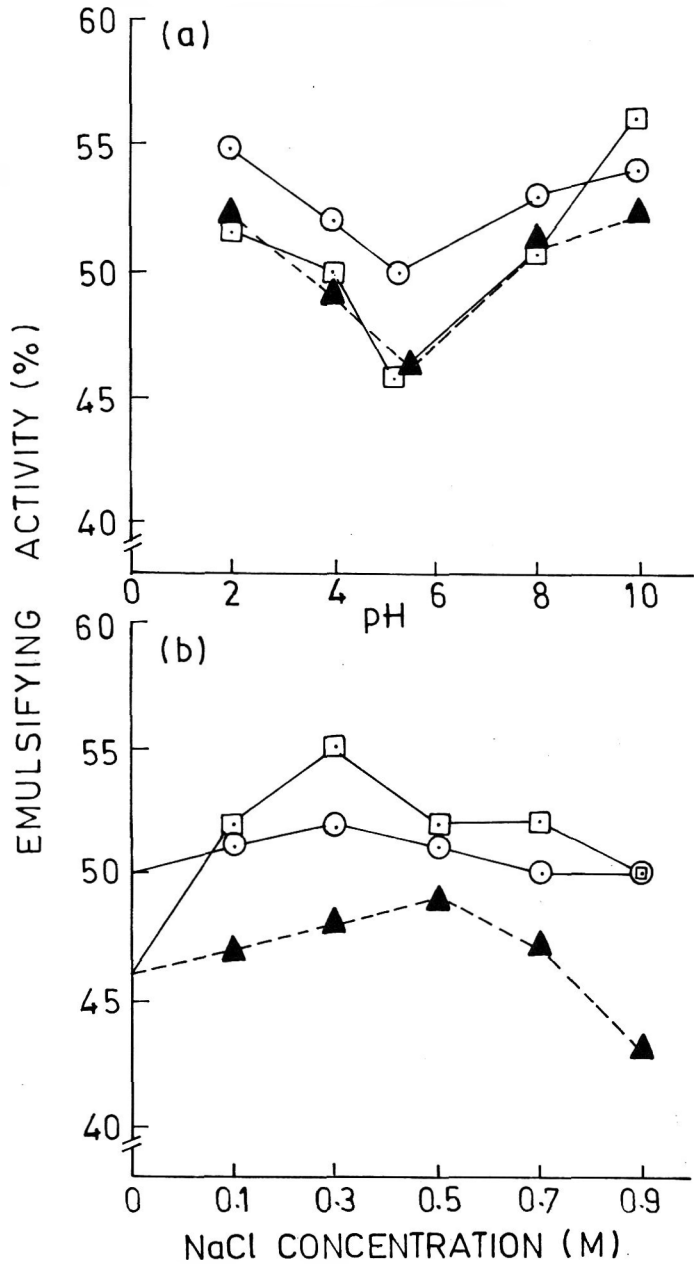

Fig. 3. Effect of pH (a) and NaCl (b) on % emulsifying activity. RPI-I : (—O—O—), RPI-2 : (—□—□—) and Rapeseed meal : (—▲—▲—)

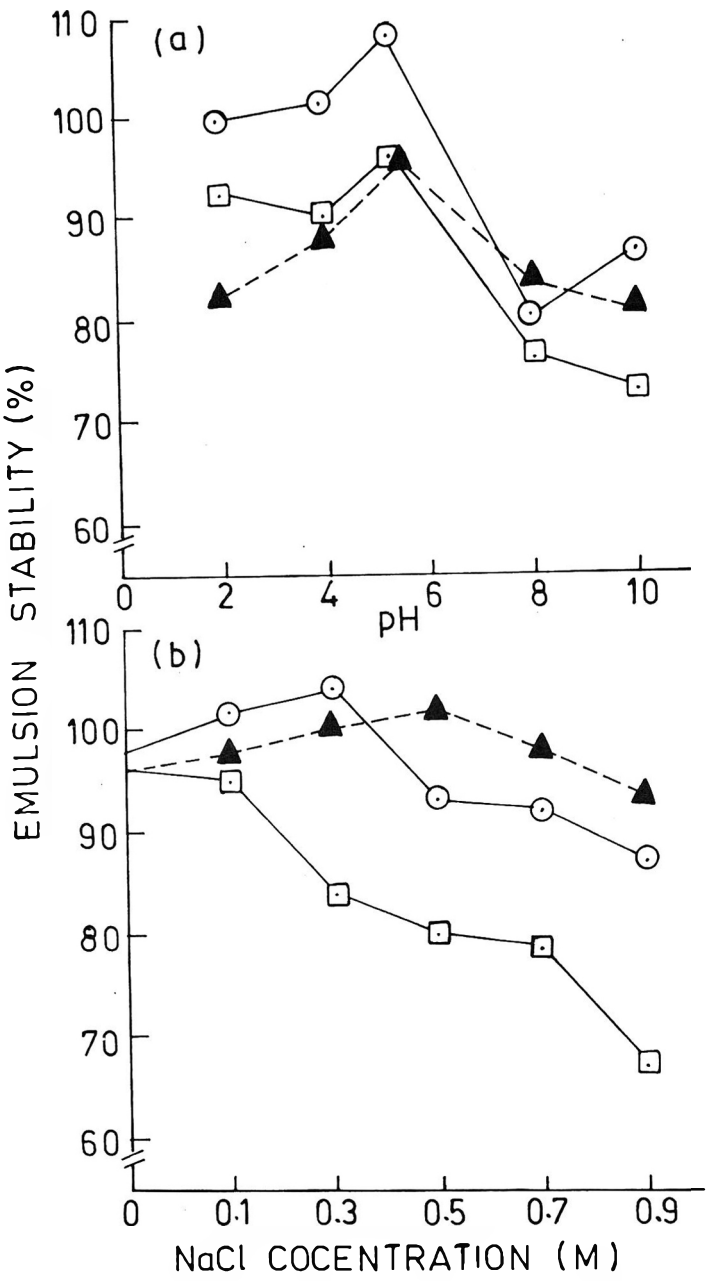

Fig. 4. Effect of pH (a) and NaCl (b) on % emulsion stability. RPI-1 : (—O—O—), RPI-2 : (—□—□—) and Rapeseed meal : (—▲—▲—)

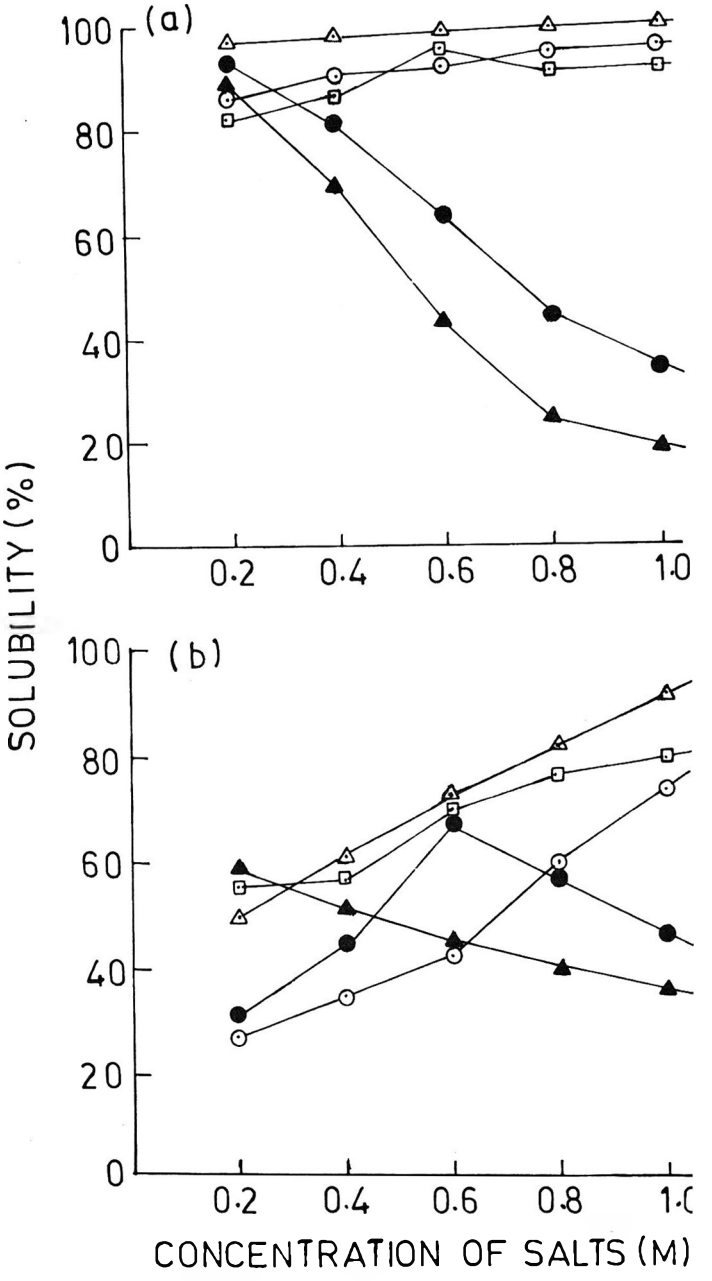

Fig. 5. Effect of different salts :(ammonium sulphate : —▲—▲— ammonium nitrate : —●—●—, sodium citrate : —O—O— sodium chloride : —□—□— and potassium iodide : —Δ—Δ— on solubility of (a) RPI-1 and (b) RPI-2.

maximum at isoelectric points (Fig. 4). Since ES involves heating of protein isolates, there is dissociation of some proteins, and sub-units so formed, can form hydrophobic groups, which interact with the lipid phase.

Among different salts, nitrate and sulphate ions decreased the solubilities in both the isolates (Fig. 5), due to the salting-out effect of these ions. In the presence of citrate, iodide and chloride ions, solubility of RPI-1 remains almost same, whereas solubility of RPI-2 increased linearly with increasing concentrations of these ions, due to the salting-in effect (Fig. 5). Salt also affects foaming properties and emulsifying properties by enhancing solubility at lower concentrations. At higher concentrations salting-out may occur, thus reducing foaming and emulsification (Figs. 2, 3 and 4).

At present, 'toria' protein isolates are not being utilized in India in food systems. The present studies indicate that functional properties of these protein isolates are better than those of rapeseed meal and some of the soybean products. Therefore these can be used in food systems.

The first author is thankful to CSIR, New Delh

for financial assistance.

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Received 1 June 1993; revised 27 September 1994; accepted 25 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 166-168

Suitability of Reverse Osmosis Concentrated Milk for the Manufacture of *Paneer*

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Suitability of reverse osmosis concentrated milk for the manufacture of *paneer* was examined. Buffalo milk was concentrated, employing reverse osmosis to about 1.5 (25% TS) and 2.0 (33% TS)-folds. Reverse osmosis concentrates as such and after dilution to the composition of normal buffalo milk (6% fat and 9.5% TS) were used for the manufacture of *paneer*. Product from reverse osmosis processed milk retained higher moisture in comparison with control *paneer* and hence, the yield was about 2 to 3% higher. The recovery of milk solids in reverse osmosis *paneer* was always more than 68%, whereas in control *paneer*, it was 66.9%. Despite distinct variations in the texture profile of reverse osmosis *paneer* vis-a-vis control *paneer*, the sensory scores of the two types of products did not differ significantly.

Keywords : Reverse osmosis concentrate, Buffalo milk, *Paneer*, Whey, Rheological properties.

In the last two decades, several reverse osmosis (RO) plants have been installed in the dairy industry the world over, mainly for the concentration of milk and whey (Abbot et al. 1979; Cheryan et al. 1990). RO requires least energy per unit of water removed, as compared with other dewatering processes (Cheryan et al. 1987). It avoids the use of high temperature or changes of phase in the solvent, thereby minimizing flavour changes and damage to the milk constituents (Cheryan et al. 1990). The organoleptic quality of RO concentrated milk as such, and on dilution has been found to be comparable to that of normal milk (Gupta and Pal 1993). Since milk is recycled under a very high pressure in RO system, some of the earlier workers (Barbano et al. 1983; Gupta and Pal 1993) noticed damage to the fat globules. Hence, it becomes imperative to assess the suitability of RO concentrated milk for the manufacture of dairy products. Its effect on the quality of milk powder (Dixon 1985), cheddar cheese (Bynum and Barbano 1985), *khoa* (Pal and Cheryan 1987) and *dahi* (Kumar and Pal 1993b) have been already reported. Production and shelf-life of *paneer* as affected by various factors have been studied by various workers (Bhattacharya et al. 1971; Kulshresta et al. 1987; Haridas and Narayanan 1976). This communication describes the suitability of RO-processed milk for the manufacture of *paneer*, a popular coagulated Indian dairy product.

Reverse osmosis and paneer *manufacture :* Buffalo raw milk, obtained from Experimental Dairy of the Institute, was standardized to 6% fat. It was filtered through a muslin cloth, and then heated to about 60°C, without holding, for inactivation of lipase. After cooling to 50°C, the milk was concentrated to about 1.5 (25% TS) and 2.0 (33%TS)-folds, employing reverse osmosis. A portion of standardized milk was used as such for making control *paneer*. A tubular type, pilot scale RO plant (PCI Ltd., Hampshire, England), having composite membrane (AFC 99), with an area of 0.9 m^2 was used for concentration of milk (Kumar and Pal 1993a). During concentration, the temperature and pressure of milk were controlled at 50°C and 30 bar, respectively. Reverse osmosis concentrates (ROC) were used as such (1.5 and 2.0-folds) and after dilution to the composition of initial milk (6% fat) for the manufacture of *paneer*. The method recommended by Sachdeva and Singh (1988) was adopted with slight modification. A 0.5% citric acid solution was used for coagulation of ROC (undiluted), in place of recommended 1% strength. However, for control and diluted ROC, there was no change in the strength of coagulant. For each batch of *paneer*, 2 kg each of normal buffalo milk, diluted ROC and 1 kg of undiluted ROC were used.

Chemical and sensory analysis of paneer *and whey :* The total solids (TS) in *paneer* and whey were determined gravimetrically (MIF 1959). Standard Gerber method was employed for the determination of fat in *paneer* (BIS 1979) and whey (BIS 1977). *Paneer* samples were evaluated for flavour, body, texture, colour, appearance, and overall acceptability by a panel of six judges, selected from the faculty of Dairy Technology Division. A 9-point Hedonic scale, as described by Amerine et al (1965), was used by the panelists. A Universal Testing Machine (Model 4301, Instron Ltd., Buckinghamshire, U.K.), attached with a strip chart recorder and printer, was employed for measuring the texture profile of *paneer* samples,

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as per the method of Bourne (1978). A load cell of 10 Neutons was applied. Cylindrical samples of *paneer* of uniform size (1.54 cm height and 1.54 cm diam) were compressed to 20% of their original height, using a crosshead speed of 5 cm/min, and chart speed of 10 cm/min. A constant temperature of 25°C was maintained during all measurements.

Chemical composition of paneer *and whey:* The moisture content of control *paneer* was 48.13%, which increased to 51.72 and 50.54% with the use of 1.5 and 2.0-folds RO concentrated milk, respectively (Table 1). Dilution of RO concentrates to the composition of normal buffalo milk and making of *paneer* therefrom, further increased the moisture content to about 53%. The homogenization-like effect of the RO process (Gupta and Pal 1993) could be mainly responsible for higher moisture retention capacity of *paneer*. Earlier workers (Singh and Kanawjia 1991) have also observed a similar effect on homogenized milk, in comparison with the non-homogenized milk. On the basis of fat (on dry matter basis) and moisture contents, all types of RO *paneer* conformed to the PFA requirements. The yield of *paneer* made from RO processed milk was found to be 2-3% higher, in comparison with that of control *paneer*, obviously due to the higher moisture retention in the former case. The recovery of solids also followed the same trend (Table 1). The lowest recovery of total solids (66.9%) in control *paneer* could be ascribed to higher losses of total solids (5.95%), and fat (0.15%) in its whey. On the contrary, the recovery of solids in RO *paneer* was always more than 68%. The amount of whey obtained during the manufacture of *paneer* from directly RO concentrated milk was lowest, which could be mainly responsible for its highest percentage of total solids.

Rheological properties of paneer : Control *paneer* was found to be harder than RO *paneer* (Table 1). Hardness of *paneer* made from undiluted RO concentrates was higher than that prepared from diluted RO milk. The levels of total solids in RO milk also effected the hardness values. The higher moisture content in RO *paneer* could be mainly responsible for decreased hardness. Earlier workers (Pal and Garg 1989) have also reported similar effect of moisture level on the hardness of *paneer*. The springiness value of control *paneer* was more than that of RO *paneer*, but no definite trend could be observed among the different types of RO *paneer*. RO *paneer* was distinctly less cohesive than control *paneer*, the average value in the former group being 0.72, while in latter case, it was 0.97. These trends could also be corroborated with the sensory results, wherein RO *paneers* were criticised for their brittle texture. Since gumminess and chewiness are the products of hardness x cohesiveness and hardness x cohesiveness x springiness, respectively, the values for these two rheological properties were also higher for the control *paneer*.

Sensory quality of paneer : There was no significant difference in the flavour, texture, appearance and overall acceptability scores of control *paneer* and that obtained from either diluted 1.5-fold RO milk or 1.5 undiluted ROC (Table 1). The use of 2.0-fold ROC, after slight modification in the manufacturing process, also produced acceptable products and the sensory scores of such *paneers* did not differ significantly from those of control *paneer*. The texture of RO *paneer* was, however, criticised to be slightly brittle. The slight deviation in texture of RO *paneer* from that of normal *paneer* could most probably be ascribed to higher lactose content in RO milk and homogenization effect of the process (Barbano et

TABLE 1. EFFECT OF RO PROCESSING OF BUFFALO MILK ON DIFFERENT QUALITY ATTRIBUTES OF *PANEER*

Attribute	Control *paneer*	RO *paneer* made from 1.5 x ROC	2.0 x ROC	Diluted 1.5 x ROC	Diluted 2.0 x ROC
Chemical composition and yield					
Paneer					
Moisture,%	48.13	51.72	50.54	53.20	53.37
Fat %	26.70	24.60	25.60	23.90	24.10
Fat on dry mater basis,%	51.56	51.06	51.96	51.05	51.71
Yield,%	21.30	23.10	23.40	24.00	24.20
Recovery of solids,%	66.90	68.62	69.14	68.07	68.39
Whey					
Total solids,%	5.95	8.84	8.54	5.69	5.54
Fat,%	0.15	0.05	0.05	0.03	0.02
Rheological properties					
Hardness, N	1.19	0.90	0.95	0.82	0.83
Springiness, mm	4.33	4.07	4.17	4.00	4.25
Cohesiveness	0.97	0.73	0.73	0.72	0.71
Gumminess, N	1.15	0.66	0.69	0.59	0.59
Chewiness, mmN	4.96	2.67	2.89	2.34	2.52
Sensory quality (score based on 9 point Hedonic scale)					
Flavour	7.64	7.57	7.56	7.58	7.61
Body and texture	7.53	7.50	7.47	7.60	7.48
Colour and appearance	7.50	7.63	7.64	7.60	7.58
Overall	7.54	7.57	7.50	7.60	7.52

ROC = Reverse osmosis concentrates. All the values are average of 3 trials.

$$\text{x (concentration factor)} = \frac{\text{Initial weight of milk}}{\text{Weight of concentrate}}$$

al. 1983; Gupta 1991).

It is concluded that the use of RO concentrated milk for *paneer* manufacture results gives higher yield, without affecting its sensory properties and consumer acceptability.

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Received 2 August 1993; revised 30 August 1994; accepted 25 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 169-171

Effect of Incorporation of Puffed *Bengal*gram Flour on the Quality of Bread

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Puffed *Bengal*gram flour was substituted at 5 to 25% levels in bread formula. As the level of puffed *Bengal*gram flour increased, dough stability and mixing tolerance index decreased. Substitution beyond 20% resulted in a progressive decrease in loaf volume and deterioration in crumb grain as well as texture. Addition of potassium bromate was found to be an effective improver. Puffed *Bengal*gram flour-substituted bread could be stored well upto 4 days in polyethylene bags.

Keywords : High protein bread, *Bengal*gram incorporation, Rheological properties, Baking qualities, Bread improvers, Sensory attributes, Storage studies.

Greater emphasis has been placed on the use of composite flours in bakery products, especially in bread making during the last 10-15 years (McConnel et al. 1974). Sorghum (Tripathi and Date 1975), proso millet (Lorenz and Dilsaver 1980), and pearl millet (Badi et al. 1976) have been used to prepare composite flours. Now, considerable interest has been generated in improving the nutritional value of wheat flour by adding legume flours (McConnel et al. 1974). Pulse flour is an excellent source of proteins and lysine and consequently, it improves the biological utilization of wheat proteins (Sahni et al. 1975). Incorporation of cowpea (Mustafa et al. 1986), soya bean (Sahni and Krishnamurthy 1975), and *mung* been (Thompson 1977) flours have been evaluated. However, information on possibilities of utilizing puffed *Bengal*gram flour (PBGF) is lacking. Puffed *Bengal*gram is popular in India, as ready-to-eat snack, and is easily digestible (Geerwani and Theophilus 1979). Hence, this study was undertaken to standardize the acceptable level of PBGF in bread formula, with respect to baking and organoleptic qualities, with a view to determine the supplementary value of PBGF in bread.

Maida and puffed *Bengal*gram *dhal* were purchased from local market. Commercial bread improver is from Helios Food Additives Pvt Ltd., Bombay. The ingredients mentioned on the label were proteins, yeast food, emulsifiers and permitted enzymes. The dhal was cleaned and ground in a plate mill (M.C. Dalal and Co, Madras) in the laboratory. Bread was prepared by straight dough method (Sahni and Krishnamurthy 1975) using (g) 150 *maida*, 2.2 yeast, 13 *vanaspathi*, 2.2 salt, 30 sugar and 90 ml water. Yeast was dispersed in small part of warm water (45°C), containing 5g sugar, and held for 10 min. The remaining part of water was used to dissolve remaining sugar and salt. All the ingredients were mixed in the dough mixer, (Sumeet SP-16, Electronic Food Processor, Nasik) at room temperature and dough was allowed to ferment for 60 min. at 32°C. The fermented dough was placed in greased pan for proofing. The proof-time was not kept constant, and it was based on constant height of proofed dough. Baking was done at 220°C for 25 min. PBGF was substituted at 0, 5, 10, 20 and 25% levels to replace *maida*, and breads were prepared as above. Improvers like glycerol monostearate (0.5%), commercial bread improver (0.5%), ascorbic acid (250 ppm) and potassium bromate (75 ppm) were used at 15, 20 and 25% substitution levels.

The organoleptic properties of the breads were evaluated by fifteen judges on a Hedonic scale (Amerine et al. 1965) of 1 to 4, the latter being given to the highest quality attribute and the average score was calculated. The loaf volume was measured by mustard replacement method (ISI 1968). For storage studies, breads were packed in polythene pouches, and stored at ambient conditions (32-36°C and 67-74% RH). The strength of the dough in terms of dough development time, dough stability and mixing tolerance index was determined, by using Brabender farinograph (AACC 1969). Brabender amylograph was used to determine the gelatinization characters of the flour (AACC 1969). Sampling of the bread was done as per AOAC (1975) method, and the results were expressed on fresh weight basis. The samples were hydrolyzed as per Block et al (1956), and lysine was determined quantitatively by thin layer chromotography

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TABLE 1. EFFECT OF SUBSTITUTION OF PBGF ON THE RHEOLOGICAL AND BAKING QUALITIES OF BREAD

PBGF level, %	Dough development time, min	Dough stability, min	Mixing tolerance index, BU	Gelatinization starting temp, °C	Temp. at peak viscosity	Peak viscosity, BU	Proof-time, min	Loaf volume, ml
0	2.5	11.0	60	60	88.5	690	75	945
5	2.5	8.0	40	60	88.5	640	75	928
10	2.5	7.0	40	60	88.5	610	75	923
15	2.5	6.5	40	63	88.5	540	90	893
20	2.5	4.0	40	63	87.0	470	90	810
25	2.0	3.0	30	63	84.0	340	90	700
SED	1.87 NS	1.60 NS	4.47 NS	1.21 NS	1.82 NS	5.84 **	1.86 **	7.449 **
CD	3.76	4.11	11.49	3.11	4.69	15.02	4.8	19.15
20% PBGF + 0.5% glycerol mono stearate	3.0	6.0	30	ND	ND	ND	53	920
0.5% commercial bread improver	2.5	7.0	30	ND	ND	ND	52	919
250 ppm ascorbic acid	2.5	8.5	40	ND	ND	ND	53	930
75 ppm potassium bromate	3.0	8.0	30	ND	ND	ND	53	932

ND - Not done, NS - Not significant, ** - Significant at 1% level, Flour used in bread formula : 150 g

(Jayaraman 1985), while methionine was estimated by the method described by McCarthy and Sullivan (1941). The data were statistically analyzed by completely randomized design (Federer 1955)

The rheological properties and baking qualities of *maida* substituted with different levels of PBGF are shown in Table 1. The dough development time was not affected upto 20% substitution. At 25%, the dough development time was reduced from 2.5 min with the use of glycerol mono stearate at 0.5% level or ascorbic acid at 250 ppm. Stability of the dough decreased, as the level of PBGF increased. The stability could be restored back to a certain extent, by using improvers at 20% substitution of PBGF. Similarly, mixing tolerance index was reduced with the increase in PBGF level. The proof-time of PBGF substituted dough increased with the increase in PBGF level. It was efficiently reduced with the use of improvers. The proof-time of the control bread was 75 min, which increased to 90 min as PBGF was substituted upto 20% level. Bushuk and Hulse (1974) and Sarhan et al (1986) have also reported that addition of improvers enhanced the baking qualities of the composite flours.

The loaf volumes of the bread at 0, 5, 10, 15 and 20% substitution levels of PBGF were 945, 928, 923, 893 and 810 ml. respectively. The improvers efficiently counteracted any adverse effect, and the loaf volume was increased to 919.5 and 938.0 ml at 20% substitution level of PBGF. The mechanism of improvement by ascorbic acid is due to the reduction in - SH groups, which helps to increase the loaf volume (Tsen 1965). The baking qualities of bread showed that PBGF could be incorporated only upto 10%, without any improver in the bread formula, while the substitution level could be increased to 20%, if improvers like ascorbic acid (250 ppm) or potassium bromate (75 ppm) are used.

Gelatinization temperature was not changed up to 10% PBGF substitution, but it increased at higher PBGF substitution. The temperature at peak viscosity decreased, as the substitution level of PBGF increased. The reduction in peak viscosity is mainly due to the gradual reduction in the starch content of the flour due to the incorporation of PBGF.

Organoleptic qualities of PBGF-substituted bread : Crust colour of the bread was not affected by substitution with PBGF at all levels. However, the increased level of PBGF resulted in dull crumb colour and coarser grain. When the PBGF level was increased to 15%, the bread was found to be sweet in taste. To modify this effect, additional amount of 0.5% salt was used in the formula. The organoleptic scores were reduced from 3.6 for control bread to 3.0 at 15% PBGF substitution level. Ascorbic acid (250 ppm) and potassium bromate (75 ppm) improved the organoleptic quality of the bread, made with 20% substitution by PBGF and scored 3.4 and 3.6, respectively. Breads prepared with all substitution levels of PBGF developed mould growth after 4 days of storage at ambient conditions. The mould species identified were *Penicillium* spp, *Aspergillus niger* and *A. flavus*.

Nutritional qualities of PBGF-substituted bread : The moisture contents of the breads prepared with different levels of PBGF were found within the specifications (ISI 1977). The protein content of the control bread was 7.59 g/ 100g. while the protein

TABLE 2. EFFECT OF SUBSTITUTION OF PBGF ON THE PROXIMATE COMPOSITION OF BREAD

Nutrients	Substitution levels of PBGF, %							
	0 (T_1)	5 (T_2)	10 (T_3)	15 (T_4)	20 (T_5)	25 (T_6)	SED	CD
Moisture, g %	34.35	34.85	35.01	35.14	36.59	36.63	0.2278	0.5574**
Proteins, g %	7.59	8.06	8.50	9.12	9.44	9.82	0.0430	0.1052**
Lysine, mg %	134	178	221	265	309	353	3.5580	8.7060**
Methionine, mg %	123	132	136	144	146	150	2.3790	5.8210**

** Significant difference at 1% level

value increased to 9.44 g/ 100 g at 20% substitution with PBGF. Lysine content of the bread increased to 309 mg/100 g in the 20% PBGF-substituted bread, in contrast to 134 mg/100 g in control bread. With respect to methionine, the control bread contained 123 mg/100 g and by subtituting with 20% PBGF, it increased to 146 mg/100 g. (Table 2).

It is concluded that the puffed *Bengal*gram flour could be incorporated upto 20% level in bread formula. However, bread improvers had to be used in the formulas to get breads with necessary gas retention capacity. The protein content increased by about 24% at 20% substitution of PBGF.

The authors are thankful to Dr. Haridas Rao, Scientist, CFTRI, Mysore for help in rheological studies of the flour and to Ford Foundation, USA, for providing a fellowship to KR.

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Received 12 October 1993; revised 5 September 1994; accepted 26 November 1994

J. Food Sci. Technol., 1995, Vol. 32, No. 2, 172-177

***The Lipid Hand Book - 2nd Edition with dictionary section;* Edited by Frank D. Gunstone, John L. Harwood and Fred B. Padley; Published by Chapman and Hall, 2-6, Boundary Row, London SEI 8HN, U.K. 1994, pp 722+551, Price : £ 255/-**

The book entitled "The Lipid Hand Book-2nd Edition" is a well documented comprehensive handbook on Lipids, edited by Frank D. Gunstone, John L. Harwood and Fred B. Padley and published by Chapman and Hall. At the outset, the book consists of a total of 12 chapters on various aspects of lipid-related topics. They include 1. Fatty acid structure 2. Lipid structure 3. Occurrence and characteristics of oils and fats 4. Separation and isolation procedures 5. Processing of fats and oils 6. Analytical methods 7. Synthesis 8. Physical properties: structural and physical characteristics 9. Physical properties: optical and spectral characteristics 10. Chemical properties 11. Lipid metabolism and 12. Medical and agricultural aspects of lipids.

Of particular importance are the details, under which one can see the inputs in terms of exhaustive details, including thermodynamics. The authors have taken into consideration all the database, available to them in terms of the sources of the lipids, the basic properties, the production of the raw material from where such lipids are consolidated and worked. The different botanical names of the species and the characteristics of the oil and also the figures of stocks of imports and exports and ending stocks go to show, how careful the authors are in organising their database in a comprehensive manner, which is fully informative. Specific items, such as efficiency of lipid turnover and other tissue lipids, algae lipids, lipids from fungi, lipids of viruses appear to be fascinating. Details of techniques, processes and raw material preparation is another attraction in this handbook. It is fully descriptive with exhaustive references of the citations.

The lipid water interaction is another area, wherein a lot of documentation is not available in many libraries, and this has also been taken care of by editors. High resolution NMR, enzyme production and function of eicosanoids, biosynthesis of spingo lipids, medical aspects of vitamins (fat-soluble), including speciality lipids is completely covered in the first part. This is followed by a section, which is compiled by the chemical database and CAS registry number index, which makes this handbook one of the rare comprehensive lipid handbooks.

The above compehensive lipid handbook makes an invaluable addition in any library system in the subject area of lipids from any source depending upon what information one is looking for. The novelty of this book is that of both basic data, as well as chemical data followed by processing data backed up by instrumentation, chemistry aspects, thermodynamic interpretation, exhaustive index of reference and a comprehensive registry, which elevate this handbook to a very high level of documentation. I congratulate the authors for this fine job of consolidating the information. The fact that it is going for second edition with all the modification is itself an indication of the popularity and the scientific content of the book.

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***Wheat - Production, Properties and Quality;* Edited by W. Bushuk and V.F. Rasper; Published by Blackie Academic and Professional, an imprint of Chapman and Hall, Western Claddens Road, Bishopbriggs, Glasgow G642NZ, U.K., 1994, pp 239., Price : £ 65/-**

The 8th World Congress of Food Science and Technology, was held in Toronto, in 1991. In addition to presentations by individual researchers, a number of invited papers were presented as plenary lectures by some of the leading figures in International food science and technology. These papers were compiled by a series of editors into books and this book is a part of the same. This book presents some of the most significant ideas, which will carry food science and technology through the nineties and into the new millenium. With the latest scientific and technological findings, this book is a boon to the scientific workers in general, and wheat growing countries like India in particular. This book contains fifteen contributory papers by well known scientists from different parts of the world. The book covers three major aspects of wheat in a detailed and precise manner. All the chapters are very well written, and presented in a simple understandable language, covering the salient features.

The first chapter covers worldwide wheat production, trade and its utilization. Second chapter

discusses the contribution of wheat-based products to world food supply and human nutrition. Chapter three covers the methods, criteria, methodology and approaches used to evaluate bread wheat and bread quality. The fourth chapter deals with the importance of wheat grain grading, standards and their consistency. The next chapter describes the recent developments in flour milling, including the flour milling requirements and developments in equipment as well as processes. In chapter 6, the research developments in bread baking technology have been covered under various heads like nutritional recommendations, processing techniques, labelling and quality assurance etc. Chapters 7 to 9 discuss the structure and functionality of wheat carbohydrates, proteins and lipids. Very useful and relevant information and references have been presented. Chapter 10 covers an important aspect i.e., enzymes of sprouted wheat and their possible technological significance. Pre-harvest sprouting of wheat is a world wide problem. This chapter briefly summarizes the effect of sprout damage on processing quality of different products. Chapters 11 and 12 are on the importance of soft wheat and Durum in the production of quality cookies and crackers; and pasta products, respectively. These chapters discuss the various quality factors, and the factors affecting them. The thirteenth chapter provides information on the physical characters of gluten protein and starch fraction, production of starch from wheat flour and extrusion cooking of wheat starch as well as flour. The last two chapters discuss the role of conventional as well as biotechnological breeding and genetic manipulation in the improvement of wheat quality.

This book is a valuable contribution to the field of Food Science in general, and wheat in particular. It will be useful, not only for academicians and research scientists, but also the students, industrial R&D workers etc. It is a hard bound volume with excellent printing and contains 239 pages. Special thanks are due to the editors and contributors for bringing out such a valuable book.

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***HACCP- A Practical Approach;* by Sara Mortimore and Carol Wallace; Published by Chapman and Hall, 2-6, Boundary Row, London SEI 8HN, U.K. 1994, pp 296, Price : £ 65/-**

HACCP is a proven system, which gives confidence that food safety is being effectively managed. It is a cost-effective system, which targets resource to critical areas of processing and in doing so, reduces the risk of manufacturing and selling unsafe products. Due to increased awareness of hazards in general, and participation of people from all areas of the operation in particular, the product quality is improved. The major seven principles, which outline how to establish, implement and maintain a HACCP plan for the operation under study is briefly given in chapter 1 itself.

This book is written by 2 safety management professionals with years of practical experience in the United Kingdom's well known food companies. It is based upon the international HACCP approach advocated by the Codex Alimentarius Committee on Food Hygiene (1993), and the National Advisory Committee on Microbiological Criteria for Foods (NACMCF 1992) in the United States of America. The former is a committee of the WHO/FAO Codex Alimentarius Commission.

HACCP is now widely acclaimed by the food industry and by Government regulatory agencies to be a cost-effective means to prevent the incidence of identifiable foodborne biological, chemical and physical hazards. In spite of this necessity, most currently available publications or training programmes are quite inadequate in this regard. This book tries to improve this situation. It is a refreshingly concise but at the same time, giving the full treatment of hazard analysis and risk assessment, HACCP plan development, implementation and maintenance.

Drawbacks of HACCP: If not properly applied, it may not act as an effective control system.

The book is divided into 10 chapters. It is nicely bound and reasonably priced.

This is a valuable resource material to those who are concerned with HACCP application in their food manufacturing or regulatory activities and a must for academic institutions, R&D institutions connected with food quality assurance and also food manufacturers.

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***Shelf-life Evaluation of Foods;* Edited by C.M.D. Man and A.A. Jones, Published by Blackie Academic and Professional, Western Cleddens Road, Bishopbriggs, Glasgow, G 642 NZ. UK. 1994, pp 321, Price : £ 75/-**

Shelf-life is most vital for Product Quality, as

it is a key component of marketability. It involves every stage of product preparation from the selection of raw materials, post-harvest handling of produce and its storage, preparation as well as every step of subsequent treatment and satisfaction. Therefore, sound criteria have to be established to determine each step that affects quality from field to the users. Shelf-life determination and evaluation is a multi-dimensional activity, for which indicative factors have to be established. Each aspect of shelf-life such as its evaluation, determining factors and their prediction could not have been better dealt with. The coverage of the book includes a variety of products from primarily processed and packaged fruits and vegetables, salads, chilled yoghurt and dairy products, ready-to-cook and ready-to-eat foods of plant and animal origin, a variety of snacks and confectionery products. Most technological aspects of preparation and processing such as thermally processed, frozen and chilled products are well covered. Methods of shelf-life determination are discussed in relation to raw materials and technologies used as well as related conditions of storage, giving due attention to quality and consumer satisfaction of the products. The products and processes discussed are predominantly for the western style products. Attention given to traditional foods of countries like China, India and Indonesia is very little, as the authors seem to have mainly the knowledge and experience of the food of western part of the world. The countries, where two-third of humanity lives, but who have not yet given attention to most of their ethnic foods for quality and shelf-life can also benefit a great deal from the methods discussed to evaluate foods and establish their own parameters of safety and increasing longevity of shelf-life.

The scientific and technological component of shelf-life evaluation is universal, but the application of the knowledge to products and the technology used have to be cultural specific. The methods of evaluation discussed can be modified and applied to many more products. The volume is a collection of rich experience and practical knowledge, which can be of real value to the industry and institutions active in packaging studies.

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***Safety and Nutritional Adequacy of Irradiated Food;* Published by World Health Organization, Geneva; 1994, pp. 161. Price : Sw.fr. 42/-; in developing countries Sw. fr. 29=40/-**

A major question often asked by consuming public, National and International Consumer Organizations as well as Governmental authorities responsible for the approval of sale of irradiated foods for human consumption is about its safety and wholesomeness. Despite the proven technological applications of irradiation processing of foods for specific objectives and its intensive processing methods such as canning and freezing, the industrial application of the technology on a commercial scale is yet to be achieved. The major hindrance for the adoption of this promising technology by the food industry and trade has been the distrust or even fear that this technology arouses in certain quarters and its acceptance by consumers.

Adopting a public health approach, the book prepared by the World Health Organization provides authoritative information on the safety and nutritional adequacy of foods processed by irradiation. It is pertinent to note that the report of the Joint FAO/IAEA/WHO Expert Committee meeting on the Wholesomeness of Irradiated Food in 1980 was a major turning point in the scientific evaluation of the safety of irradiated foods. With more than 500 references to the scientific literature, this publication is the most comprehensive compilation, WHO has ever produced on the subject.

The book concentrates on the specific scientific questions that must be answered before government authorities can approve irradiation, as a safe technique for improving shelf-life, reducing food losses and incidence of foodborne diseases. The book organised into 9 chapters provides concise and factual information on the technology, chemistry, toxicology, microbiology and nutritional quality of irradiated foods.

The history of food irradiation, the comparative aspects of different radiation sources, such as Cobalt-60 and Cesium-137 radioisotopes, X-rays and electrons generated by machines, using electrical energy and the mechanisms underlying the radiation processing of foods are briefly dealt in chapter 2. Food irradiation application covers a wide spectrum of plant and animal products. This includes inhibition of sprouting in root, tuber and bulb crops; insect disinfestation in cereals, pulses, spices, fresh and dried fruits; parasite disinfection in meat, fresh pork etc; delay of ripening in fresh fruits; elimination of spoilage and pathogenic microorganisms in fresh and frozen seafoods, poultry and meat; microbial decontamination in spices, certain food additives and ingredients; and sterilization (in combination with mild heat) of

meat, poultry, seafoods, prepared foods and hospital diets. These aspects are dealt with in chapter 3.

Consumer concerns on question of induced radioactivity and the toxic effects of chemical substances produced in foods through irradiation, called radiolytic products are addressed in chapter 4. The findings are entirely reassuring in this regard. All available evidence shows that radiolytic products formed in irradiated foods are very similar to those found in foods that have been processed using conventional methods.

Considerable international research effort is presently directed on developing methods of detecting irradiated foods. Such methods will help in promoting the acceptance of irradiated foods by governments, in commerce, and most importantly by the consumers. The promising analytical techniques based on chemical, biological and physical changes in irradiated foods are summarized in chapter 5.

Chapter 6 reviews the results of several hundred toxicological studies, conducted on experimental animals over the past four decades by feeding a variety of foods irradiated at different doses. Based on the data on sub-chronic toxicity studies in rats, mice and dogs; chronic studies in rats, monkeys and pigs; reproduction and teratology studies in rats, mice, dogs, hamsters and rabbits; mutagenesis studies in different animal species, and human feeding studies in China. The book concludes that "food irradiation is the most thoroughly investigated food technology from a toxicological point of view and that the toxicological database indicates no adverse toxicological effects of this technology in the radiation dose ranges tested".

Concern that irradiation will result in increased induction of mutants that may possess increased pathogenicity, virulence, or radiation resistance has been expressed, but there is no scientific evidence that such transformations take place. This is the conclusion of chapter 7, which deals with microbiology of irradiated foods.

There have been claims that irradiated foods lose some of their nutritional value. These claims are verified in chapter 8. Extremely precise measurements show that nutritional value of irradiated foods hardly differs from that of foods processed by other methods. Some vitamins are more sensitive to irradiation than others, and such losses can be limited by suitable procedures, like irradiating foods at low temperature or in the absence of oxygen.

Chapter 9 gives an overview of the concerns and overall conclusions. In conclusion, the book stresses that "As long as requirements for good manufacturing practice are implemented, food irradiation is safe and effective. Possible risks resulting from disregard of good manufacturing practice are not basically different from those resulting from abuses of other processing methods, such as canning, freezing and pasteurization".

The conclusions reached by the World Health Organization, a specialized agency of the United Nations with primary responsibility for international health matters and public health, will instil confidence in the consuming public, regarding the safety and nutritional adequacy of irradiated foods.

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***Food Packaging and Preservation* : Edited by M. Mathlouthi, Published by Blackie Academic and Professional, an imprint of Chapman and Hall, Western Cleddens Road, Bishopbriggs, Glasgow G642 NZ, U.K., 1994, pp. 275. Price : £ 69/-**

This book under review provides an up-to-date overview of important and rapidly growing area of food packaging and preservation. This book, which contains thirteen chapters, is aimed at dealing with the multi-disciplinary speciality of food packaging more as science. It discusses various aspects of packaging materials in relation to food packaging. This includes permeability characteristics of plastic packaging materials, interaction between plastics and food involving food flavours and migration of plastic constituents into food, problems of recycling, reuse and disposability of the materials, which are posing problems of environmental pollution. This book partly includes papers presented at a symposium on "Food packaging interactions and packaging disposability", held at the International Food Technology Exposition and Conference, during 15-18 November 1992, at Haag, The Netherlands.

The first chapter deals with permeability and structure of polymeric packaging materials, and gives details on basic principles, experimental techniques and parameters affecting permeability. Chapter two deals with migratory aspects of testing plastics, using alternate fatty food simulants. Principles of migration and comparison of results from migration measurements into fats, oils and fat simulants, using plastics like polyolefins, polyvinyl chloride, polystyrene etc. are being dealt.

Topic of food flavour and packaging interactions comprising absorption of flavour compounds and flavour changes in plastic packaging materials is dealt in chapter three. Microwavability of packaged foods, comprising details on microwave heating, microovens, packaging materials, shape and size and monitored microwave heating is discussed in chapter four. Similarly, effect of irradiation of polymeric packaging materials with and without food simulating solvents, kinetics of degradation, experimental methods, and materials to study the effect of irradiation are discussed in chapter five.

Water activity sorption behaviour and shelf-life of cheeses and effect of package coating with hydrosorbentpolymers on shelf-life, conventional packages and their improvement are discussed in chapter six. Use of trehalose, as food volatile preserving additive is the topic of discussion in chapter seven.

Current topic of importance on packaging of fruits and vegetables with reference to modified atmosphere packaging (MAP), is dealt in chapter eight. The type of films used in MAP, and influence of MAP on respiratory activity, ethylene synthesis, chemical composition, the organoleptic quality of products and also factors such as temperature, RH and light affecting MAP storage are briefly discussed. Another important current topic on "Technology and properties of edible and bio-degradable materials" comprising microbial polymers (polyesters), synthetic polymer/biopolymer mixture and polymers of agricultural origin (flours, starches, proteins) are discussed in chapter nine. Further, details on properties such as organoleptic, mechanical, water/lipid solubility and barrier properties of the above bio-packaging materials and also their application are given. Similarly, chapter ten deals with biosynthesis of poly (3 hydroxy butyrate) i.e., PHB and poly (3 hydroxy alkanoates) i.e., PHA which belong to group of biopolymers, which have great potential in future years in view of non-biodegradaility of conventional petro-chemical-based plastics. A general overview on biosynthesis pathways of forming PHA, the fermentative production of PHA, the polymeric properties and biodegradability and some applications of PHA is given. Potential use of biopol (trade name of PHB polymer) as bottles, mouldings-films, fibres, non-woven fabric and as coating on to paper are indicated.

Chapter eleven deals with NMR imaging of packaged foods, wherein principles of NMR imaging and its measurement are discussed. Current burning topic of recycling, reuse and disposal of food packaging materials has been briefly discussed in chapter twelve. Recycling schemes in the UK for metal, plastic, paper/board and glass are described. Role of environmental pressure groups, such as friends of earth (FOE), women's environmental net work (WEN) and Industrial bodies such as ReCOUP (Recycling of used plastic containers Ltd.), and INCPEN (The industry committee for packaging and the environment) on recycling and reuse of plastics are discussed. Also, details on legislation, recycling symbols, life cycle analysis (LCA) are provided.

Chapter thirteen presents an up-to-date review on the shelf-life of milk and dairy products. In this chapter, effects of physico-chemical parameters, such as emission spectra of sunlight, fluorescent tubes and light transmission of packaging materials are discussed. Also, effects of light exposure on milk, yoghurt and butter specially on vitamin (riboflavin), proteins, free amino acids, on peroxide formation and colour are touched upon. Further, photodegradation mechanism, effects of processing on the photosensitivity of milk products are highlighted. Intrinsic factors, such as composition, pH redox potential and extrinsic factors, such as light intensity and exposure, degree of transmittance, temperature and oxygen permeability of packaging materials involved in shelf-life of dairy products are also discussed.

An important feature of this book is presentation of conclusions and inclusion of important and nascent references at the end of each chapter. The authors have attempted to bring out newer developments in the field. New trends, such as microwavability of packaged foods. migratory aspects, biopolymers and their application, recycling, reuse and disposability of plastic materials, NMR imaging of packaged foods, and permeability characteristics in relation to shelf-life are dealt in lucid manner. Topics on MAP of fruits and vegetables, cheeses, and dairy products are useful in achieving increased shelf-life. Researchers in the field of food packaging will find the subject matter of this book timely and representative of the best work in the field. It is a very useful addition to food technology library, and serves the interests of food and packaging scientists/technologists.

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***Primary Cereal Processing:* A comprehensive source book, edited by Bernard Godon and Claude Willm, Published jointly by VCH Publishers, Inc., 220 East 23rd Street, New York, 10010, VCH Verlagsgesellschaft mbH, P.O. Box 101161, 69451, Weinheim, Germany and VCH Publishers (UK) Ltd., 8 Wellington Court, Cambridge CBI 1HZ, U.K., 1994, pp 544, Price : DM 234/-**

This excellent book titled "Primary cereal processing" starts with the chapter "History and ethnology of the industries of primary processing and traces the origins: human and animal strengths", using the forces of nature, rudiments, improvement of the millstones and the evolution of livestock feed industries. Chapter two addresses on the "Economic equilibrium and dynamism" and deals with the scenario of wheat milling industry, the starch, the malt and the 'durum' wheat semolina industries with French experiences.

Next chapter, "Legislative aspects" enumerates the objective of the European Economic Community treaty, which was to establish a common market, functions and obligations of contracting states, quotas and their transfer, and purchase of milling rights. The chapter on "Biochemical composition of cereals" covers general grain characteristics like external appearance, chemical composition, histological variations in grain composition of oats, wheat, maize, barley, rye, triticale and rice. The subsequent, chapters deal with "Physical characteristics of grains", "Microbiology of cereals and flours", "Contaminants originating from cereal insects and acarids" and consequences of entomological cereal contamination. The following few chapters cover the milling techniques for wheat, maize and rice. The major topics concern milling value of wheat, break roll mill performances and evolution of milling terminologies of plan sifter, bolting and purification along with air classification.

The chapter on "The blending of powdery matter" discusses in detail the theoretical aspects behind solid mixing, including parameters of the mix, demixing and controlling the homogeneity of a mix and predicting its stability. Chapter on "Dry milling presents milling diagrams along with quality aspects of soft wheat milling. In the chapter on "Hard wheat milling", the reader is given the opportunity to learn about the semolina industry's origin, specific problems, along with new needs requiring fulfilment, due to the greater collaboration between semolina mills and the pasta-making industries. Other milling subjects covered are "Dry and wet milling of maize" and "Processing of rice." In the chapter on "Handling, packing and transport of finished products", main principles and machines are dealt with, both for mechanical and pneumatic handling. General principles concerning explosion hazards, preventive methods and advice concerning the set of industries and their maintenance form the salient issues of the subsequent chapter. Other chapters deal with 'Automation', 'Computerization', 'Flour ageing', 'Defining flour quality according to its use', 'Additives for improving flour quality for specific bakery products' and a general topic on 'Primary cereal processing in developing countries.'

The book is well written with Figures, and Tables. The book is recommended to practising cereal, food and feed technologists, food processors and engineers, R&D scientists and students.

This book will be a valuble addition to the libraries.

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Statement about ownership and other particulars
of the periodical entitled

JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

as required to be published under Rule 8 of
the Registration of Newspapers (Central) Rules 1956.

FORM IV

1.	Place of Publication :	...	Mysore
2.	Periodicity of the Publication	...	Bimonthly
3.	Printer's Name	...	Shri Shivakumar Jwalamukhi Job Press Bangalore-560 004.
4.	Publisher's Name	...	Dr. K. Udaya Sankar [for and on behalf of Association of Food Scientists and Technologists (India)]
	Nationality	...	Indian
	Address	...	Central Food Technological Research Institute, Mysore-570 013
5.	Editor's Name	...	Dr. B.K. Lonsane
	Nationality	...	Indian
	Address	...	Central Food Technological Research Institute, Mysore-570 013

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INDIAN FOOD INDUSTRY

A Publication of Association of Food Scientists and Technologists (India)

Contents of March - April 1995 issue

Reg. No. 24918/64

Published by the Secretary AFST (India) CFTRI, Mysore-570 013 and Printed at
M/s. Jwalamukhi Job Press, 44/1, K.R. Road, Bangalore-560 004, India.