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EDITORIAL

In 1986, a new section was introduced in the Journal of Food Processing and Preservation entitled "Computer Codes and Applications." In Issue 1, Volume 11 (1987), we will have our first "Data Bank" paper. We look forward to receiving papers for both of these sections in 1987.

The quality of a Journal is as good as its Editorial Board and its reviewers. I would like to thank the Editorial Board for its services this last year. Continuing on the Editorial Board are W. Breene, F.F. Busta, J.N. Cash, O. Fennema, T.P. Labuza, B.G. Swanson, K.R. Swartzel and R. Villota. Appointed to new three year terms on the Editorial Board are M. Karel, R.T. Toledo, R.W. Wrolstad and L. Satterlee. Rotating off the board is G. Reineccius. I want to thank Gary for his years of service on the board. I also want to thank the following who have served as reviewers for papers for Volume 10:

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DARYL LUND, EDITOR

CONTENTS

STEEPING OF WHOLE AND DRY MILLED MAIZE KERNELS IN OGI PREPARATION

J.O. AKINGBALA[1], E.U. ONOCHIE[2], I.A. ADEYEMI[3] and G.B. OGUNTIMEIN[1]

[1]*Food Technology Department,*
University of Ibadan,
Ibadan, Nigeria

[2]*National Youth Corps Service at Akure*
[3]*Food Technology Department,*
University of Ife, Ile Ife, Nigeria

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ABSTRACT

Ogi was prepared by steeping whole kernels and dry milled flour in water for 72 and 18 h, respectively. Steeped maize and mash were wet milled, sieved and sedimented.

Yields of ogi by the two methods was not different ($P \leq 0.01$). The pH decreased more rapidly in the steep of whole maize than in the steep of milled maize although a lower ultimate pH was obtained for steep of milled maize. More protein was recovered in ogi from steeped whole maize than in ogi from steeped dry milled maize. However, more fiber and lipid was recovered in ogi from the dry milled than in ogi from steeped whole maize. There was no difference in ash concentrations of ogi after the two methods of processing. Apparent pasting viscosity, viscosity at 92 °C, setback viscosity, and stability of the hot and cold pastes were greater in ogi from steeped whole maize than in ogi from dry milled maize.

Steeping of maize before milling is a better method of ogi preparation because it produced ogi with better porridge and stiff gel properties and also better nutrient composition than steeping of dry milled maize.

INTRODUCTION

Ogi is a starchy endosperm extract of fermented cereal grains, also known as akamu by the Hausas of Nigeria, Mahewu or Kenkey by the Bantus of Ghana. Ogi is cooked into a hot porridge called eko or akamu, or a solid gel called agidi or kafa (Akingbala *et al.* 1981).

[1]All correspondence should be sent to: Dr. J.O. Akingbala, Food Technology Department, University of Ibadan, Ibadan, Nigeria.

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The traditional process of making ogi has many slight variations (Banigo and Muller 1972; Akingbala *et al.* 1981; Akinrele 1970; Oke 1967 and Banigo and Adeyemi 1975). Maize, sorghum, millet or rice is steeped in water for two to three days to soften. The soft grain is ground on a grinding stone or pounded in a mortar with a pestle. The bran is sieved away from the endosperm with plenty of water. The ogi sediments, and the wash water may be decanted or left on for one or two days to ferment the ogi.

With the availability of power mills to grind grain for ogi, the long steeping period before milling no longer appears necessary and commercial ogi makers have reduced the steep time before milling. One method of reducing steep time involves steeping maize in hot water to softness prior to milling (Banigo and Adeyemi 1975).

Fermentation of grain gives ogi its flavor (Banigo and Muller 1972) and improves nutritional quality (Umoh and Fields 1981; Hamad and Fields 1979a and 1979b; Kanzanas and Fields 1981). Banigo and Muller (1972) added lactic acid to corn flour to simulate the sour taste of ogi. However, lactic acid addition did not give the required flavor nor improve the nutritional quality of ogi protein.

Umoh and Fields (1981) and Adeyemi (1983) fermented dry milled maize for Nigerian adidi, and dry milled sorghum for ogi manufacture, respectively. However, these authors did not relate whether the milling before steeping of maize or sorghum affected the rate of pH fall. The objective of this study is to evaluate the effect of milling maize before steeping on the rate of pH fall and the overall quality of ogi.

MATERIALS AND METHODS

The maize variety, FARZ 34 used in this study was supplied by the National Cereals Research Institute, Ibadan. The maize was cleaned, packed in polythene bags and stored under ambient temperature (28 to 30 °C).

Ogi was prepared by steeping 100 g whole maize in 200 mL water for 72 h decanting the steep water, and blending the maize in a Waring Blender with 200 mL water for 4 min. The blended mixture was sieved through a U.S. number 45 standard sieve (355 μm) using 600 mL of water to separate the throughs from the tail. The throughs were left to sediment overnight before the wash water was decanted (Fig. 1).

Ogi was also prepared from dry milled maize. Maize was milled in a hammermill to pass through a 600 μm screen. The dry milled maize (100 g) was steeped in 200 mL of water for 18 h. Two hundred milliliters of water was added to the mash before blending in a Waring Blendor for 2 min. Ogi was washed off the bran through a U.S. number 45 standard sieve with 600 mL water and allowed to sediment overnight before the wash water was decanted (Fig. 2).

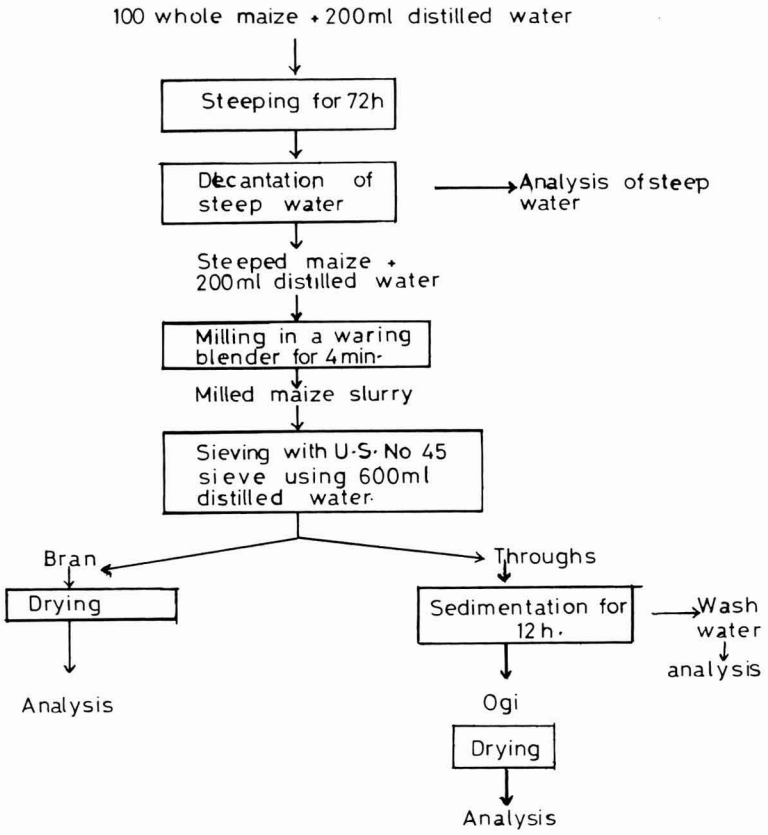

FIG. 1.
LABORATORY PREPARATION OF OGI FROM WHOLE MAIZE KERNELS

The total solids in decanted steep and wash water was determined by drying a 50 mL aliquot at 130 °C for 2 h and expressed as percentage of the dry weight of the steeped maize. Recovery of ogi and bran were determined by drying a 2 g subsample in the forced air oven at 130 °C for 2h to determine moisture content. Results were expressed on dry weight basis. The pH of the steep of whole grain and mash was determined at the onset of steeping, and at 6, 12, 24, 36, 48, 60 and 72 h with a Matrohm Herisan pH meter E520.

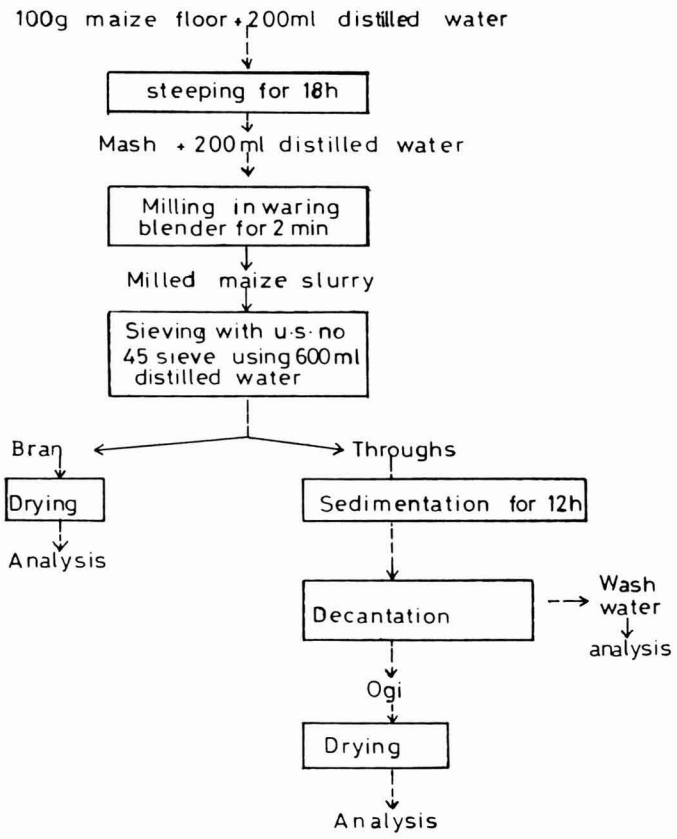

FIG. 2.
LABORATORY PREPARATION OF OGI FROM DRY MILLED MAIZE FLOUR

Proximate Chemical Analyses

Proximate analysis of maize, ogi and bran was determined. Moisture, ether extract and ash were determined according to AACC (1976). Nitrogen was assayed semi-automatically in a Tecator Kjeltec system and converted to crude protein by multiplying by 6.25 (AACC 1962). Crude fiber was determined using the Tecator Fibertec system (AACC 1962). Nitrogen free extract (NFE) was calculated by difference. Apparent viscosity of cooking ogi paste was observed with a Brabender Viscoamylograph using a large (450 mL) bowl and a 350 cg sensitivity cartridge. A maize starch (BDH Laboratory Reagents, BDH Chemical Ltd., Poole, England) was run as comparison.

RESULTS AND DISCUSSION

The yields of ogi, bran, steep and wash water solids from the two methods of ogi preparation is presented in Table 1. About 5.5 and 8.3% of the maize was not accounted for in dry milled and wet milled methods of ogi preparation, respectively. Yields of bran was reduced, when ogi was prepared by steeping maize flour as compared to steeping whole grain. The reduced yield is probably because the dry milled grain was also wet milled, and the double grinding incorporated some of the bran into the ogi. However, the difference in the recovery of the bran was not reflected in the yield of ogi which was similar for the two methods. Similarity in ogi yields may have been caused by the greater loss of maize as solubles in the wash water of the dry milled maize. Particles of maize remained in colloidal suspension in wash water of dry milled maize, even after the wash water was allowed to sediment overnight. The wash water of ogi from steeped whole maize was clear after sedimenting overnight. There was no loss in steep water solids in the dry milled maize because the flour absorbed all steep water. Steep water solid losses from the whole grain was also negligible.

Table 1. Mean[1,2] yields of ogi, bran and solids

	Ogi	Bran	Steep[3] Water Solids	Wash Water Solids	Total
Milled maize	79.8±1.2	6.5±0.9	N.A.[4]	8.7±1.5	94.5
Whole maize	79.1±1.5	8.0±0.8	0.3±0.0	4.3±0.6	91.7

1. All means are expressed as percentage dry weight of maize.
2. Means of 9 replicates
3. Steep water was absorbed by steeped dry milled maize and was not decanted.
4. Not applicable (N.A.)

Proximate Chemical Composition of Maize, Ogi and Bran

Ogi from steeped whole grain had a greater percentage of protein than ogi from dry milled maize (Table 2). Bran from steeped whole maize had a greater protein content than bran from dry milled maize. Mild acidity developed during steeping may predispose exposed protein bodies of the dry milled maize to solubilization and loss as soluble protein in the wash water. Protein recovery from the ogi and bran of steeped whole maize was 74%, while 65% protein was recovered from ogi and bran from the dry milled method. Protein losses of up to 40% during the processing of maize to ogi were reported by Oke (1967).

Table 2. Mean[1] proximate composition[2] of maize, ogi and bran

	PROTEIN	ETHER EXTRACT	ASH	CRUDE FIBER	NITROGEN FREE EXTRACT
Maize	11.6±0.1	4.5±0.1	1.3±0.0	2.6±0.0	80.0
Ogi dry milled maize	8.8±0.9	2.3±0.2	0.6±0.1	2.1±0.4	85.3
Ogi whole maize	9.7±0.0	2.0±0.0	0.6±0.1	1.1±0.3	87.6
Bran dry milled maize	8.7±0.9	1.0±0.0	0.7±0.1	14.1±0.2	75.5
Bran whole maize	11.5±0.5	0.5±0.0	0.7±0.1	16.3±0.2	70.9

1. Means are percentage dry weight of maize, ogi and bran, respectively.
2. Proximate composition are means of 9 replicates three duplicate/replicate.

The oil content of maize was 4.5% and agrees with values generally reported for maize (Oke 1967; Banigo and Muller 1972b). Ogi from dry milled maize had a slightly greater oil content than ogi from steeped whole maize while the oil content of the bran from dry milled maize was about twice the amount of the steeped whole maize. The greater oil content of ogi from dry milled maize may be due to lipids from the germ binding to the endosperm during dry milling of maize. The germ of steeped whole maize may have been tempered and plasticized during steeping and removed as bran. The greater oil content of ogi from dry milled maize may predispose the ogi to rancidity during dry storage. Recovery of oil in ogi bran dry milled maize was 40.8 compared to 35.2% in ogi from steeped whole maize, and 1.4 compared to about 1% from steeped whole maize, and 1.4 compared to about 1% for respective bran fractions, indicating a loss of oils of over 50% during ogi processing. Oke (1967) reported a 25% loss of oil during processing of maize into ogi.

Thirty seven percent of the ash in the maize was recovered in ogi, while 4.8 and 4.4% was retained in brans from the dry milled and the steeped whole maize methods, respectively. The ash contents of ogi and bran from the two methods of processing ogi were not significantly different. More crude fiber was retained in ogi from maize dry milled before steeping than from steeped whole maize while the reverse is true for their respective bran fractions. Incorporation of a greater quantity of bran should increase the yield of ogi from the dry milled over the

yield of ogi from the wet milled whole maize. However there was no significant difference in ogi yields of the two methods of ogi processing because of greater amounts of solid losses in steeped dry milled maize over steeped whole maize. The difference in the nitrogen free extract (NFE) of ogi prepared from dry milled and whole maize was not significant (Table 2). The NFE was the only component present in ogi in greater quantities than in the origincal maize. Concentration of endosperm material in ogi through losses of other components during processing increased the NFE content of ogi above that of the maize grain.

pH of Fermenting Steep

The pH of whole maize steep decreased sharply from 6.3 to 4.6 after 12 h and increased gradually till it reached a pH of 4.8 after 72 h steeping (Fig. 3). Similar trends of sharp initial decrease in pH within the first 24 h of steeping, and gradual decrease in pH were reported by Akingbala *et al.* (1981), Banigo and Muller (1972a) and Fields *et al.* (1981). Wagoner (1948), reported that steeping maize longer than 24 h resulted in the solubilization of the protein matrix. Banigo and Muller (1972a,b) contend that the subsequent increase in pH, might be due to the buffering action of solubilization of the proteins and that fermentation of maize into ogi is mainly a lactic acid fermentation. Akinrele (1970), isolated *Cornybacterium sp. Aerobacter clocae Lactobacillus plantarum, Candida mycoderma, Saccharomyces cervisiae* and *Rhodotorula* from fermenting maize mash. These microorganisms may be responsible for the observed decrease in pH of the maize steep.

The pH of dry milled maize steep did not decrease as fast as observed for steep of the whole maize. Milling the grain may have exposed the endosperm matrix protein and dislodged some of the protein bodies into the steep. The buffering effects of proteins may have been responsible for the initial pH, lag in pH of the fermenting mash. However, after the initial pH lag phase, pH of steep decreased at a fast rate to 4.1 after 24 h steeping and thereafter a more gradual reduction of pH to 3.6 at 72 h was observed. The final pH of the dry milled maize steep may be due to a greater availability of starch substrate to the fermenting microorganisms through the greater surface area of the exposed starchy endosperm (Banigo and Muller 1972a). Banigo and Muller (1972a) reported a significant correlation between acidity and acceptability of maize ogi by a taste panel and set maximum acceptability pH of ogi at 3.7.

Brabender Amylograph Paste Viscosities

Paste viscosities of standard maize starch and ogi are presented in Table 3. The apparent pasting temperatures in the ogi prepared by the two methods of processing ogi were not significantly different. However, the apparent pasting temperature of ogi was greater than observed for the standard maize starch, due

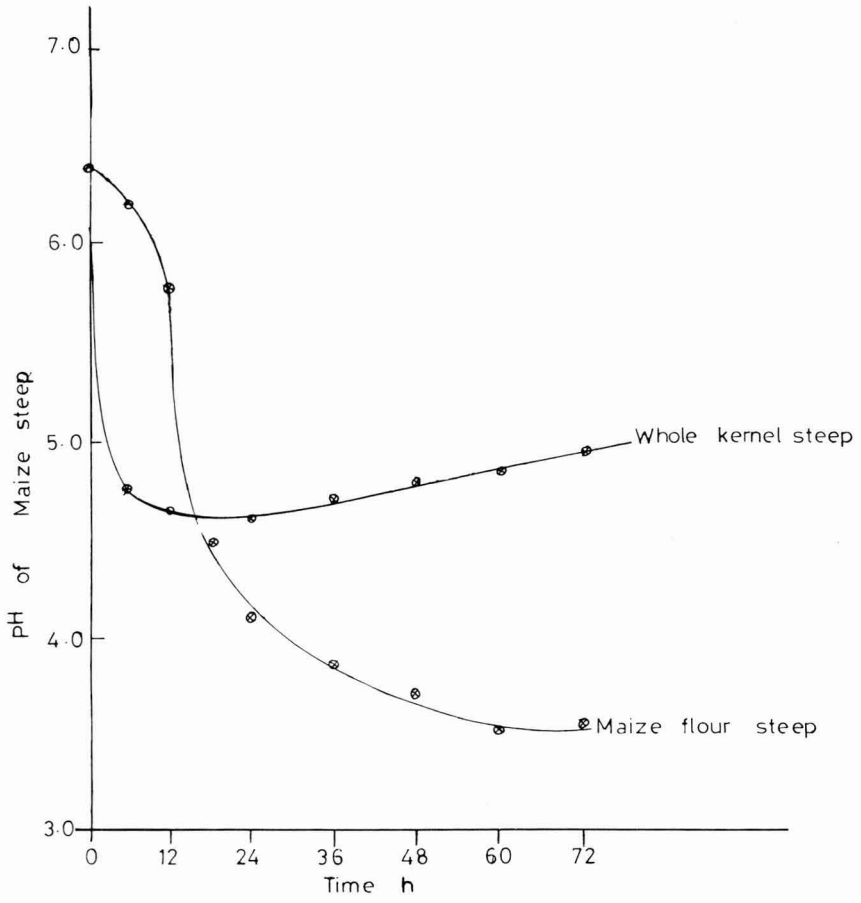

FIG. 3.
pH PROFILES OF FERMENTING WHOLE MAIZE AND DRY MILLED MAIZE, STEEPS

to the amount of starch damage from acid hydrolysis during fermentation of the maize to ogi (Akingbala *et al.* 1981) and the smaller concentration of starch in ogi compared to maize starch. The apparent pasting and setback viscosities as well as stability of the hot and cold paste towards shearing was smaller in ogi from the dry milled than in ogi from steeped whole maize. Greater damage may have occured to the maize starch during dry milling. Greater exposure of the endosperm to hydrolytic enzymes of the fermenting microorganisms and a greater amount of fiber and oil in ogi may have reduced the viscosity observed in ogi from dry milled maize compared to viscosities of ogi from steeped whole maize.

Table 3. Mean[1] paste viscosities of standard maize starch, and ogi[2]

SAMPLE	APPARENT GELATINIZATION TEMPERATURE °C	APPARENT PASTE VISCOSITIES (BU)[3]				
		PEAK	AT 92°C	15 min at 92°C	At 50°C	15 min at 50°C
Standard maize starch	67.8	960	880	640	1560	1600
Ogi milled maize	77.3	450	360	370	920	N.A.[4]
Ogi whole maize	77.1	510	490	450	1630	1830

1. Data are means of 2 replicates
2. Concentration 8% on dry weight basis
3. Brabender units, (BU)
4. Not available (N.A.)

CONCLUSION

Ogi was prepared by steeping whole maize kernels for 72 h before wet milling and wet seiving, and by dry milling the maize before steeping for 18 h and wet sieving. Yields and proximate composition of ogi prepared by the two methods were similar. However, protein content of ogi from steeped whole maize was greater than the protein content of ogi from dry milled maize. Fermentation was faster in the steep of whole compared to the steep of dry milled maize, although the ultimate pH of steep of whole maize was greater than the ultimate pH of dry milled maize steep.

Texture of the finished product, either as eko, the porridge, or adigi, the firm paste, is the single most important index of acceptability of ogi. Ogi prepared from steeped whole maize had greater pasting and setback viscosities which are desirable properties of eko and adigi, respectively. Therefore, preparation of ogi by the traditional method of steeping whole maize with a reduction of steeping time to 12 h when the most acidic pH was observed may be more desirable than dry milling the grain before steeping.

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PASTE PROPERTIES OF SORGHUM FLOUR AND STARCHES

J.O. AKINGBALA

Department of Food Technology
University of Ibadan
Ibadan, Nigeria

and

LLOYD W. ROONEY

Soil and Crop Science Department
Cereal Quality Laboratory
Texas A&M University,
College Station, Texas 77843

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ABSTRACT

The paste properties of sorghum starch and flour were measured. Mean swelling power and solubility of starch showed significant varietal differences that were highly correlated with the amylose content of the varieties. There was a significant difference in means of the apparent gelatinization temperatures of starch from sorghums grown in different years. The mean apparent gelatinization temperature of sorghum flours was 10°C greater than observed for sorghum starch and was dependent on the particle size of the flour. Apparent peak pasting viscosity of waxy starch was greater than that of the nonwaxy. However the apparent peak pasting viscosity of the nonwaxy flour was greater than that of the waxy. Apparent viscosities were greater for pastes from smaller than larger flour particles in both acid and alkali pHs.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. (Moench)) grows in the tropics, semi tropics and arid areas of the world (Vogel and Graham 1978). The grain provides a substantial amount of the caloric intake for the people of Asia and Africa where it is used for food and beer (Swaninathan 1971; Doggett 1970).

[1]All correspondence should be sent to: Dr. J.O. Akingbala, Food Technology Department, University of Ibadan, Ibadan, Nigeria.

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Textural, eating and storage quality of sorghum food products may be attributes of its flour and starch paste. Therefore it is important that we study these properties as means of selection for sorghum food quality.

Several methods have been used to measure and predict the cooking and paste properties of sorghum starches and flour. Otterbacher and Kite (1958) used the amylograph to measure apparent viscosities of sorghum starches. Others (Leach *et al.* 1959, Elder and Schoch 1959, Schoch 1965, Akingbala *et al.* 1981), have used the amylograph to measure the paste properties of sorghum starches and predict the use of the flour in foods. Scheuring 1977, using the amylograph to measure sorghum starch viscosities, reported that waxy sorghums are unsuitable for making tô, a traditional African stiff paste food.

This study was conducted to examine the pasting properties of flour and starch of some sorghum varieties selected by the International Crop Research Institute for the Semi Arid Tropics (ICRISAT) Hyderabad, India, for International Food Quality Trial (IFQT), as a means of predicting the texture and storage properties of food from these sorghums.

MATERIAL AND METHODS

Sorghum Samples

Sorghum samples evaluated in this study include 25 varieties selected for International Food Quality Trials by ICRISAT. The grain was grown in ICRISAT plots, Hyderabad, India in the post rainy seasons of 1979 and 1980. Sorghum variety S29 and variety 940 grown at the ICRISAT center, Kamboinse, Upper Volta, were included.

Starch Isolation

The wet milling procedure of Norris and Rooney (1970) was used in isolating starch from the sorghum samples. After isolation and purification, the pure starch, containing less than 0.3% protein was dried overnight in a forced air oven at 16 °C. Amylose content of starch was determined by the method of Webb (1972) as modified by Ring *et al.* (1981).

Flour

Sorghum (100 g) was pearled in a Strong Scott barley pearler for 60 s and then reduced to flour in a laboratory hammermill fitted with a 0.61mm screen. Flour was sieved through U.S. numbers 60 and 80 standard screens. A brush was used to move the flour over the screens to prevent matting and ensure complete separation of overs and throughs. The overs of U.S. No. 60 and the throughs of the number 80 standard screens were collected.

Swelling Power

Measurement of the swelling power and solubility of starch was conducted as described by Leach *et al.* (1959), modified for small samples. Starch (0.3g) was weighed into a 40 mL glass centrifuge tube with screw cap. Exactly 30 mL distilled water was added from a burette and the tube was shaken in a water bath at preset temperatures (60, 65, 70, 75, 80 and 90 °C) at a rate that kept the starch particles suspended. Shaking was for 30 min with gentle manual swirling of the tube at 10 min intervals to ensure complete suspension of the particles. At the end of 30 min shaking, the tube was centrifuged at 2200 rpm for 7 min. The supernatant was carefully decanted into a 100 flask, filled to volume, a 20 mL aliquot was pipetted into an aluminum weighing dish, and dried at 130 °C for 3 h. The weight of the solubles and weight of the paste in the tube were determined. Starch swelling power and solubility was calculated using the formula by Leach *et al.* (1959).

Amylogram

The Brabender visco/amylo/graph (Type VAV, model 3042 G.W. Brabender Instruments, Inc., 50 H. Wesley St., South Hackensack, NJ) was used to measure apparent viscosities of starch and flour. A 10% (dwb) starch slurry (4 g starch in 40 mL of distilled water) was cooked in a small amylograph bowl rotating at 75 rpm using 125 cg· sensitivity catridge to measure apparent viscosity in Brabender units (B.U.). A 12% (4.8g flour on dry weight basis in 40 mL H_2O) slurry of sorghum flour, the overs of number 60 and the throughs of number 80 U.S. standard sieves flour fractions were cooked similarly.

RESULTS AND DISCUSSION

The mean swelling power and solubility at 80 °C of starches from 1979 IFQT sorghum samples are presented in Table 1. There were significant differences in the swelling power and solubility of these starches. The starch swelling power was highly correlated with solubility ($r=0.80$). Both swelling power and solubility were highly negatively correlated with amylose content of the starches ($r=0.93$ and -0.73, respectively). This was in agreement with the reports of Schoch (1969), Elder and Schoch (1959) and Leach (1965). Elder and Schoch (1959) postulated that amylose reinforces the molecular network within a starch granule thereby preventing starch solubilization and swelling.

Swelling and solubilization properties of starch from sorghum varieties S29 and 940 were evaluated to determine whether differences observed in the stiffness of tô (an African stiff porridge food) prepared from these sorghums (ICRISAT 1977), were due to differences in the swelling and solubility patterns of the starches (Fig. 1 and 2). Starch from the two sorghums exhibited the two-stage swelling pattern observed in corn and sorghum starches by Leach 1965,

Table 1. Mean swelling power and solubility properties of starches from 1979 IFQT sorghums

	Swelling power[1]	Solubility[2]	Amylose%[3]
Nonwaxy	12.6±0.5	7.6±1.2	23.3±1.1
Range	11.6 to 13.3	4.7 to 10.1	21.5 to 25.7
a = 24			
Waxy	22.5±2.2	14.9±1.1	4.5
a = 1			

1. Swelling power was determined at 80 °C.
2. Solubility was determined at 80 °C.
3. Amylose was measured as percent of pure isolated starch on dry weight basis.

Elder and Schoch 1959, and Schoch 1969. The starch from sorghum variety S29 had greater solubility and swelling power than starch from variety 940 at 90 °C. This probably explains why tô made from S29 flour was firmer than that from variety 940 flour (ICRISAT 1977). Efforts to measure swelling power and solubilities of these starches at 95 and 98 °C, were unsuccessful because of difficulties in keeping these temperatures constant. Also the starch water mixture formed a floculate at these temperatures which could not be easily and completely separated by centrifuging.

Apparent Gelatinization Temperature

A summary of the Brabender visco/amylo/graph properties of 1979 and 1980 IFQT sorghum flour and starches is presented in Table 2. The apparent gelatinization temperature of the 1979 IFQT nonwaxy sorghum starches ranged from 58.5 to 77.5 with a mean of 74.6 °C and was significantly higher than that of 1980 nonwaxy starches with a range of 70.0 to 73.4 and a mean of 71.9 °C. The apparent gelatinization temperature of the waxy starch was within the range of temperatures observed for the nonwaxy starches.

The mean apparent gelatinization temperatures of nonwaxy sorghum flours was about 10 °C higher than that of the starches (Table 2). The higher apparent gelatinization temperatures may have been due to restrictions on the swelling of starch granules by the cell walls and endosperm protein matrix of the flour. Also the flour particles have greater size than the starch granules and thus will require more heat energy to paste. Wada *et al.* (1979) reported that the gelatinization temperature of unisolated starch was higher than that of the isolated starch.

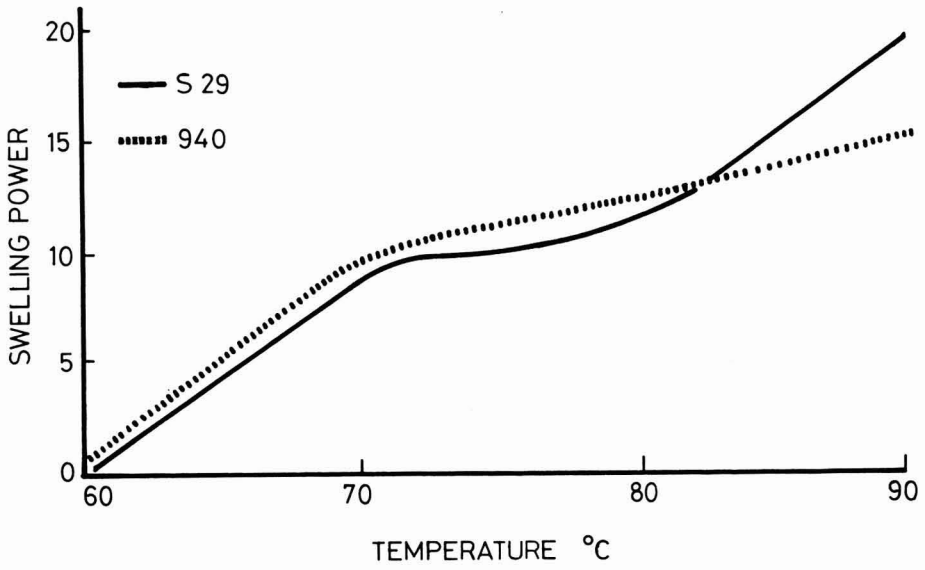

FIG. 1.
SWELLING POWER OF STARCHES OF S29 AND 940 SORGHUM VARIETIES

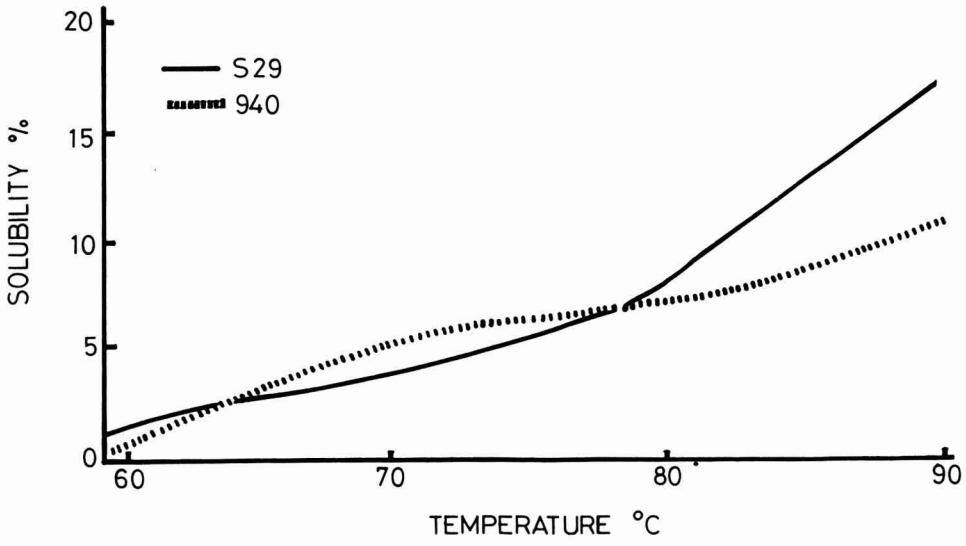

FIG. 2.
SOLUBILITY OF STARCHES OF S29 AND 940 SORGHUM VARIETIES

Table 2. Mean* visco/amylo/graph properties[1] of starches and flours of 1979 and 1980 IFQT sorghums

Samples	Apparent gelatinization temp (°C)	Apparent Pasting Viscosities (BU)[2] Peak	1 hr at 95°C	1 hr at 50°C	1 hr at 50°C
1979 Nonwaxy IFQT Starches	74.6±1.9	957±129	488±85	818±137	896±127
n = 24 Range	68.5 to 77.5	750 to 1170	390 to 675	610 to 1030	700 to 1130
Waxy starch		1000	285	355	355
1980 Nonwaxy IFQT Starches	71.9±0.9	788±78	430±55	930±153	1323±265
n=24 Range	70.0 to 73.4	640 to 970	320 to 520	675 to 1250	780 to 1915
Waxy starch	69.0	1000	295	485	450
1979 Nonwaxy IFQT	85.8±3.4	322±139	273±59	684±154	591±115
n = 19 Range	76.8 to 88.8	100 to 634	100 to 435	380 to 965	360 to 845
Waxy Flour	79.0	145	70	145	160
1980 Nonwaxy IFQT Flours	81.2±3.8	504±110	351±52	939±124	743±62
n = 24 Range	76.0 to 88.0	265 to 720	240 to 410	780 to 1280	620 to 925
Waxy flour	71.5	205	115	185	175

[1]Visco/amylo/graph properties were for a 10% and 12% starch and flour respectively, on dry weight basis
[2]Apparent viscosities were measured in Brabender units (B.U.)

Some heat may have been required to raise the temperature of the nonstarch fractons in the flour as it is cooked which might translate into higher apparent gelatinization temperature for sorghum flour over starch. Varietal differences in the apparent gelatinization temperatures of starch and flour may be due to differences in starch and amylose contents and the mean particle sizes of the flours (Akingbala 1982).

The apparent peak viscosity of the starches from 1980 nonwaxy sorghum samples ranged from 640 to 970 BU, while that of the waxy variety (IS158) was over 1000 BU (Table 2). This was as expected since free swelling waxy starch has a greater swelling capacity than free swelling nonwaxy starch. Several investigators (Schoch 1965; Sandstedt *et al.* 1968; Leach *et al.* 1959) have reported that waxy starches have higher pasting viscosities than nonwaxy. This might be due to restriction of the amylose fraction on the free swelling of a nonwaxy starch granule. The peak viscosity of the waxy flour was lower than the mean of the nonwaxy flours (Table 2). This probably relates to differences in the swelling properties of waxy and nonwaxy starches encased by cell walls and protein matrices. It appears that the nonwaxy starch exerts a greater force on cell walls and protein matrix than the waxy during swelling of the flour particle. This may be due to the reinforcing action of amylose on the structure of nonwaxy starch granules (Leach 1965; Schoch 1965). Thus the waxy starch flour exhibited a lower apparent viscosity than the nonwaxy throughout the amylograph cooking curve.

Effect of Environment on Paste Properties

Amylograph properties of starch and flour from 1979 and 1980 IFQT sorghums were compared (Table 2). The mean apparent gelatinization temperature, peak viscosity, setback viscosity, and stability of starch pastes from these sorghums were significantly different in the 1979 and 1980 crops. Ring *et al.* (1981) reported that amylose content of starch from the 1980 IFQT sorghums was significantly greater than amylose content the 1979 sorghum starch and observed that environment may have affected the amylose content of the sorghum starches. Freeman *et al.* (1963) also observed differences in the gelatinization temperature of starch from sorghums grown in different environments. The lower mean peak viscosity and hot paste viscosity, and the greater set-back and cold paste viscosities of the 1980 over the 1979 IFQT sorghum starches are in agreement with Schoch's (1965) explanation that amylose restricts swelling and reinforces setback or retrogradation in starch pastes.

Effect of Flour Particle Size on Paste Properties

It appears from the amylograms that the size of the aggregate particles in the sorghum flour affected the viscosity of the paste significantly. The apparent gelatinization temperature was greater for flour of larger than of smaller particles. This would be expected as more heat energy would be required to paste the larger than the smaller flour particles. Flours of similar particle sizes have similar apparent gelatinization temperatures e.g., the apparent gelatinization temperature of flours of P721, CSHS and E351 varieties with particles smaller than 117μ (throughs of number 80 U.S. standard sieve) was not significantly different. Also the apparent gelatinization temperatures of the coarse flours (overs of number 60 U.S. standard sieve) in Table 3, was not different.

Differences in the peak viscosities of coarse and fine flours may be due to differences in the amount of flour particles that were pasted. The peak viscosity of the coarse flour was significantly lower than that of the fine flour at 95 °C. However, under prolonged heating condition (heating at 95 °C for 1 h, more of the starch granules of the coarse flour was pasted, and the difference in the apparent viscosities of fine versus coarse flour was reduced (Table 3). When cooled to 50 °C, the apparent viscosity of the coarse flour paste became significantly greater than that of finer flours. It is probable that other nonstarch components of flour (cell walls and protein matrix) contributed to viscosity and stability of the flour paste as it cools.

Effect of pH on Flour Pastes

The effect of pH on the flour and flour fractions (coarse and fine fractions) of variety CSHS is presented in Fig. 3 and 4. The coarse flour fraction (overs of No. 60 U.S. standard sieve) had significantly greater apparent gelatinization temperature than the flour and the fine particles at pH 4.2 (Fig. 3). The coarse particles had the lowest apparent viscosities under the different cooking conditions. This is consistent with earlier observations for coarse flour and might be due to the relatively greater size of the particles.

At pH 8.8, the apparent gelatinization temperature of flour was similar to that of the coarse particle fraction, but lower than that of the fine particles (Fig. 4). This might be due to greater dissolution of the fine particles by the alkali. However, the apparent viscosities followed a trend, similar to that obtained at pH 4.2 i.e., the fine fraction had the greatest viscosity while the coarse fraction had the lowest.

Apparent viscosities of flour pastes were generally greater at pH 4.2 than at pH 8.8. However, the peak viscosity of the fine flour fraction was greater at pH 8.8 than at 4.2 probably due to alkali swelling of starch and the lowering effect of acid hydrolysis on viscosity of starch (flour) at pH 4.2.

Table 3. Mean[1] amylograph properties[2] of flours at two different particles sizes

	Sample	Apparent Gelatinization Temp. °C	Apparent pasting Viscosities (BU). Max Pasting	95°C	1 hr at 95°C	50°C	1 hr at 50°C
P721	80 U.S. Std. Sieve	74.5±0	570±0	565±7	270±14	737±11	580±14
	60 U.S. Std. Sieve	-	-	-	-	-	-
CSH-5	80 U.S. Std. Sieve	74.5±0.5	585±7	583±4	370±14	740±0	725±21
	60 U.S. Std. Sieve	88.0±1.1	350±14	225±7	350±14	870±14	840±0
E35-1	80 U.S. Std. Sieve	76.5±0.5	445±7	440±0	320±0	860±14	675±7
	60 U.S. Std. Sieve	90.0±0.7	345±7	65±7	350±0	950±0	905±7

[1]Means were for two(2) replicates
[2]Amylograph properties were for 12% flour slurry on dry weight basis at pH 7.0
[3]Apparent pasting viscosities were in Brabender Units (BU)

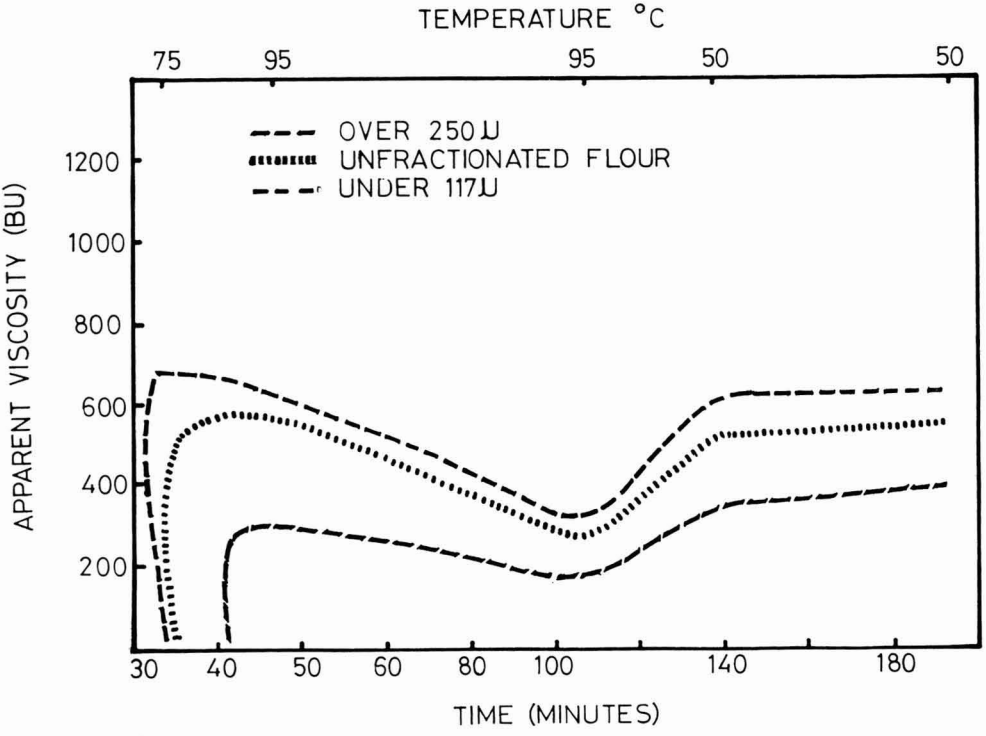

FIG. 3.
BRABENDER PASTE VISCOSITIES OF CSH5 FLOUR AND FLOUR FRACTIONS AT pH 4.2

CONCLUSION

The paste properties of several varieties of sorghum were evaluated. Results indicate that the apparent gelatinization temperature of sorghum flour was about 10 °C higher than that of the starch possibly due to restriction on the swelling of starch granules in flour particles. The apparent gelatinization temperature of the waxy sorghum starch was within the range observed for starch from the non-waxy varieties. The viscosities of sorghum flours appear related to the size of particles in the flour. Coarse particles exhibited lower paste viscosities and were less sensitive to pH than fine particles due to relatively smaller amounts of pasted starch granules and the reduced effect of acid or alkali on large compared to small particles. The swelling and solubility properties of sorghum starches were negatively correlated with the amylose content and might be good indicators of the textural properties of food made from sorghum starches. However, particle

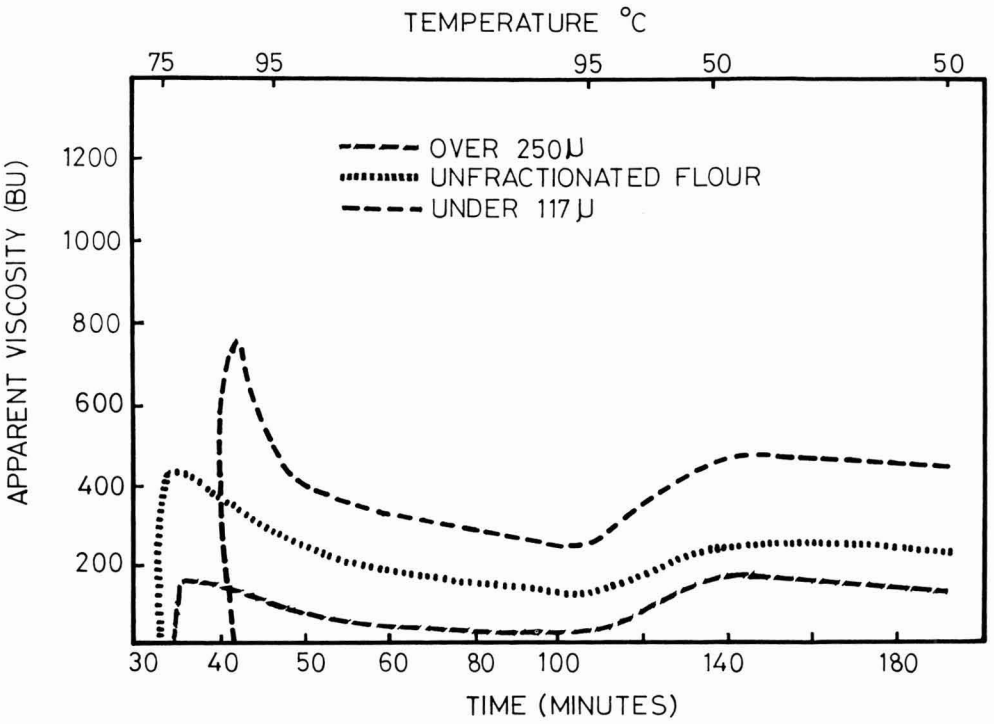

FIG. 4.
BRABENDER PASTE VISCOSITIES OF CSH 5 FLOUR AND FLOUR FRACTIONS AT pH 8.8

size and distribution may be better parameters of texture in food made from sorghum flours, than starch or amylose, because of their influence on potential action of starch granules during increased temperature of water.

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COMPARATIVE EVALUATION OF GHEE IN TIN AND POLYETHYLENE PACKAGES DURING STORAGE

P. CHAUHAN[1] and B.K. WADHWA[2]

Dairy Chemistry Division
National Dairy Research Institute,
Karnal-132001, India

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ABSTRACT

Ghee samples were packaged in tin and polyethylene packages and stored at 37°C for 195 days. Samples were analyzed every other week for five traits viz. free fatty acids (FFA) level, peroxide value (PV), total carbonyl content (TCC), moisture content (MC) and flavor score (FS). Ghee packaged in tin had higher average FFA, PV, TCC and MC as compared to ghee packaged in polyethylene. In contrast to results of various chemical parameters, ghee in tin packages had a higher average level of FS as compared to ghee packaged in polyethylene. However, differences in FS became almost negligible at the end of the storage period. Though a strong recommendation can not be made, yet keeping in view the results of chemical parameters, negligible flavor differences at the end of the storage period, involvement of low cost and easy handling, polyethylene packages should be preferred to tin packages for storage of ghee.

INTRODUCTION

Ghee during storage undergoes chemical changes. The net effect of these chemical changes is oxidative deterioration and is catalyzed by air, light, temperature, humidity, metals, etc. Thus, packaging materials used has an important role in the storage of ghee. In recent years, new packaging materials and packaging methods have been developed with a view to extend the shelf-life of the dairy products and to facilitate their transportation and distribution. In general, commercial ghee is packaged in tin containers. Tin packaging has certain limitations; a large capital outlay for the equipment and the additional distribution costs involved in carrying the deadweight of the tin containers. The

[1]This work was submitted in partial fulfilment of the requirements for the degree of Master of Science in Dairying (Dairy Chemistry) to the Kurukshetra University, Kurukshetra (India).
[2]To be addressed for all correspondence

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dairy industry has shifted towards polyethylene packages because of low cost and easy handling. There is paucity of systematic information on the shelf-life of ghee in polyethylene packages compared with tin packages. The present study was planned to evaluate ghee in polyethylene and tin packages during storage.

MATERIALS AND METHODS

Preparation of Ghee Samples

In Laboratory. Cream samples (from mixed cow and buffalo milk) collected from the Experimental Dairy of the Institute were churned into butter. Butter was clarified in an aluminum vessel at a temperature of 110 °C.

In plant. Ghee samples were drawn directly from the Experimental Dairy of the Institute prepared in practice as follows: Cream was churned into butter in a conical shaped butter churn. Butter was clarified in a steam jacketed double walled stainless steel vessel at a temperature of 110 °C.

Storage of Ghee Samples

Four ghee sampels prepared in the lab and in the plant were packaged in lacquered tin containers (250g capacity) and in low density polyethylene (LDPE) pouches (250g capacity) wrapped in another outer thick high density polyethylene (HDPE) cover with perfect air tight sealing. Samples were stored in an incubator at 37 °C. Once a container was used for analysis, it was discarded.

Analysis of Ghee Samples

Flavor Evaluation of Ghee Samples. Ghee samples were kept in 50 mL beakers at a temperature of 40 °C and subjected to flavor evaluation every other week by a panel of four judges. The panelists were asked to grade the samples using a Hedonic Scale (Elizabeth 1977). The 9-point Hedonic scale was modified as a 90-point scale to cover the minor differences in the flavor of ghee samples on a wide range of score as describe below.

Attribute	(Out of 90)
Like extremely	81–90
Like very much	71–80
Like moderately	61–70
Like slightly	51–60
Neither like nor dislike	41–50
Dislike slightly	31–40
Dislike moderately	21–30
Dislike very much	11–20
Dislike extremely	1–10

Determination of Free Fatty Acids (FFA) Level, peroxide Value (PV), Total Carbonyl Content (TCC) and Moisture Content (MC). FFA level (% oleic acid), PV (milliequivalent of oxygen/kg fat) and MC (%) of ghee samples were determined every other week as described in IS: 3508 (ISI, 1966). TCC (micromoles/g fat) was determined by flask method of Rama Murthy and Jain (1973).

The data were statistically analyzed using 3-way Factorial model (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Figure 1 delineates the changes occuring with ghee made in both plant and lab and stored in tin and polyethylene packages. Under both processing conditions, ghee in tin packages developed acidity more steadily when compared to ghee in polyethylene as shown by the gap between the graphs of tin and polyethylene packages (a).

Plant ghee stored in both tin and polyethylene packages showed irregular behavior in PV development up to 120 days. However, 120 days onwards up to 195 days, ghee in tin packages developed PV more steadily as compared to ghee in polyethylene. In lab ghee, an erratic behavior in PV was observed throughout the storage period in both tin and polyethylene packages. However, at the end of the storage period (180–195 days), ghee in tin packages developed PV more steadily as compared to ghee in polyethylene (b).

Plant ghee in tin packages developed carbonyls more regularly and steadily as compared to ghee in polyethylene packages. Lab ghee in both tin and polyethylene packages showed erratic behavior up to 120 days in the development of carbonyls and ultimately developed the same level at 150 days of storage. Afterwards, ghee in tin packages developed less carbonyls when compared to ghee in polyethylene (c).

The moisture content of ghee decreased during storage. Under both processing conditions, ghee in tin packages had more MC at all periods of storage when compared to ghee in polyethylene as shown by the gap between graphs of tin and polyethylene packages (d).

In general, ghee in tin packages under both processing conditions had higher flavor score when compared to ghee in polyethylene. However, the differences became almost negligible at the end of the storage period (e).

Statistical analysis revealed that under both processing conditions, ghee in tin packages had significantly higher FFA level ($P \leq 0.05$), PV, TCC, MC and FS ($P \leq 0.01$) than those in ghee in polyethylene. Ghee in tin packages had significantly higher ($P \leq 0.01$) average FFA level (0.69), PV (1.24), TCC (6.65), MC (0.139) and FS (63.33) than those (0.63, 1.13, 6.43, 0.124 and 56.21, respectively) in ghee in polyethylene.

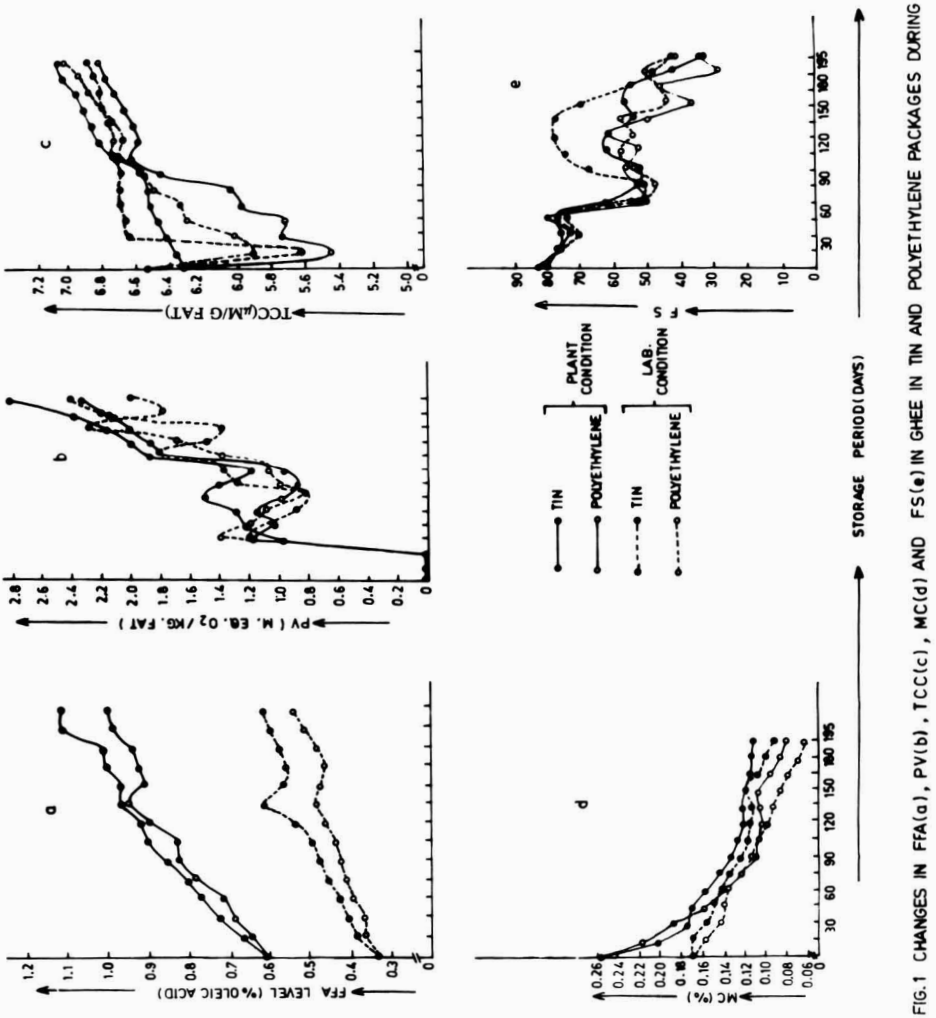

FIG.1 CHANGES IN FFA(a), PV(b), TCC(c), MC(d) AND FS(e) IN GHEE IN TIN AND POLYETHYLENE PACKAGES DURING STORAGE

Thus it can be inferred that ghee in tin packages had undergone more hydrolytic and oxidative changes during storage as compared to ghee in polyethylene. On the contrary, ghee packaged in tin had better flavor quality when compared to ghee in polyethylene. The higher moisture content in ghee in tin during storage as compared to ghee in polyethylene might account for the differences in hydrolytic and oxidative changes. Ghee in double polyethylene packaging might get better protection from moisture and air resulting in less pronounced chemical changes during storage. Further the catalytic action of metals on autoxidation could be expected more in tin (tinned-iron) containers.

The correlation of flavor with various parameters showed that total carbonyls, FFA, peroxides and moisture content present in ghee significantly ($P \leq 0.01$) contributed to off-flavor development in ghee. Literature reports (Rao *et al.* 1977; Singh and Ram 1978 and Wadhwa *et al.* 1979) also indicate that flavor deterioration was related to chemical changes during storage. However, Lalitha and Dastur (1953), Bell and Parson (1975) and Murthy *et al.* (1984) have reported that the rate of change in the chemical characteristics did not correlate much with sensory evaluation.

It can be concluded that though, ghee in tin packages had higher average FFA, PV, TCC and MC as compared to ghee in polyethylene, these differences were probably not sufficient enough to cause much flavor differences at the end of the storage period. Though a strong recommendation can not be made, yet keeping in view the results of chemical parameters, negligible flavor differences at the end of the storage period, involvement of low cost and easy handling, polyethylene packages should be preferred to tin packages for storage of ghee.

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KINETICS OF BEAN PROTEIN THERMAL DENATURATION

A.I. HOHLBERG

Departamento de Ingenieria Quimica,
Universidad Catolica de Chile,
Casilla 6177, Santiago, Chile.

and

D.W. STANLEY[1]

Department of Food Science,
University of Guelph,
Guelph, Ontario, N1G 2W1 Canada

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ABSTRACT

*A kinetic model for the thermal denaturation of the 7S protein of common black beans (*Phaseolus vulgaris*) was developed. Thermal analysis was performed on hydrated (9:1) solutions of the proteins with a differential scanning calorimeter (DSC). Kinetic parameters were obtained by analyzing peaks in the DSC thermogram using the Borchardt and Daniels method. Denaturation temperature for 10% solutions increased from 382 to 387°K when increasing the heating rate from 5 to 30°C/min, while the enthalpy was steady at about 0.4 J/g solution. The reaction order for phaseolin denaturation was found to be close to 2.5, with an activation energy of 932 KJ/mol and a pre-exponetial factor of 127 min^{-1}. A critical evaluation of the peak temperature versus heating rate method revealed that the former method was less appropriate and accurate for determining the activation energy of protein denaturation.*

[1]To whom correspondence should be addressed.

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INTRODUCTION

Proteins are known to undergo conformational changes when heated in dilute solutions. This phenomenon, denaturation, is an important determinant of food protein functionality and is induced by factors such as heat, pH and/or chemical compounds (Wu and Inglet 1974). It is associated with an enthalpic change in the system that can be measured using calorimetric techniques. Differential scanning calorimetry has been used to study the thermodynamics of the denaturation of small globular proteins (Steim 1965; Privalov and Khechinashvili 1974; Privalov 1979; Fugita and Noda 1981), common food proteins (Sturtevant 1980; Wright 1982; Biliaderis 1983; Findlay *et al.* 1986) and, specifically, grain food proteins (Hermansson 1978; Armstrong *et al.* 1979; Wright and Boulter 1980; Arntfield and Murray 1981; Danielenko *et al.* 1985).

Since Borchardt and Daniels (1957) proposed a method to obtain kinetic parameters for chemical reactions from the DSC record, corrections to the model and new methods have been suggested (Rogers and Smith 1970; Ozawa 1970; Duswalt 1974; Sandu and Lund 1984). These methods have been successfully used in single step reactions. The kinetic data are usually derived from the shape, singular points or areas beneath the DSC curve, depending on the heating rate and initial concentration of the reactant.

Kinetic models of changes occurring in food during processing have been used to predict and assess the desired final quality of the products (Labuza 1980; Saguy and Karel 1980). Protein denaturation has also been studied from a kinetic point of view. Laidler and Bunting (1973) reviewed the use of kinetic analysis for protein denaturation and applied it to enzymes. They explained the variability in experimental orders of reaction in terms of the use of the true order of reaction with respect to concentration or the apparent order of reaction with respect to time. In most of the work they reviewed, protein denaturation followed true first order kinetics. This observation seems to indicate that denaturation occurs as a single step, first order reaction. However, some results indicated that true orders of reaction greater than one have been obtained and can be attributed to cooperative polymolecular reaction or to complex mechanisms with more than one step. Data reported for apparent order of reaction were, in most cases, different from one. This was explained by the presence of intermediate products, impurities or by the presence of more than one protein.

The purpose of this study was to develop a model for the complex phenomenon of the unfolding of a large subunited legume protein using a relatively simple DSC-kinetic approach. Two dynamic methods were used to calculate the apparent order of reaction and the thermodynamic kinetic parameters.

MATERIALS AND METHODS

Isolation of Bean Protein

Protein globulins were extracted from common dry black beans (*Phaseolus vulgaris* var. Orfeo) according to the scheme outlined in Fig. 1. Pharmacia Fast Performance Liquid Chromatography (FPLC) equipped with a gel filtration Superose 12 column was used to isolate a 7S fraction rich in phaseolin, also known as vicilin, glycoprotein II or G1 globulin, the major storage protein present in common beans (Barker *et al.* 1976; Bollini and Chrispeels 1978; Mosse and Pernollet 1980). The eluting buffer was 0.1 M phosphate with 0.3 M NaCl. Phaseolin was collected from a well-resolved single peak and was identified by molecular weight (168 Kd). The purity of this protein was 98% (w/w) according to a further separation with a Pharmacia Mono Q ionic exchange column.

Freeze-dried protein isolate was dissolved in 0.1 M phosphate buffer (pH 7.0–0.3 M NaCl) on a 10% (w/w) basis. Hermetically sealed DSC pans were prepared with samples weighing between 6 and 10 mg. These were analyzed in a DuPont 910 DSC at heating rates varying from 5° to 30° C/min. The samples were scanned against a reference pan with buffer solution that had similar heat capacity.

Kinetic Methods

A DuPont 1090 Thermal Analyzer with different software programs was employed in the analysis of the DSC curves resulting from heating the samples between 30° and 140°C. The DSC cell was calibrated using indium as a reference according to Norm ANSI-ASTM E 698/79.

The Borchardt and Daniels (B/D) DSC kinetic program was used to calculate the apparent order of reaction (n), activation energy (E), pre-exponential factor (Z) and heat of denaturation (H_d) from a single scan of the reaction. These values were obtained by a nonlinear regression from the expressions proposed by Borchardt and Daniels (1957). The program uses data from 20 equally spaced peak segments over the region from 10% of the peak height to 50% of the peak area (DuPont DSC Kinetic Data Analysis Program bulletin). The reference and sample pans were alternated in order to obtain the exothermic peak required for the analysis. A flat baseline was used to evaluate the peak since there was no appreciable change in the heat capacity of the solution during the endotherm. This software also provided the Arrhenius and conversion plots that can be used to predict the course of the denaturation under different temperature-time regimes.

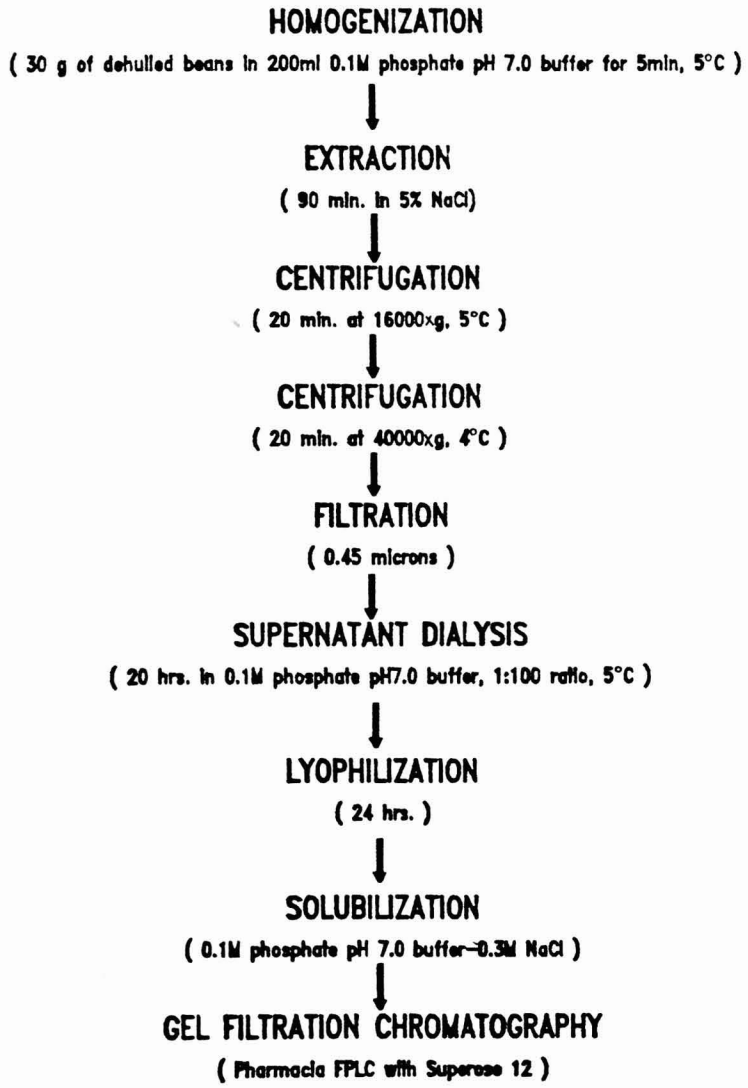

FIG. 1.
SCHEME FOR PHASEOLIN SEPARATION

A second dynamic method derived from the evolution of the peak temperature with the heating rate was used to compare the kinetic parameters obtained from the B/D DSC method (Ozawa 1970; Kassman 1980; Sandu and Lund 1984). The following approximate solution was used to solve the general order reaction equation as proposed by Sandu and Lund (1984):

$$\ln(B/T_m^2) = \ln (C_0^{n-1} Z R/E) - E/R T_m \qquad \text{(Eq. 1)}$$

where B is the heating rate, R is the gas constant, T_m peak temperature and C_o the initial concentration of reactant. From this relation it is possible to estimate kinetic parameters from the coefficients of a weighted least squares linear regression between $1/T_m$ and $\ln(B/T_m^2)$. Triplicate analyses were carried out for 6 different heating rates (5°, 10°, 15°, 20°, 25° and 30°Cmin) and the peak temperatures determined using the general analysis program.

RESULTS AND DISCUSSION

Borchardt and Daniels Method

Examination of the average energy and temperature of denaturation obtained for each heating rate employed (Table 1) showed that there was no significant difference ($p > 0.05$) between the enthalpies obtained at different heating rates, although there was an appreciable coefficient of variation (C.V. = 16.5%) among the single runs. The average energy required to denature the protein was 3.78 J/g of pure protein, which greatly exceeds the value of 1.6 J/g reported by Wright and Boulter (1980) for unseparated bean proteins isolated under similar conditions. As expected, the peak temperature shifted to higher values as the heating rate was increased. Peak temperatures were reproducible between runs, with coefficients of variation smaller than 0.5% for all the heating rates. At 10°C/min the temperature obtained for the peak of transition was 382.3°K, which is higher than the previously reported value of 363.3°K (Wright and Boulter 1980). These greater temperatures and enthalpies obtained demonstrate that purified phaseolin is harder to denature by heat than mixed bean proteins. The high temperature required to denature phaseolin, compared to vicilin from other legumes, may be explained by the presence of glycosylated sugar moieties covalently bonded to terminal amino acids of the subunits.

Table 1. Denaturation temperatures and enthalpies. Average for triplicates

Heating Rate (°C/min)	Av.Weight (mg)	Peak Temperature (°K)		Enthalpy (10% solutions) (J/g)	
		Avg.	S n-1	Avg.	S n-1
5	7.50	382.37	0.350	0.368[a]	0.135
10	8.56	382.83	0.306	0.369[a]	0.090
15	9.36	385.00	0.001	0.364[a]	0.019
20	8.83	385.73	0.551	0.462[a]	0.030
25	7.40	386.50	0.264	0.384[a]	0.042
30	7.73	386.90	0.459	0.322[a]	0.053

[a]No significant difference ($P > 0.05$)

Results obtained using the B/D kinetic method (Table 2) indicate that denaturation of isolated bean protein can be represented by a single step reaction with an apparent order of reaction between 2 and 3. The small standard error and large correlation coefficient (s.e. ≤ 0.044 s^{-1}; $R^2 \geq 0.990$) from the Arrhenius plot are an indication of the fit of the kinetic model to the thermal scans. Figure 2 shows the Arrhenius plot and DSC curve for a typical scan. No significant difference ($p > 0.05$) was found between the orders of reaction, activation energies and pre-exponential factors at different heating rates. The variability of n, E and log Z from run to run was less than 10.5%. An average activation energy of 932 KJ/mol was found, larger than values given by Labuza (1980) for smaller proteins such as milk peroxidase (788 KJ/mol) and egg albumin (552 KJ/mol).

The apparent order of reaction, between 2 and 3, may be a consequence of polymolecular denaturation reactions or the presence of intermediate products. Another possible explanation for the nonintegrity of the reaction order is that phaseolin may dissociate before denaturation. This can occur because it is comprised of three subunits in a tetrameric structure (Bollini and Chrispeels 1978). Protein association has been reported to occur in the 7S soybean protein when heated in salt solution (Hermansson 1978), and in common bean 7S protein when heated in 0.05M potassium phosphate buffer at pH 7.0 (Chang and Satterlee 1981). The latter authors reported an increase in the size of the heat denatured protein of at least 1.5 times.

Table 2. Borchard/Daniels kinetic parameters. Average for triplicates

Heating Rate (°C/min)	Reaction Order (n)		Activation Energy (KJ/mol)		Preexp. Factor (1/min)		St. Error (1/sec)
	Avg.[a]	Sn-1	Avg.[a]	Sn-1	Avg.[a]	Sn-1	Avg.
5	2.22	0.220	967.3	160.9	132.3	22.03	0.044
10	2.58	0.407	1050.3	136.4	144.3	19.14	0.033
15	2.68	0.066	908.3	16.6	124.3	2.08	0.022
20	2.52	0.107	869.0	31.4	119.0	4.36	0.012
25	2.45	0.282	845.0	130.2	115.0	20.57	0.025
30	3.00	0.170	953.0	21.0	129.7	11.68	0.027
AVERAGE	2.58	0.209	932	82.7	127	13.3	0.027

[a]No significant difference ($P > 0.05$)

A possible simplified pathway for the reaction was proposed by Hermansson (1978):

$$nP_n \xrightarrow{\text{fast}} nP_d \xrightarrow{\text{slow}} (P)_n \quad \text{(Eq. 2)}$$

where P_n, P_d represent the native and denatured protein and n is the number of protein molecules. This model assumes that the first step of denaturation occurs much faster than the second one, and therefore it can be studied as a single reaction. An addition to the model was proposed by Armstrong *et al.* (1979), who considered subunit dissociation as an initial rapid step of the reaction.

Peak Temperature Dynamic Method

As both variables proposed in Eq. 1 have an intrinsic error it was necessary to use a weighted least-square regression. This resulted in the following equation:

$$\ln(B/T_m^2) = 115.1 - 47844.7/T_m \quad \text{(Eq. 3)}$$
$$R^2 = 0.918$$

From the coefficients determined in this equation it is possible to calculate an apparent activation energy of 398 KJ/mol. However, other kinetic parameters cannot be determined independently. A plot of the data used in this correlation (Fig. 3) shows a slight curvature as is expected for reactions with orders different from one (Sandu and Lund 1984).

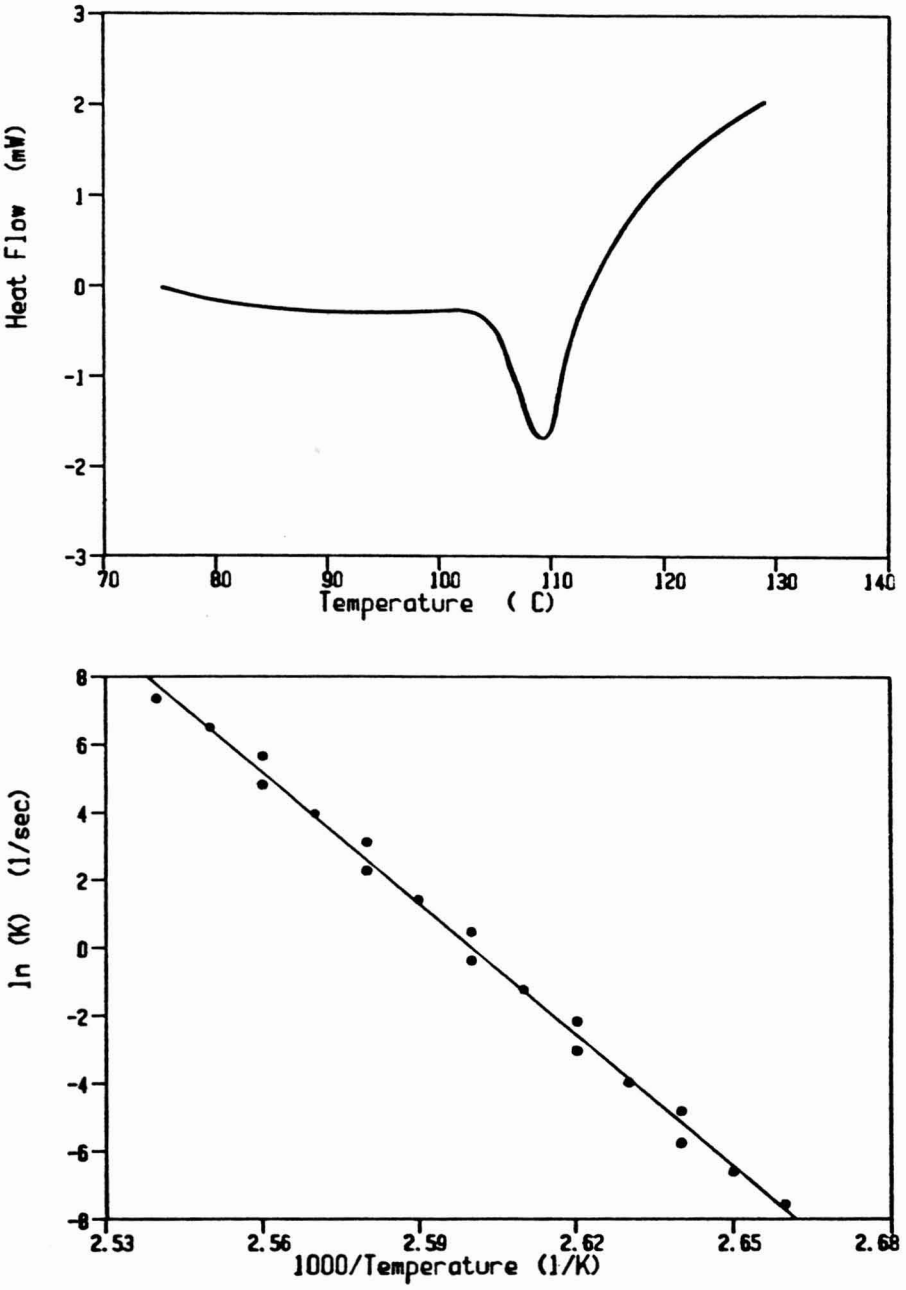

FIG. 2.
DSC THERMOGRAM AND BORCHARDT AND DANIELS ARRHENIUS PLOT FOR PHASEOLIN DENATURATION AT A HEATING RATE OF 10°C/MIN

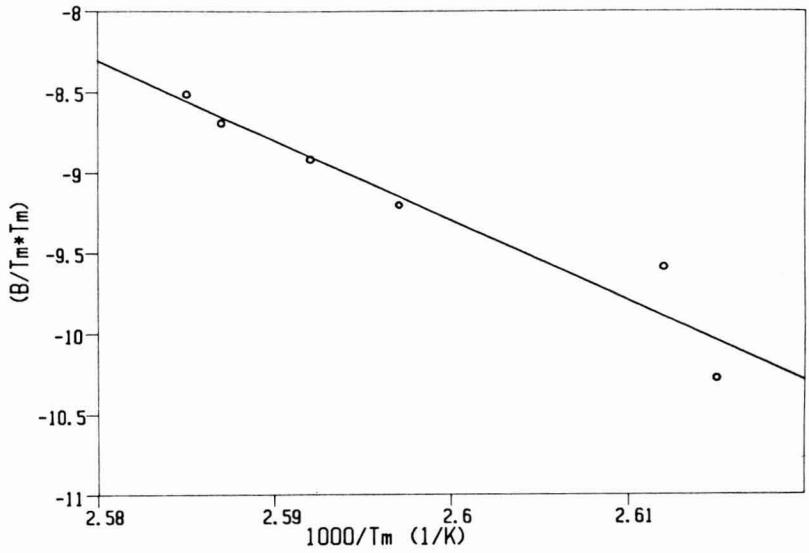

FIG. 3.
HEATING RATE vs. PEAK TEMPERATURE METHOD
REGRESSION OF $(1/T_m)$ vs. (B/T_m^2)

Differences in the activation energy values calculated by the two methods may be because the peak temperature/heating rate method only considers one point of each curve and, although the variability of this point is small, the use of such limited information of the scan (as compared to the B/D method) could diminish the accuracy of the results. Another important difference between the methods is that the heating rate/peak temperature method assumes that only one phenomenon occurs during the transition. In the case where two or more steps are taking place, the expression previously proposed (Eq. 1) becomes invalid. Since protein denaturation involves a series of cooperative mechanisms it is not possible to assume that the shifting of the peak temperature is due only to one of these components. Therefore, the B/D method may be more appropriate to model the thermal denaturation of proteins.

Other Thermodynamic Properties

Independent values for the enthalpy and the entropy of formation of the Eyring's activated complex (Labuza 1980) were calculated from kinetic results obtained in the B/D DSC method. The enthalpy of formation (H*) was derived from the activation energy as follows:

$$H^* = E - R\,T_m \qquad \text{(Eq. 4)}$$

The entropy of formation (S*) was derived from the kinetic pre-exponential factor:

$$S^* = R\,(\log(Z) + \log(h/k\,T_m) - 1) \qquad \text{(Eq. 5)}$$

where k is the Boltzman constant, h the Plank constant and T_m the peak temperature in degrees Kelvin. The resulting values are shown in Table 3.

The results obtained in this preliminary work support further research with a wider range of experimental conditions. The extension of the model with variables such as concentration, ion strength and pH should provide important for the processing of food proteins.

Table 3. Thermodynamic properties of phaseolin denaturation

Heating rate (°C)	H^* (KJ/mol)	S^* (KJ/°C*mol)
5	964.1	1.25
10	1047.1	1.35
15	905.1	1.19
20	865.8	1.14
25	841.8	1.11
30	949.8	1.23
AVERAGE	929.0	1.21

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COMPARISON OF STEAM CANNER PROCESSING WITH OTHER METHODS OF HOME CANNING

T.V. RAMAKRISHNAN[1], EDWARD A. LAPERLE[2] and K.M. HAYES[1]

[1]*Department of Food Science & Nutrition*
Chenoweth Lab
University of Massachusetts
Amherst, MA 01003

[2]*Ball Corporation, Muncie, IN*

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ABSTRACT

A comparison was made between steam canner and other conventional methods of home canning such as boiling water bath and pressure canner at 5 and 10 lb. of pressure. Several heat penetration studies were done and the processes were evaluated using sound thermobacteriological and mathematical basis. Only acid products such as tomato juice, tomatoes and apple sauce, were considered in this investigation. The final process times calculated for the three products and the come-up time needed for each equipment, indicates that steam canner method may be more efficient than other methods for home canning of acid-food products.

INTRODUCTION

Numerous studies have been made on home canning methods (Cover *et al.* 1943, 1956; Esselen and Tischer 1945) over the years. Procedural details for the home canning of fruits and vegetables, and also the process times needed for the safety and stability of the products are available from several sources (Hayes *et al.* 1956; Toepfer 1946; USDA 1976). Most of the recommended methods relate to the processing of acid-foods such as tomatoes and apple sauce at the temperature of boiling water (212 °F) and low-acid foods like green beans, peas and corn at 10 lb. of pressure (240 °F). Recent studies have focussed attention on processing home canned foods at 5 lb. (226 °F) and 15 lb. (250 °F) pressure settings (Zimmerman *et al.* 1978; Zottola *et al.* 1978). Besides the conventional water bath and pressure canner, there is one other equipment called steam canner available on the market for home canning. The steam canner is comparable to the boiling water bath and is designed for acid-food products (pH below 4.6) wherein the elimination of the spores of *C. botulinum* is not a consideration in

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the process evaluation. Only two quarts of water are needed for the steam canner processing. The jars of fruits or tomatoes are placed on a rack which allows the steam from the water in a shallow pan to circulate freely around the jars. A metal dome shaped lid encloses the jars on the rack and has two holes at the bottom for the steam to escape.

The design of the steam canner suggests that it may have some advantages over the conventional boiling water bath method of processing of acid-food products. However, recommended process times are not easily available for the steam canner method (Hall 1978). This paper addresses this problem and also describes the comparitive studies made on home canning methods using steam canner, boiling water bath, and also pressure canner at 5 and 10 lb. pressure settings. Commonly home canned acid products such as tomatoes, tomato juice and applesauce were used as examples. This investigation involves numerous heat penetration studies and the process evaluation is based on well established thermobacteriological and mathematical concepts.

MATERIALS AND METHODS

The pressure canners were obtained from Presto Industries, Inc., Eau Clair, WI and Micro Aluminum Company, Maintowoe, WI. The steam canner was purchased from Gardenway, Charlotte, VT. All the equipments were adapted to allow thermocouple wire leads to pass through the lids without any loss of steam. The pressure vessels were complete with pressure gauges, air vents and pressure regulators. Ecklund type T copper-constantan thermocouples along with a digital temperature recording device (Kaye Instruments, Medford, MA) was employed for all the temperature measurements. An electric stove was used as a heat source in order to duplicate the home conditions as closely as possible.

The canning methods adopted for the products tomato juice, tomatoes and applesauce were those recommended by USDA in Bulletin No. 8 (1976). All the products were hot packed and the initial temperatures were set at 180 °F for tomato products and 190 °F for applesauce. Seven quart jars and eight pint jars were processed during each run of the experiment. Thermocouples were placed at the point of slowest heating. Come-up-time was counted from the instant the heat was first applied until the processing temperature was reached. The process time was considered to begin when the canner reached the required processing temperature or the corresponding pressure. Sufficient venting time was allowed to assure an adequate level of steam in the chamber.

RESULTS AND DISCUSSION

Methods of Process Evaluation

The evaluation of process time in all cases was based on the appropriate use of heat penetration data and application of thermobacteriological and mathematical concepts (Stumbo *et al.* 1982). The time-temperature relationships obtained in the heat penetration experiments were transformed into semi-log heating curves and the needed processing parameters were derived. The symbols used in describing thermobacterial and processing variables are as listed by Stumbo (1973). Some of the symbols are defined as follows:

D Value - Represents the resistance of an organism at a specific temperature; numerically equal to the time required to reduce the initial load by 90% or 1 log cycle.

z Value - Reflects the relative resistance of an organism at different temperatures; numerically equal to the Fahrenheit degrees required for the TD curve to traverse one log cycle.

f_h - Time, in minutes, required for the straight line portion of the Semilog heating curve to traverse one log cycle. It takes into account the nature of the food, size of the container and the processing temperatures.

j_{ch} - Lag factor for the heating curve. It is modified by the initial food temperature, the retort temperature and the f_h.

F_o - The equivalent, in minutes at 250 °F, of all heat considered with respect to its capacity to destroy spores of a particular organism. Can also be expressed as F^{18}_{250} since z of 18 is also a reference value like the temperature of 250 °F.

F_s - Integrated lethal capacity. All the heat received at different points of the container is expressed by this value and generally equated to F_o.

F_c - The lethal capacity of all the heat received at the center of the container.

Thermobacteriological Consideration

Since the products used were tomato juice, tomatoes and applesauce, there is no concern about the elimination of the spores of *C. botulinum*. For acid products below pH 4.6, the organism commonly used to establish the process is *Bacillus coagulans*. Although the resistance of the spores of *B. coagulans* could vary from one situation to another, a reasonable value of D_{250} of 0.01 min

(Stumbo 1973) was used for the purpose of establishing the process. The number of log cycles reduction of the spores desired depends on the level of contamination. For tomato products, 6 and 8 log cycles reductions were used as standards while for applesauce, the corresponding reductions were 4 and 6 log cycles. Since the z values also tend to vary from one set of condition to another, the process evaluations were done at 3 different z values of 16, 18 and 20F°. The target process value is defined as the $F_0(F^{18}_{250})$ value to be achieved during the process, which is based on the D_{250} value and the log cycles reduction desired. To achieve the same F_0, it is necessary to process the food for different periods of time if the z value is changed from 18F° to 16 or 20F°.

Calculation of Process Time

All the process calculations were done by sophisticated computer programs (Stumbo *et al.* 1982). In the final evaluation of the process time, the processing conditions, heat penetration parameters and the thermobacteriological criteria were treated together. The calculations were done using the integrated lethality approaches of Stumbo (1973). The application of this method results in one process time and two process values, F_s and F_c. The F_s is also equal to the target process value, F_0. For the same process value of F_s, it is possible to get different F_c values depending upon the thermal diffusivity of the products, the container size and processing conditions. All F_s and F_c values were expressed as equivalents of F_0.

Comparison of Different Methods of Home Canning

The heat penetration parameters derived, the thermobacteriological criteria and the process times calculated are listed Tables 1 through 12 for tomato juice, tomatoes and applesauce, respectively. Each product was processed using boiling water bath, steam canner, and pressure canner at 5 and 10 lb. of pressure. It is apparent from the data presented that the final process time needed is considerably influenced by the type of home canning method used and also the thermobacteriological criteria such as F_0 and z values considered.

In order to compare the efficiency of the steam canner with the other three methods of home canning, process times were selected for tomato products adopting a basis with a z value of 18 F° and 6 log cycles reduction. For applesauce, a criteria with a z of 20 F° and 4 log cycles reduction was considered. For process times thus selected for each product and the come-up times needed for different methods of processing are listed in Tables 13, 14 and 15 for tomato juice, tomatoes and applesauce, respectively. For both pint and quart jars, the steam canner was found to require the least amount of venting time, 17 and 20 min, respectively, which includes sufficient allowance to achieve a rich mixture of steam and air. It is evident that the time needed for processing and also the

Table 1. Processing of tomato juice by boiling water bath

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of Bacillus coagulans	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	212	180	50	1.6	16	6 log cycles	0.06	0.045	49.3
					18		0.06	0.043	36.2
					20		0.06	0.043	27.4
					16	8 log cycles	0.08	0.064	56.8
					18		0.08	0.063	41.7
					20		0.08	0.062	31.9
Quarts	212	180	75	1.7	16	6 log cycles	0.06	0.044	64.3
					18		0.06	0.043	47.4
					20		0.06	0.042	35.7
					16	8 log cycles	0.08	0.063	73.3
					18		0.08	0.062	54.3
					20		0.08	0.061	41.5

Table 2. Processing of tomato juice by steam canner

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process time needed (min.)
Pints	213	180	45	1.6	16	6 log cycles	0.06	0.045	43.7
					18		0.06	0.043	32.4
					20		0.06	0.043	24.9
					16	8 log cycles	0.08	0.064	50.2
					18		0.08	0.063	37.3
					20		0.08	0.062	28.8
Quarts	213	180	73	1.7	16	6 log cycles	0.06	0.044	60.9
					18		0.06	0.042	45.3
					20		0.06	0.042	34.4
					16	8 log cycles	0.08	0.063	69.3
					18		0.08	0.062	51.9
					20		0.08	0.061	39.9

Table 3. Processing of tomato juice by pressure canner at 5 lb. of pressure

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	227	180	39	1.4	16	6 log cycles	0.06	0.041	24.1
					18		0.06	0.040	19.8
					20		0.06	0.040	16.1
					16	8 log cycles	0.08	0.060	26.9
					18		0.08	0.059	22.2
					20		0.08	0.059	18.3
Quarts	227	180	71	1.6	16	6 log cycles	0.06	0.040	39.1
					18		0.06	0.039	31.8
					20		0.06	0.039	25.8
					16	8 log cycles	0.08	0.059	43.2
					18		0.08	0.058	35.6
					20		0.08	0.058	29.2

Table 4. Processing of tomato juice by pressure canner at 10 lb. of pressure

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	240	180	37	1.5	16	6 log cycles	0.06	0.037	17.6
					18		0.06	0.038	14.9
					20		0.06	0.037	12.8
					16	8 log cycles	0.08	0.056	19.2
					18		0.08	0.057	16.6
					20		0.08	0.056	14.4
Quarts	240	180	71	1.6	16	6 log cycles	0.06	0.037	33.3
					18		0.06	0.037	28.7
					20		0.06	0.037	24.5
					16	8 log cycles	0.08	0.056	36.2
					18		0.08	0.056	31.3
					20		0.08	0.056	27.1

Table 5. Processing of fresh tomatoes by boiling water bath

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	212	180	45	1.5	16	6 log cycles	0.06	0.045	45.5
					18		0.06	0.044	33.2
					20		0.06	0.043	25.2
					16	8 log cycles	0.08	0.064	52.5
					18		0.08	0.063	38.5
					20		0.08	0.062	29.3
Quarts	212	180	59	1.5	16	6 log cycles	0.06	0.044	53.5
					18		0.06	0.043	39.0
					20		0.06	0.042	29.3
					16	8 log cycles	0.08	0.064	61.5
					18		0.08	0.062	45.0
					20		0.08	0.061	34.3

Table 6. Processing of fresh tomatoes by steam canner

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	213	180	56	1.6	16	6 log cycles	0.06	0.044	50.7
					18		0.06	0.043	37.6
					20		0.06	0.042	28.6
					16	8 log cycles	0.08	0.064	58.0
					18		0.08	0.062	43.1
					20		0.08	0.061	33.3
Quarts	213	180	64	1.6	16	6 log cycles	0.06	0.044	55.1
					18		0.06	0.042	40.8
					20		0.06	0.042	30.9
					16	8 log cycles	0.08	0.063	62.8
					18		0.08	0.062	46.8
					20		0.08	0.061	36.0

Table 7. Processing of fresh tomatoes by pressure canner at 5 lb. of pressure

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	227	180	52	1.5	16	6 log cycles	0.06	0.040	30.6
					18		0.06	0.040	25.0
					20		0.06	0.039	20.3
					16	8 log cycles	0.08	0.059	33.9
					18		0.08	0.059	28.0
					20		0.08	0.058	23.0
Quarts	227	180	61	1.6	16	6 log cycles	0.06	0.040	35.4
					18		0.06	0.040	28.9
					20		0.06	0.039	23.5
					16	8 log cycles	0.08	0.059	39.1
					18		0.08	0.059	32.2
					20		0.08	0.058	26.6

Table 8. Processing of fresh tomatoes by pressure canner at 10 lb. of pressure

Type of Jar	Canning Temp. (^{o}F)	Inital Food Temp. (^{o}F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	240	180	52	1.5	16	6 log cycles	0.06	0.037	23.8
					18		0.06	0.037	20.2
					20		0.06	0.037	17.2
					16	8 log cycles	0.08	0.056	26.0
					18		0.08	0.056	22.3
					20		0.08	0.056	19.2
Quarts	240	180	65	1.6	16	6 log cycles	0.06	0.037	28.9
					18		0.06	0.037	24.4
					20		0.06	0.037	20.3
					16	8 log cycles	0.08	0.056	31.5
					18		0.08	0.056	26.9
					20		0.08	0.056	23.0

Table 9. Processing of applesauce by boiling water bath

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	212	190	62	1.6	16	4 log cycles	0.04	0.026	36.1
					18		0.04	0.024	23.1
					20		0.04	0.024	14.2
					16	6 log cycles	0.06	0.044	46.1
					18		0.06	0.043	31.1
					20		0.06	0.042	20.9
Quarts	212	190	91	1.6	16	4 log cycles	0.04	0.025	43.9
					18		0.04	0.024	26.9
					20		0.04	0.023	14.8
					16	6 log cycles	0.06	0.044	56.5
					18		0.06	0.042	37.2
					20		0.06	0.041	23.7

Table 10. Processing of applesauce by steam canner

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	213	190	73	1.6	16	4 log cycles	0.04	0.025	39.1
					18		0.04	0.024	25.4
					20		0.04	0.023	15.6
					16	6 log cycles	0.06	0.044	49.5
					18		0.06	0.042	33.8
					20		0.06	0.042	23.0
Quarts	213	190	110	1.6	16	4 log cycles	0.04	0.024	45.1
					18		0.04	0.023	26.8
					20		0.04	0.022	16.1
					16	6 log cycles	0.06	0.043	58.9
					18		0.06	0.041	37.9
					20		0.06	0.041	25.1

Table 11. Processing of applesauce by pressure canner at 5 lb. of pressure

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	f_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	227	190	62	1.5	16	4 log cycles	0.04	0.021	23.1
					18		0.04	0.021	17.0
					20		0.04	0.021	11.9
					16	6 log cycles	0.06	0.040	28.3
					18		0.06	0.039	21.8
					20		0.06	0.039	16.4
Quarts	227	190	94	1.6	16	4 log cycles	0.04	0.020	28.3
					18		0.04	0.020	19.5
					20		0.04	0.020	12.3
					16	6 log cycles	0.06	0.039	35.5
					18		0.06	0.039	26.2
					20		0.06	0.039	18.5

Table 12. Processing of applesauce by pressure canner at 10 lb. of pressure

Type of Jar	Canning Temp. (°F)	Inital Food Temp. (°F)	F_h (min.)	j_{ch}	z Value	Reduction of *Bacillus coagulans*	F_s Desired (min.)	F_c Achieved (min.)	Process Time Needed (min.)
Pints	240	190	61	1.5	16	4 log cycles	0.04	0.018	18.5
					18		0.04	0.018	14.5
					20		0.04	0.018	11.0
					16	6 log cycles	0.06	0.037	22.1
					18		0.06	0.037	18.0
					20		0.06	0.037	14.5
Quarts	240	190	94	1.5	16	4 log cycles	0.04	0.018	25.5
					18		0.04	0.018	19.4
					20		0.04	0.018	12.0
					16	6 log cycles	0.06	0.036	30.3
					18		0.06	0.036	24.2
					20		0.06	0.036	19.4

Table 13. Processing times for tomato juice

Type of Jar	Type of Process	Come-up Time (min.)	Process Time (min.)	Total Time (min.)
Pints	Water Bath	26	37	63
	Steam Canner	17	33	50
	5 lbs. Pressure	27	20	47
	10 lbs. Pressure	29	15	44
Quarts	Water Bath	27	48	75
	Steam Canner	20	46	66
	5 lbs. Pressure	32	32	64
	10 lbs. Pressure	33	29	63

Table 14. Processing times for fresh tomatoes

Type of Jar	Type of Process	Come-up Time (min.)	Process Time (min.)	Total Time (min.)
Pints	Water Bath	26	34	60
	Steam Canner	17	38	55
	5 lbs. Pressure	27	25	52
	10 lbs. Pressure	29	21	50
Quarts	Water Bath	27	39	66
	Steam Canner	20	41	61
	5 lbs. Pressure	32	29	61
	10 lbs. Pressure	33	25	58

Table 15. Processing times for applesauce

Type of Jar	Type of Process	Come-up Time (min.)	Process Time (min.)	Total Time (min.)
Pints	Water Bath	26	15	41
	Steam Canner	17	16	33
	5 lbs. Pressure	27	12	41
	10 lbs. Pressure	29	11	40
Quarts	Water Bath	27	15	42
	Steam Canner	20	17	37
	5 lbs. Pressure	32	13	45
	10 lbs. Pressure	33	12	45

corresponding come-up-time in the steam canner are less than that required with the boiling water bath in most cases studied. The total time involved in processing, including come-up-time and processing time for the steam canner is very close to processing at 5 or 10 lb. of pressure. These results suggest that the steam canner method of home canning seems to have some advantage over the other methods particularly in terms of efficiency. The analysis of data presented in Tables 13, 14 and 15 also indicates that there is a possibility of saving energy if the steam canner is used for home canning wherever possible since the processing time corresponds to greater consumption of energy in water bath processing and come-up-time is high energy demanding in pressure processing (Zimmerman *et al.* 1979). It is important to point out that the steam canner is useful only with high-acid and acid-food products and it should not be used with low-acid foods. For a successful application this equipment, appropriate recommended processing time for the specific food and container size should be used.

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INFLUENCE OF STORAGE CONDITIONS ON QUALITY OF COWPEA SEEDS AND PRODUCTS PROCESSED FROM STORED SEEDS[1]

K.H. MCWATTERS, M.S. CHINNAN,
R.E. WORTHINGTON AND L.R. BEUCHAT

Department of Food Science
University of Georgia Agricultural Experiment Station
Experiment, GA 30212

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ABSTRACT

*Effects of storing cowpeas (*Vigna unguiculata*) at 2°C/65% R.H., 21°C/55% R.H., and 35°C/65% R.H. for 10 months in open metal cans, in high density polyethylene bags flushed with 100% CO_2, and in nylon/saran/curpolymer/polyethylene laminate bags flushed with 100% CO_2 were determined. No major adverse quality changes occurred in cowpeas stored at 2 or 21°C and evaluated as a reconstituted boiled vegetable. Peas stored at 35°C absorbed less water during soaking and required greater force to shear after boiling than peas stored at 2 or 21°C. The rate of death of yeasts and molds on cowpeas stored at 2°C was slower than the rate of death at 21 or 35°C. Decortication efficiency improved under the conditions of storage utilized and may be related to an increase in seed hardness. Cowpeas stored at 2 and 21°C produced akara (fried cowpea paste) with better overall sensory quality than peas stored at 35°C.*

INTRODUCTION

During prolonged storage conditions of high humidity and high temperatures, cowpeas (blackeye peas), like other leguminous seeds, increase in hardness (Sefa-Dedeh *et al.* 1979; Swanson *et al.* 1985). Hardening impairs cookability in that affected seeds do not become tender during cooking, even when the cooking time is greatly extended. When cowpeas are milled into flour or paste, the hard-seed condition could also influence the ease and efficiency of seed coat removal, milling quality, the functionality of milled products, and the quality of foods in which cowpea paste or flour are utilized as a primary ingredient.

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Methods of storage employed in areas of the world which rely upon the cowpea as a major protein-calorie source often do not afford protection for dry seeds, particularly in tropical or subtropical environments. A packaging method which extends the usual shelf-life of peanuts and pecans, both raw and roasted, has been developed by Holaday and coworkers (1979). The method utilizes the CO_2 adsorption properties of these commodities and involves placing them in plastic pouches impervious to air and CO_2, flushing them with CO_2 and then heat-sealing the pouches. CO_2 is adsorbed into the pores of the commodity, forming a vacuum inside the pouch. Likewise, cowpeas packaged by this method also adsorbed CO_2 and produced a vacuum inside the bag. Although no formal quality tests were conducted on the peas, Holaday and coworkers (1979) observed no insect infestation or change in appearance after six months of storage at ambient conditions. Benefits of CO_2 packaging which were noted included its effectiveness, simplicity, low cost, low energy requirements, and adaptability for small or large operations.

The objective of the present study was to determine the effect of storage temperature, package type, and CO_2 on the quality of whole cowpea seeds and meal processed from stored seeds.

MATERIALS AND METHODS

Materials and Storage Conditions

Dry cowpeas were obtained from Hayes Food Products Co., Greenville, SC and held at 2 °C/65% R.H. in paper bags until used. Under these conditions, peas equilibrated at a moisture content of 13%. Prior to packaging for storage, cowpeas were allowed to equilibrate at least 24 h at room temperature and relative humidity. Flexible packaging materials included a high-density polyethylene (Flex-on, Inc., Senoia, GA) and a nylon/saran/curpolymer/polyethylene laminate (Curlon® 550, Curwood, Inc., New London, WI). Permeability properties of these films are shown in Table 1. Peas were divided into 1.8 kg lots, packaged, flushed with 100% CO_2, and sealed with a Multivac AG 500 sealer (Koch, Kansas City, MO). Control samples were stored in metal cans fitted with screen lids. Test and control samples were stored at 2 °C/65% R.H., 21 °C/55% R.H., and 35 °C/65% R.H. Because the controlled environment room at 21 °C was already in use for a long-term storage study, it was not practical to achieve a relative humidity of 65%. In subsequent discussion, environmental conditions involving temperature and relative humidity are referred to as temperature only. After 10 months of storage, samples were removed from storage and evaluated for moisture content, water absorption, sensory quality, texture (shear force), yeast and mold populations, decortication (seed coat removal) efficiency, and quality of akara (deep-fat fried cowpea paste).

Table 1. Permeability properties of the packaging films used for storing cowpeas

Gas or Vapor	High Density Polyethylene[1] (100 micron thick)	Polyethylene Laminate[2] (90 micron thick)
Oxygen ($l/m^2/24$ h)[3]	11.5	< 0.2
Carbon dioxide ($l/m^2/24$ h)[3]	36.0	< 1.0
Water vapor ($g/m^2/24$ h)[4]	18.4	0.077

[1]Sacharow and Griffin 1980
[2]Technical Service Bulletin, Curwood, Inc., New London, WI
[3]At 25 °C, 0% R.H., 1 atm
[4]At 37.8 °C, 90% R.H., 1 atm

Analysis of Whole Seeds and Meal

Moisture content of whole seeds was determined by drying 5 g samples in a forced-air oven at 103 °C for 72 h (AACC 1983). Moisture content of cowpea meal processed from stored seeds was determined by vacuum drying 5 g samples for 24 h at 70 °C. Water absorption was determined by soaking peas in excess tap water for 15 h at 25 °C, after which peas were blotted dry and weighed. Peas to be evaluated for sensory quality and objective texture measurements were soaked overnight (40 g peas in 300 mL of tap water) and boiled for 40 min in the soak water to which sufficient salt had been added to give a final salt concentration of 1%. Samples were evaluated for sensory attributes of appearance, color, aroma, texture, and flavor by seven experienced panelists. Evaluations were conducted in partitioned booths under incandescent lighting. Each sample was evaluated in duplicate, with duplicate evaluations conducted on different days. A scale of 9 to 1 was used for scoring, with 9 representing the highest score for each attribute. Objective texture measurements of 25 g samples were made with a Food Technology Corp. texture-test system equipped with a standard shear-compression cell and 136 kg transducer ring. Peak heights were measured and converted to Newtons/gram (N/g) of cooked sample.

Duplicate samples (20 g) were analyzed after 5 and 10 months storage for total yeast and mold populations. Cowpeas were deposited in 80 mL of 0.1 M potassium phosphate buffer (pH 7.0) and homogenized in a Colworth Stomacher for 2 min. The wash buffer was serially diluted and surface-plated (0.1 mL) in duplicate on plate count agar supplemented with 50 μg/mL each of chlortetracycline-HCl and chloramphenicol. Colonies were counted after 3–5 days incubation at 25 °C.

Decortication

A mini-PRL dehuller developed at the Plant Biotechnology Institute of the National Research Council, Saskatoon, Canada (Reichert *et al.* 1984) was used in decorticating the cowpea samples. Cowpeas from two 1.8 kg lots stored under similar conditions were combined from which 3.2 kg batches were used for decortication. Decortication was done in six one-minute stages. At the end of each stage, the dehuller was stopped and the grain was removed. The fines were separated by passing through a No. 20 Tyler sieve. The hulls, eyes and other light material were aspirated using a seed cleaner. The cleaned material was weighed to determine the percent extraction level or percent kernel removed. A 100 g sample was saved to estimate decortication efficiency parameters, and the remainder was reintroduced into the dehuller for the next stage of decortication. The 100 g samples mentioned above were classified into several categories for estimating decortication efficiencies as described by Hudda (1983).

Analysis of Cowpea Paste and Akara

Akara is a deep-fat fried food which contains cowpea paste as the principal ingredient. It was utilized to evaluate functionality and end product quality that may have been affected by storage. Paste was prepared from decorticated whole seeds and from meal processed from stored, then decorticated seeds. Procedures for preparing meal and paste and frying conditions have been described by McWatters and Brantley (1982) and McWatters (1983). Physical measurements of apparent viscosity of whipped paste and shear force, moisture content, and crude fat content of akara were determined by procedures described previously (McWatters 1983; McWatters and Chhinnan 1985).

Sensory quality attributes of akara were evaluated by an experienced ten-member panel using four-point scales for sponginess (4 = very spongy, 1 = slightly spongy), oiliness (4 = very oily, 1 = slightly oily), aroma and flavor (4 = typical of akara, 1 = severely off or objectionable), and preference (4 = like extremely, 1 = dislike). A set of three to four samples consisting of an unidentified control (sample stored at 2 °C in open metal can) and coded products from the various storage temperature/packaging treatments was evaluated at each session. Samples for each set were prepared in the morning, cooled to room temperature, and covered with aluminum foil until evaluated at mid-afternoon. Samples were arranged in random order on heat-resistant white plates, reheated at 205 °C for 4 min in a conventional oven, and evaluated while warm in individual booths equipped with incandescent lighting. Tap water at room temperature was provided for the panelists to rinse their mouths after tasting each sample.

Statistical Analysis

Data were analyzed using analysis of variance procedure, PROC ANOVA, of Statistical Analysis System-SAS 79 (Helwig and Council 1979).

RESULTS AND DISCUSSION

The permeability properties of the flexible packaging materials (Table 1) were considered in their selection. The laminated film has the capability of maintaining introduced atmospheres and is an effective moisture barrier. While polyethylene does not prevent interchange with atmospheric gases, it is economical, has effective moisture barrier properties, and could possibly retain CO_2 for sufficient time to permit CO_2 fumigation to control infestation by the cowpea bruchid, *Callosobruchus maculatus*. Although both types of flexible packages were flushed with CO_2, only the laminated film retained the CO_2 atmosphere during storage. No insect infestation was detected in any of the packages after 10 months of storage.

Storage temperature and packaging interaction had a significant effect on the moisture content, water absorption, shear force, and yeast/mold populations of cowpeas (Table 2). As was to be expected, moisture content was affected to a greater extent when cowpeas were stored in open cans than in closed flexible bags. For example, the highest (13.1%) and lowest (9.4%) moisture concentrations were observed in samples stored in open cans. There was little difference in the moisture barrier properties of the two flexible films when compared within temperatures except at 35 °C where moisture concentration was higher in cowpeas packaged in high-density polyethylene than in laminated film. Samples stored at 35 °C in either of the flexible packages absorbed less water during soaking than any of the other treatments. Shear force values of cooked peas indicate that increasing the storage temperature increased the hardness of cowpeas packaged in both types of flexible film. For cowpeas stored in open cans, there was no difference in the force required to shear samples at 2 or 21 °C. Cowpeas stored in open cans at 35 °C were significantly harder than similarly packaged samples at 2 or 21 °C but were not as hard as samples packaged in flexible film and stored at 35 °C.

Stanley and Aguilera (1985) and Aguilera and Stanley (1985) recently reviewed the textural defects in cooked reconstituted legumes. They concluded that there are several mechanisms, none being completely dominant, which are responsible for seed hardening and postulated that these mechanisms may have a nonenzymatic as well as enzymatic component. Hardening defects are initiated by structural and compositional factors but can be controlled, at least partially, by storage and processing conditions.

Table 2. Effect of storage temperature and package type on moisture content, water absorption, shear force, and yeast/mold populations of cowpeas[1]

Storage temperature (°C)	Package type[2]	Moisture (%)	Water absorption (%)	Shear force (N/g)	Yeast/Mold Population (per g)	
					5 months	10 months
2	C	13.1^{a}	106.1^{ab}	6.2^{ef}	395^{c}	325^{b}
	H	12.5^{bc}	106.9^{ab}	5.2^{g}	1162^{a}	662^{a}
	L	12.7^{ab}	106.5^{ab}	5.5^{fg}	682^{b}	747^{a}
21	C	9.4^{g}	109.4^{a}	6.0^{ef}	98^{d}	45^{c}
	H	12.4^{bc}	105.0^{ab}	6.5^{e}	108^{d}	12^{c}
	L	12.2^{c}	104.3^{b}	7.4^{d}	53^{d}	10^{c}
35	C	10.5^{f}	102.9^{b}	12.9^{c}	13^{d}	0^{c}
	H	11.6^{d}	93.2^{c}	18.8^{a}	3^{d}	5^{c}
	L	11.1^{e}	96.2^{c}	15.3^{b}	0^{d}	0^{c}

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Unless otherwise indicated, data were taken after 10 months storage.

[2]C = control samples stored in open metal cans, H = samples stored in high-density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

The rate of death of yeasts and molds on cowpeas stored at 2 °C was slower than the rate of death at 21 or 35 °C. After 5 and 10 months, populations were significantly higher in all samples stored at 2 °C. Storage under temperature and relative humidity conditions evaluated in this study would protect cowpeas against fungal deterioration.

For sensory data analysis of whole seeds and akara, control sample scores corresponding to each set were analyzed to test their variation among sets. No statistical difference at the 5% significance level was found among controls. This allowed the sensory data for control samples to be pooled and analyzed, as the objective data were, as a function of storage temperature and package type.

Analysis of sensory data revealed that appearance, color, and aroma scores of soaked, boiled cowpeas were not significantly influenced by the conditions of storage. Flavor scores were significantly influenced by storage temperature but not by package type. Peas stored at 2 and 21 °C received the same mean flavor score (7.5) which was significantly higher than the mean flavor score (6.5) for peas stored at 35 °C. Panelists frequently described the flavor of samples stored at 35 °C as "undercooked" and "weak;" off-flavor was rarely mentioned as a reason for the lower score of the 35 °C samples.

Storage temperature and package type had major effects on texture scores (Table 3). Mean scores for peas stored at 2 and 21 °C were not significantly different from each other but were significantly higher than the mean score for peas stored at 35 °C. Samples stored in polyethylene and laminate bags had similar mean scores for texture which were significantly lower than the mean score for peas stored in open cans. Panelists frequently described samples which received low texture scores as "hard" and "undercooked." The sensory evaluations for texture coupled with the objective data for water absorption and texture (shear force values) indicate that the flexible package/CO_2 atmosphere treatment did not prevent but rather enhanced the development of a hardened condition in cowpeas stored at high temperature and high humidity.

Table 3. Sensory evaluation of the texture of cowpeas cooked after 10 months of storage[1]

Storage temperature (°C)	Package Type			Mean
	Open can	Polyethylene bag	Laminate bag	
2	7.4	7.2	7.4	7.3[a]
21	7.4	7.4	7.2	7.3[a]
35	5.7	4.4	4.8	5.2[b]
Mean	6.9[a]	6.3[b]	6.5[b]	

[1]Means values in a column or row not having a common superscript are significantly different at $P \leq 0.05$

A recent study by Onayemi *et al.* (1986) has shown that storing cowpeas in a nitrogen atmosphere effectively maintained the good quality attributes of cowpeas, including nutritional and water imbibition properties. Nitrogen storage was more effective than metal drums or jute bags for maintaining seeds with good cookability characteristics and was recommended for use in the major cowpea producing regions of Africa as a means of reducing food loss and preventing the misuse of chemical preservation methods.

Hudda (1983) defined various parameters describing decortication efficiency such as PEL (percent extraction level or percent of usable material recovered), PWOE (percent of decorticated cowpeas with the hilum completely removed), and PUD (percent of completely undecorticated cowpeas). Estimates of PWOE and PUD at 90% extraction level (PEL) for various storage conditions are given in Table 4. Improvement in decortication efficiency is seen from the increase in PWOE values and reduction in PUD values. Generally, PWOE values increased with the increase in storage period and storage temperature. However, storage period had a more pronounced affect than storage temperature. Although no general pattern was observed in PUD values, PUD values of cowpeas stored at 35 °C were estimated to be lower after 10 months of storage compared to those after 5 months of storage. Increase in hardness of the cotyledons in storage is believed to contribute to the improvement in decortication efficiency.

In evaluating the effects of storage of cowpea seeds on akara quality, it was necessary to adjust the moisture in paste made from either whole seeds or meal to a uniform content before frying. Moisture content of whole seeds and meal and the quantity of water required for these adjustments are shown in Table 5. Final moisture content before frying of paste from whole seeds and meal was 61.3% and 60.0%, respectively. For whole seeds, pastes made from 2 °C samples required the least additional water whereas the 35 °C samples, having decreased water absorption capacity, required the most additional water.

The effect of temperature for storing cowpeas on some physical characteristics and sensory scores of akara made from meal and whole seeds are shown in Table 6. For akara prepared from meal, greater force was required to shear samples made from peas stored at 35 °C than at 2 and 21 °C. This may have been due to the hardening phenomenon associated with high-temperature/high moisture storage, to the significantly lower crude fat content of the 35 °C products, or to both factors. Preference scores for akara prepared from either meal or whole seeds and aroma-flavor scores of akara made from whole seeds were significantly lower when cowpeas were stored at 35 °C than at 2 or 21 °C. Panelists rated the flavor of akara from the 2 and 21 °C treatments as "reasonably typical of akara" whereas akara from the 35 °C treatment was rated as "slightly off." For preference scores, panelists indicated that they "liked moderately" akara made from the 2 and 21 °C treatments whereas akara from the 35 ° treatment was "liked slightly." Other sensory attributes, i.e., sponginess and oiliness, were not influenced significantly by storage temperature or type of packaging.

Table 4. Decortication efficiency of cowpeas at 90% extraction level for selected storage conditions

Storage temperature (°C)	Package type[1]	Percent of seeds with hilum completely removed (PWOE)		Percent of completely undecorticated seeds (PUD)	
		Duration of Storage, months		Duration of Storage, months	
		5	10	5	10
2	C	77.1	82.5	9.3	10.9
	H	73.2	78.1	11.4	12.2
	L	65.5	81.3	19.1	8.5
35	C	76.0	83.4	15.8	7.7
	H	76.2	85.4	13.8	9.2
	L	75.7	86.8	11.5	10.3

[1]C = control samples stored in open metal cans, H = samples stored in high-density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

Table 5. Moisture content of whole cowpea seeds after 10 months of storage and of meal processed from stored seeds and the quantity of water added to adjust cowpea pastes to the same moisture content before frying

Storage temperature (°C)	Package type[1]	Whole Seeds				Meal	
		Moisture Content (%)		Wt. soaked, dehulled peas (g)	Water added (ml)[2]	Moisture content (%)	Water added (ml)[3]
		Initial	Soaked peas				
2	C	13.1	33.8	248.88	167	11.0	245
	H	12.5	33.4	249.87	168	10.9	246
	L	12.7	33.8	250.39	166	10.5	248
21	C	9.4	30.2	246.69	188	9.8	251
	H	12.4	32.3	245.78	176	10.9	246
	L	12.2	33.2	249.76	169	11.0	245
35	C	10.5	29.1	240.02	194	10.2	249
	H	11.6	30.0	239.93	189	10.6	247
	L	11.1	30.3	242.42	186	10.6	247

[1]C = control samples stored in open metal cans, H = samples stored in high density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

[2]Amount of water added to 232 g of soaked, dehulled peas was calculated such that the final moisture content of the paste was 61.3%.

[3]Amount of water added to 200 g of meal such that the final moisture content of the paste was 60.0%.

Table 6. Effect of temperature for storing cowpeas on some physical characteristics and sensory scores of akara prepared from meal and whole seeds[1]

Storage temperature (°C)	Meal			Whole Seeds	
	Shear force (N/g)	Crude fat[2] (%)	Preference score	Aroma-flavor score	Preference score
2	9.42[b]	23.77[a]	2.9[a]	3.1[a]	3.0[a]
21	9.31[b]	24.74[a]	3.1[a]	3.1[a]	2.9[a]
35	10.42[a]	21.13[b]	2.3[b]	2.6[b]	2.5[b]

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Cowpeas were stored for 10 months, and meal was processed from stored seeds.
[2]Dry weight basis.

The interaction of storage temperature and type of packaging had a significant effect on the viscosity of paste made from either meal or whole seeds and on several characteristics of akara (Table 7). Paste made from hydrated meal had lower and more variable viscosity values overall than paste made from whole seeds. This may have been due to disruption of the usual pathways and mechanisms of water imbibition for intact seeds (Sefa-Dedeh and Stanley 1979) which were altered by milling rather than to differences in method and time of hydration for preparing paste from whole seeds and meal (McWatters and Chhinnan 1985). The lowest viscosity values were noted in meal-based paste from the 35 °C storage treatment. Aroma-flavor scores of meal-based akara were higher when the peas from which the meal was made were stored at 2 or 21 °C than at 35 °, regardless of the type of packaging. For akara prepared from whole seeds, relationships between storage conditions and shear force values, moisture content, and crude fat content were not readily apparent because the data were variable and unordered. This variation was especially evident in the moisture and fat content data at 35 °C where the highest and lowest values were observed.

Table 7. Effect of cowpea storage conditions on viscosity of cowpea paste and some characteristics of akara[1]

Storage temperature (°C)	Package type[2]	Meal		Whole Seeds			
		Paste	Akara	Paste	Akara		
		Apparent viscosity[3] (Pa.s)	Aroma-flavor score	Apparent viscosity (Pa.s)	Shear force (N/g)	Moisture (%)	Crude fat[4] (%)
2	C	21.7^{a}	3.1^{ab}	37.6^{a}	13.27^{bc}	43.1^{bc}	36.5^{ab}
	H	20.3^{ab}	3.0^{ab}	35.5^{b}	12.56^{bcd}	44.9^{ab}	35.1^{abc}
	L	19.5^{b}	3.0^{ab}	35.6^{b}	12.69^{bcd}	45.1^{ab}	34.6^{a-d}
21	C	16.5^{c}	3.3^{ab}	35.2^{b}	11.39^{d}	46.2^{a}	33.0^{cd}
	H	20.6^{ab}	3.4^{a}	36.5^{ab}	13.79^{ab}	42.7^{bc}	35.5^{abc}
	L	20.9^{ab}	3.0^{ab}	36.3^{ab}	11.89^{cd}	45.3^{ab}	34.9^{a-d}
35	C	15.3^{cd}	2.5^{dc}	36.6^{ab}	13.20^{bc}	47.4^{a}	31.8^{d}
	H	14.8^{d}	2.1^{d}	35.0^{b}	15.15^{a}	41.9^{c}	37.6^{a}
	L	15.4^{cd}	2.8^{bc}	35.0^{b}	13.86^{ab}	44.8^{ab}	34.1^{bcd}

[1]Values in a column not having a common superscript are significantly different at $P \leq 0.05$. Cowpeas were stored for 10 months, and meal was processed from stored seeds.

[2]C = control samples stored in open metal cans, H = samples stored in high density polyethylene bags flushed with CO_2, L = samples stored in laminated bags flushed with CO_2.

[3]Brookfield Viscometer Model RVT, Model C Helipath stand, T-B spindle, 5 rpm; dial readings × conversion factor of 0.8 = values in Pa.s.

[4]Dry weight basis.

CONCLUSIONS

Storage at 2 and 21 °C was effective in maintaining the quality of cowpeas for use as a reconstituted, boiled vegetable and as akara (fried cowpea paste), regardless of packaging treatment. The flexible packaging/CO_2 atmosphere treatment did not prevent but actually enhanced the development of a hardened condition in cowpeas stored under conditions of high temperature and high humidity. Cowpeas would be protected from fungal deterioration under the storage conditions utilized in this study. The improvement in decortication efficiency which occurred may have been due to an increase in seed hardness. While practical, effective approaches are of immediate need to prevent quality losses in legumes during conditions of adverse storage, an even greater need exists to elucidate the underlying mechanisms responsible for seed hardening.

This study has reconfirmed that high temperature and high humidity storage conditions should be avoided if the quality of cowpea seeds is to be maintained. If cowpeas are to be used as flour, milling prior to development of a hardened condition may minimize the undesirable textural changes that occur when whole seeds are stored under adverse conditions.

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COMPUTER CODES AND THEIR APPLICATION

A MICROCOMPUTER BASED ALGORITHM FOR QUANTITATIVE DETERMINATION OF VITAMINS FROM TURBIDIMETRIC METHODS[1]

V.N.M. RAO, K. WEBB and R.R. EITENMILLER[2]

Department of Food Science
University of Georgia
Athens, Georgia 30602

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INTRODUCTION

Vitamin assay by microbiological or other techniques requires development of a standard curve of absorbance at a selected frequency versus vitamin concentration. The standard curve thus developed is used for determining the vitamin content from the absorbance of an unknown solution. The techniques for developing a model to describe this standard curve have been a topic of considerable study by several researchers (Voigt *et al.* 1979). The use of a quadratic or higher order equation has been studied by Kavanagh (1977), and based on several vitamin assays has been found to be more accurate than a linear type model. The objective of this work is not to fit a specific model but rather to present two techniques to accurately draw and interpolate the standard curve: (1) by Lagrange's interpolating polynomials and (2) by a fourth degree polynomial regression.

[1]The use of trade names in this publication does not imply endorsement by the authors or the University of Georgia nor criticism of similar ones not mentioned.
[2]Author to whom all correspondence should be addressed.

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THEORETICAL CONSIDERATIONS

The simple theorem of polynomial interpolation upon which many numerical analyses rest says, in effect, that a straight line can be passed through 2 points, a parabola through 3, a cubic through 4, and so on. Let (X_1, Y_1), (X_2, Y_2),..... (X_n, Y_n) be a set of n points. This set of n points can be interpolated with an $(n-1)$th degree polynomial:

$$Y = P(X) = Y_1 \frac{(X-X_2)(X-X_3)\ldots(X-X_n)}{(X_1-X_2)(X_1-X_3)\ldots(X_1-X_n)} + Y_2 \frac{(X-X_1)(X-X_3)\ldots(X-X_n)}{(X_2-X_1)(X_2-X_3)\ldots(X_2-X_n)}$$

$$+ \ldots + Y_n \frac{(X-X_1)(X-X_2)\ldots(X-X_{n-1})}{(X_n-X_1)(X_n-X_2)\ldots(X_n-X_{n-1})}$$

This polynomial is known as the Lagrange's interpolating polynomial (Davis 1963) which generates a curve that passes through all the n points. However, there is an inherent practical problem with this approach. Interpolating 50 points would require a polynomial of degree 50, which is quite a time consuming task even for a computer program and more importantly would yield a curve with too many fluctuations leading to erroneous results. The method developed in this work uses a cubic spline to patch every 4 points together into a smooth curve. The spline is used for interpolating the 2 middle points and the next set of 4 points are used to develop the next spline. The endpoints are patched by a little more complex technique of generating a cubic spline up to the mid-point of the endpoint and the point next to it. Linear interpolation is used to patch the distance from the mid-point to the endpoint itself. It should be clear that the accuracy of this method is valid except for the endpoints themselves. A typical curve generated by this technique is shown in Fig. 1. The polynomial regression technique uses a fourth degree polynomial to fit the best curve through a set of points by the least squares method. The method is detailed in any textbook of statistics.

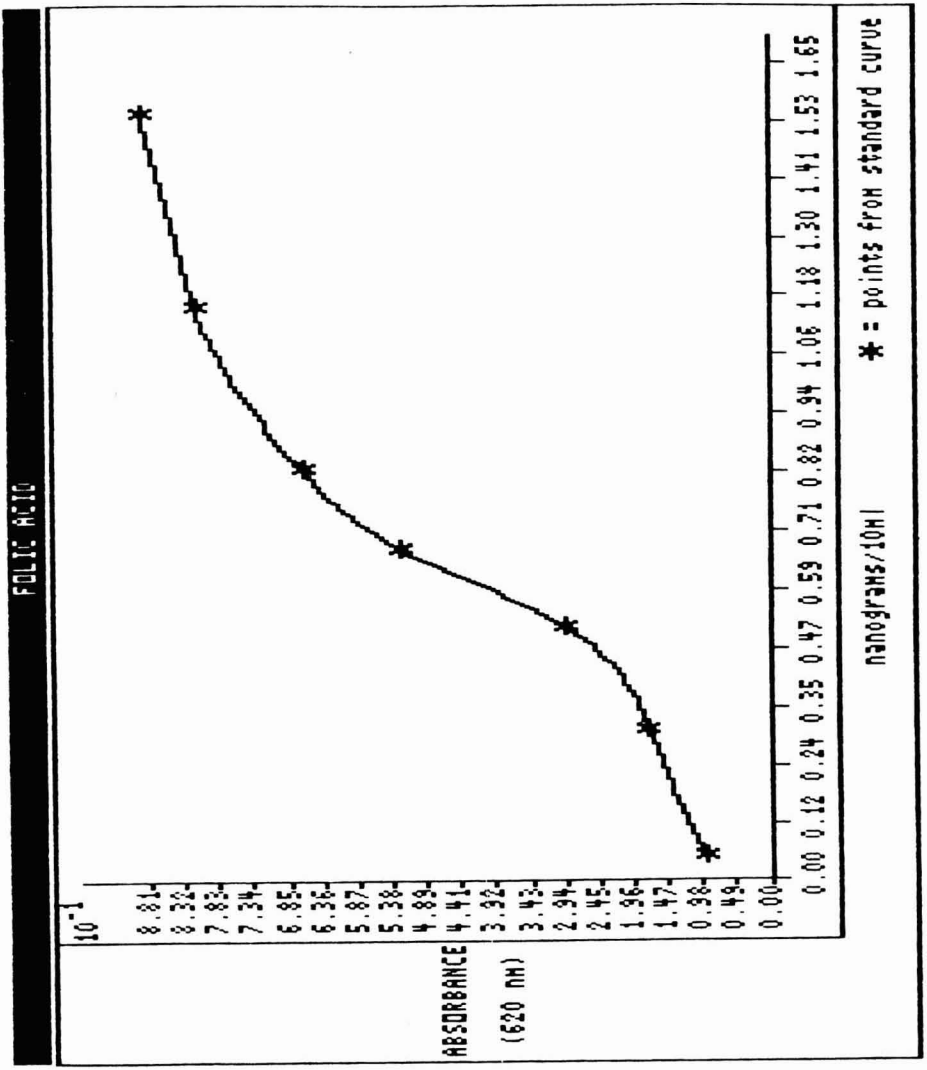

FIG. 1.
A COMPUTER GENERATED GRAPH OF ABSORBANCE AT 620 NM VERSUS VITAMIN CONCENTRATION BY LAGRANGE'S INTERPOLATING POLYNOMIAL

COMPUTER ALGORITHM

The algorithm developed here is shown as a flow chart in Fig. 2. The program was coded in PASCAL and compiled to a machine language code on an IBM personal computer. The user can access the program directly from the operating environment of the computer (usually MS DOS) by typing the name of the program at the DOS prompt. The program logo and copyright information are displayed on the screen and the user is then prompted for an answer (Y or N) for obtaining a hard copy of the results and the techniques used (interpolation or polynomial regression). The name of the vitamin assayed, along with the input data from the standard curve, are entered via the keyboard. The program allows for correction of the input data after all the data has been entered and allows the user to save the data on a disk file. The standard curve is then analyzed by the program and a set of 100 points are generated by the program using the method of cubic splines or polynomial regression. The user can then input Sample ID, number of aliquots, replications per aliquot, and the absorbance values. The computer will then calculate the corresponding vitamin amounts along with mean and standard deviation for each aliquot and a grand average and standard deviation for all the aliquots. An option for determining the percent USRDA and label declaration of the vitamin is presented, the necessary calculations are performed and the answers are displayed on the screen. The standard curve is then displayed on the screen along with an option for obtaining a hard copy on the printer. A typical session on the computer is shown in Fig. 3.

CONCLUSIONS

The computer algorithm developed in this work has been used for vitamin assays at the University of Georgia for the past several years. Each of the two options allowed in this program has certain advantages and disadvantages. An experienced user, after running both the options, can decide which of the two methods is particularly more suitable for his/her data. The use of this program at the University of Georgia has resulted in more accurate results compared to hand drawn standard curves and time savings over the use of polynomial curve fitting techniques on the mainframe. While the techniques were applied to turbidimetric data in this study, they would be equally useful for radiometric or chemical methods that rely upon standard curve generation. As the availability of microcomputers in the laboratory increases, this technique should become a valuable tool for such assays. The program has been tested on several computers including IBM-PC, Zenith-PC, COMPAQ and other IBM compatible personal computers. The program is readily available from the authors.

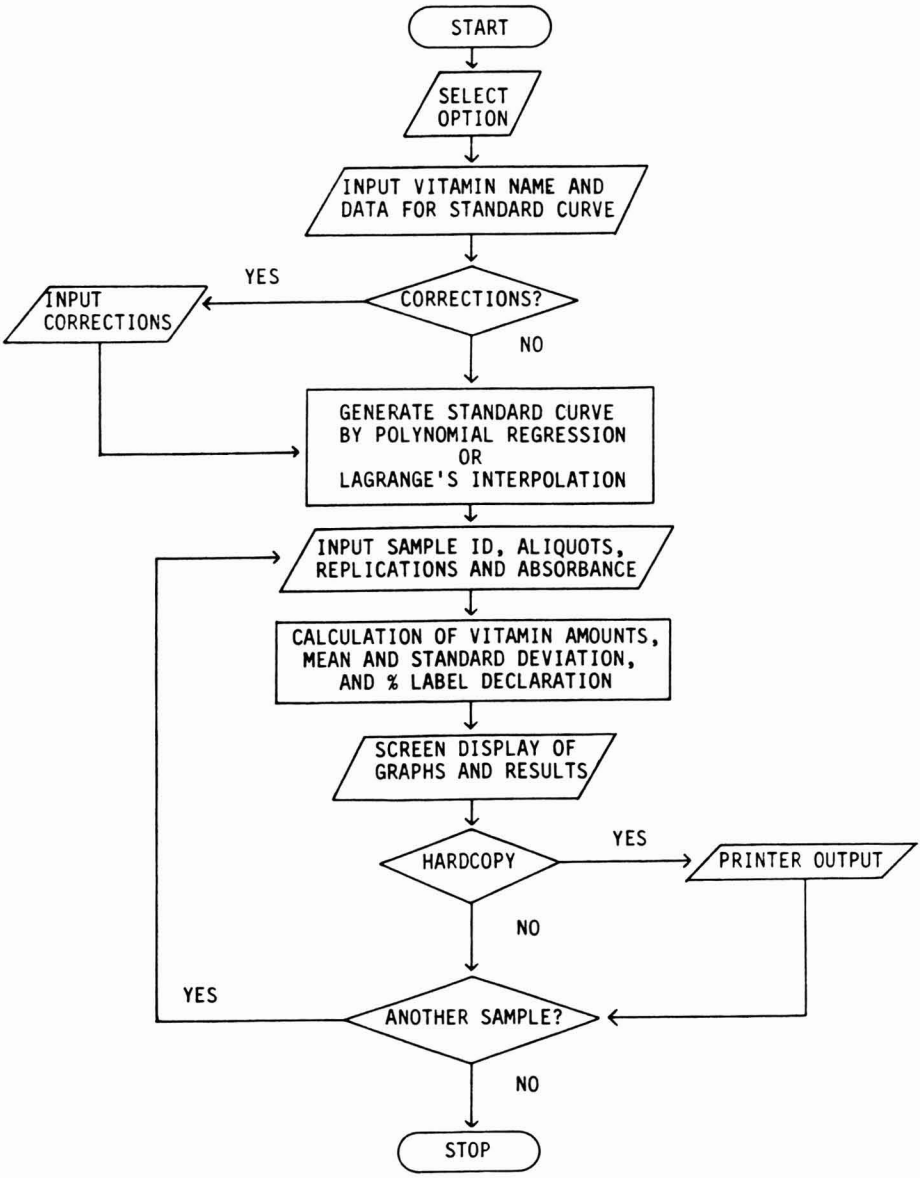

FIG. 2.
FLOW CHART OF COMPUTER PROGRAM FOR QUANTITATIVE DETERMINATION OF VITAMINS

```
VITAMIN ANALYSIS (Program coded by Rao, Webb and Eitenmiller)
(C) Copyright, University of Georgia, 1986

Vitamin being assayed:     FOLIC ACID        Date: 7/23/86

 Data for standard curve
_____________________________________________________
Nanograms/10 ml                Absorbance
   0.0500                       0.100000
   0.3000                       0.180000
   0.5000                       0.300000
   0.6500                       0.530000
   0.8050                       0.670000
   1.1200                       0.820000
   1.5000                       0.890000
_____________________________________________________
_____________________________________________________

Sample I.D. : 1(2)

Aliquot # 1   //   conversion factor = 125.00  //   diff. = 0.00

          Corrected Absorb.     nanograms/10ml       micrograms/100 units
rep # 1        0.2200              0.407350             50.918707
rep # 2        0.2100              0.387500             48.437493

mean           0.2150              0.397425             49.678100
std            0.0071              0.014036              1.754483
_____________________________________________________________________

Aliquot # 2   //   conversion factor = 62.50  //   diff. = 0.01

          Corrected Absorb.     nanograms/10ml       micrograms/100 units
rep # 1        0.4200              0.579283             36.205197
rep # 2        0.4400              0.591431             36.964437

mean           0.4300              0.585357             36.584817
std            0.0141              0.008590              0.536864
_____________________________________________________________________
mean for all aliquots :  43.13 micrograms/100 units with std. dev. of 7.633271
mean for all aliquots :  76.60 micrograms/6 fl oz

100 % label declaration :  85.00 micrograms/6 fl oz
% declared found        :  90.12
_____________________________________________________________________
_____________________________________________________________________
```

FIG. 3.
A TYPICAL PRINTOUT USING THE COMPUTER PROGRAM FOR VITAMIN DETERMINATION

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DATA BANK

PROXIMATE AND WATER SOLUBLE VITAMIN COMPOSITION OF GRAPEFRUIT AND ORANGES

C.D. JOHNSON, W.D. BRYAN and R.R. EITENMILLER[1]

Department of Food Science
University of Georgia
Athens, Georgia 30602

Accepted for Publication December 29, 1986

ABSTRACT

The proximate composition and water soluble vitamin content of Texas Ruby Red grapefruit, Florida pink grapefruit and Florida oranges was determined. Niacin, thiamin, vitamin B_6 and total folacin were significantly ($\alpha = 0.01$) higher in Florida pink grapefruit than in Texas Ruby Red grapefruit. Riboflavin, free folacin and total pantothenic acid were significantly ($\alpha = 0.01$) higher in the Texas Ruby Red variety. Riboflavin and total pantothenic acid were significantly ($\alpha = 0.01$) higher in oranges sampled at a marketing time representing maximum availability to the consumer while free pantothenic acid concentration was significantly ($\alpha = 0.01$) higher in oranges sampled near minimum availability. Although some differences were observed between values obtained and those reported in Handbook 8-9, mean values approximated those previously reported.

INTRODUCTION

With increased consumer awareness of nutritional composition of foods, the USDA Human Nutrition Information Service has been expanding and updating USDA Handbook 8 (Gebhardt *et al.* 1982). USDA determined that comprehensive data were lacking for grapefruit and oranges, two popular and widely consumed citrus fruits. This report represents part of a larger study completed for

[1]Author to whom correspondence should be sent.

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USDA to provide current compositional data for these fruits. In addition to proximate analysis, water soluble vitamin determinations included in this report were niacin, riboflavin, thiamin, vitamin B_6, total ascorbic acid, total and free folacin and total and free pantothenic acid. The effect of marketing time on the water soluble vitamin content of Florida oranges was also determined as defined by purchase time at periods of maximum and near minimum market availability to the consumer.

MATERIALS AND METHODS

Sampling Procedure

In order to obtain data representative of availability to consumers across the United States, Texas Ruby Red grapefruit were purchased from Atlanta, Denver and Kansas City while Florida pink grapefruit were purchased from Seattle, Minneapolis and Boston. Florida oranges were purchased at times representing periods of maximum and near minimum product availability to the consumer by following the United Fresh Fruit and Vegetable Association Supply Guide (Magoon 1981). Orange samples were obtained from Atlanta, Boston and Tampa in January 1983 (maximum availability) and Atlanta, Boston and Minneapolis in May 1983 (near minimum availability). Samples consisting of 10–20 kg of fruit were obtained at each sampling time.

The edible portion of each sample was divided into two subsamples of at least 500 g and chopped using a food processor equipped with stainless steel blades. Immediately after chopping and before freezing, aliquots for vitamin analysis were removed. For each nutrient, the two subsamples were analyzed in duplicate.

Proximate analyses. Nitrogen and moisture were assayed by AOAC methods (1980). Protein (AOAC Sec. 2.055-2.056, 1980) was determined by calculating Kjeldahl nitrogen to protein by using a factor of 6.25. Samples for moisture (AOAC Sec. 32.010, 1980) were brought to apparent dryness under an infrared lamp and then placed in a vacuum oven for 2 h at 70 °C at a pressure of 50 mm Hg. Fat content was determined using an isopropanol/methylene chloride extraction procedure (Landen 1982).

Water soluble vitamin analyses. Microbiological assays were used for all vitamins except total ascorbic acid which was determined fluorometrically (AOAC Sec. 43..056, 1980). The following assay organisms were used: *Lactobacillus plantarum* ATCC 8014 for free and total pantothenic acid and niacin; *Lactobacillus viridescens* ATCC 12706 for thiamin; *Lactobacillus casei* ATCC 7469 for riboflavin and free and total folacin; *Saccharomyces uvarum* ATCC

9080 for vitamin B_6. AOAC methods (Sec. 43.188, 1980) were used for extraction and analysis of vitamin B_6; however, total vitamin B_6 rather than the three individual B_6 forms was determined using pyridoxine as the standard. Total folate was quantitated after sample digestion by chicken pancreas conjugase and Pronase^R (Yamada 1979). Total pantothenic acid was extracted according to the procedure of Zook *et al.* (1956) and assayed by AOAC methods (Sec. 43.164, 1980). A combined acid and enzyme extraction (Saarivirta 1969) was used for thiamin, niacin and riboflavin. Recovery studies were completed for each vitamin analysis. In all cases, recoveries of added vitamins were greater than 94%.

Statistical Analysis

Analysis of variance was preformed using the Statistical Analysis System package (Helwig and Council 1979).

RESULTS AND DISCUSSION

Mean protein, moisture and fat content in g/100 g grapefruit were 0.69, 89.03 and 0.02, respectively. There was no significant ($\alpha = 0.01$) difference between Florida pink and Texas Ruby Red varieties. Protein and moisture values approximate those reported in Handbook 8-9. However, mean fat content was lower than previously reported (0.02 compared to 0.10 reported in Handbook 8-9).

Mean protein, moisture and fat content in g/100 g oranges were 0.79, 85.7 and 0.13, respectively. Protein content was significantly ($\alpha = 0.01$) higher for samples purchased during minimum availability. Moisture content was significantly ($\alpha = 0.01$) higher for samples purchased during maximum availability. There was no significant difference for fat content between the two sampling periods. The mean moisture value for oranges approximated the Handbook 8-9 value. The mean protein content found was higher than the Handbook value (0.79 g/100 g compared to 0.70 g/100 g) and the mean fat content found was somewhat lower than the Handbook value (0.13 g/100 g compared to 0.21 g/100 g).

Table 1 contains values for water soluble vitamin content of grapefruit and compares the overall means to Handbook 8-9 values. There was a significant difference between the Florida pink and Texas Rudy Red varieties for all vitamins assayed with the exception of total ascorbic acid and free pantothenic acid. Niacin, thiamin, vitamin B_6 and total folacin were present in significantly ($\alpha = 0.01$) greater amounts in the Florida pink grapefruit samples. Riboflavin, free folacin and total pantothenic acid were all present in significantly ($\alpha = 0.01$) higher amounts in the Texas Ruby Red grapefruit samples. Thiamin,

Table 1. Water soluble vitamin content of grapefruit

Vitamin	mg/100 g[a]				
	Florida Pink	Texas Ruby Red	Overall		Handbook 8-9
	Mean ± SD[b]	Mean ± SD[b]	Mean[c]	Range[d]	Mean[e]
Niacin*	0.281 ± 0.029	0.120 ± 0.029	0.197	0.107 - 0.288	0.200
Riboflavin*	0.014 ± 0.001	0.019 ± 0.003	0.017	0.014 - 0.022	0.020
Thiamin*	0.022 ± 0.004	0.014 ± 0.001	0.018	0.013 - 0.024	0.040
Vitamin B_6*	0.028 ± 0.004	0.024 ± 0.004	0.026	0.021 - 0.032	0.042
Total Ascorbic Acid	26.68 ± 1.94	27.03 ± 2.84	26.85	25.00 - 30.30	37.0
Free Folacin (μg)*	2.51 ± 0.43	3.45 ± 0.47	2.96	2.10 - 3.92	-[f]
Total Folacin (μg)*	6.79 ± 0.86	5.29 ± 0.52	6.15	5.15 - 7.63	9.4
Free Pantothenic Acid	0.127 ± 0.014	0.119 ± 0.017	0.123	0.109 - 0.139	-[f]
Total Pantothenic Acid*	0.194 ± 0.016	0.222 ± 0.023	0.207	0.192 - 0.247	0.283

[a]Concentrations are reported as mg/100 g except for free and total folacin which are reported as μg/100 g.
[b]$n \geq 12$
[c]$n \geq 24$
[d]Range = highest and lowest mean value from each of the six cities sampled.
[e]Values are for Florida -- raw, pink and red.
[f]Not reported in Handbook 8-9.
*Significant difference ($\alpha = 0.01$) between varieties.

Table 2. Water soluble vitamin content of oranges

Vitamin	mg/100 g[a]				
	Maximum Market Availability[b]	Minimum Market Availability[c]	Overall Mean[d]	Overall Range[e]	Handbook 8-9 Mean[f]
Niacin	0.318 ± 0.010[g]	0.323 ± 0.048	0.320	0.314 - 0.332	0.400
Riboflavin*	0.031 ± 0.002	0.023 ± 0.005	0.027	0.019 - 0.033	0.040
Thiamin	0.082 ± 0.032	0.103 ± 0.027	0.093	0.071 - 0.109	0.100
Vitamin B_6	0.049 ± 0.003	0.050 ± 0.004	0.050	0.046 - 0.054	0.051
Total Ascorbic Acid	51.93 ± 3.84	52.79 ± 0.68	52.36	49.07 - 57.11	45.0
Free Folacin (μg)	7.90 ± 0.91	8.57 ± 0.63	8.24	7.09 - 9.35	-[h]
Total Folacin (μg)	19.46 ± 1.45	20.21 ± 1.41	19.84	18.00 - 21.86	17.3
Free Pantothenic Acid*	0.129 ± 0.015	0.143 ± 0.015	0.137	0.115 - 0.151	-[h]
Total Pantothenic Acid*	0.189± 0.021	0.169 ± 0.011	0.179	0.166 - 0.208	0.250

[a]Concentrations are reported as mg/100 g except for free and total folacin which are reported as μg/100 g.
[b]Sample purchased in January 1983 in Atlanta, Boston and Tampa.
[c]Sample purchased in May 1983 in Atlanta, Minneapolis and Boston.
[d]$n \geq 24$.
[e]Range = highest and lowest mean value from each of the six cities sampled.
[f]Values are for Florida oranges.
[g]Mean ± SD ($n \geq 12$).
[h]Not reported in Handbook 8-9.
*Significant difference ($\alpha = 0.01$) between sampling times.

vitamin B_6, total ascorbic acid, total folacin and total pantothenic acid were lower than Handbook 8-9 values. Niacin and riboflavin values approximated those in Handbook 8-9.

Table 2 contains values for water soluble vitamin content of oranges sampled near maximum (January) and minimum (May) market availability to the consumer and compares the overall means to Handbook 8-9. There was no significant difference in water soluble vitamin content between sampling times except for riboflavin and free and total pantothenic acid. Riboflavin and total pantothenic acid were found at significantly ($\alpha = 0.01$) higher levels when sampled near maximum market availability and free pantothenic acid was at significantly higher levels when sampled near minimum market availability. Niacin, riboflavin and total pantothenic acid values were lower than those in Handbook 8-9. Total ascorbic acid and total folacin values were higher than those in Handbook 8-9. Thiamin and vitamin B_6 values approximated those in Handbook 8-9. One explanation for differences between values obtained in this study and those previously reported in Handbook 8-9 for grapefruit and oranges may lie in varietal differences between samples.

ACKNOWLEDGMENTS

This research was supported by USDA Contract 53-32U4-1-219 from the Human Nutrition Information Service, Consumer Nutrition Division, USDA. The assistance of the following suppliers was greatly appreciated: D'Arrigo Bros. Co. of Massachusetts, Chelsea, MA; GM Gamble Robinson Co., Minneapolis, MN; Pacific Robinson Co., Seattle, WA: Cerniglia Produce Co., Inc., Forest Park, GA; King Soopers, Denver, CO: Associated Wholesale Grocers, Inc., Kansas City, KS; and Orange Blossom Groves, Seminole, FL.

The technical assistance of F. Maddox and G. Zeigler was greatly appreciated.

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BOOK REVIEWS

Book Dairy Technology — Vol. 1 (Advances in Processing) Elsevier Applied Science Publisher Ltd. pp. 438, $72.75.

This book contains eight chapters contributed by distinguished specialists in the area of milk products processing. First chapter deals with the aspects of heat induced changes and kinetic behavior of different species. Recent advances in the separation technology such as self-desludging centrifuges, application of ultrafiltration and reverse osmosis are well elucidated in chapters two and five. Modern approach to butter processing and fat rich spreads are covered in chapter three. Energy saving techniques in the areas of high energy intensive unit operations, like evaporation and drying is explicitly detailed in chapter four, which also covers the effect of process parameters on product quality.

Problem of surplus milk and byproducts such as whey is very well explained by utilizing whey constituents in chapter six. Casein and coprecipitates also find valuable applications in the dairy and nondairy uses in chapter seven. The last chapter introduces terminologies and logics of automation. Fundamentals and applied aspects of process control are well explained. Aspects of operation and maintenance of electronic gadgets are also described.

Dairy engineers and scientists working for milk plants would benefit from modernizing their processing. Planners would find it fascinating to note aspects of energy saving, utilization of byproducts and economizing operational costs. Students of Dairy Science the world over can become acquainted with the latest advances and thus update their knowledge.

This book is very well presented and is a valuable document of recent times.

S.P. AGRAWALA

Book Dairy Technology — Vol. II, (Advances in Milk Products) Elsevier Applied Science Publisher Ltd. pp. 438, $72.75.

In this book a good attempt has been made by sixteen specialist to update the dairy product manufacturing techniques. Processing and the most recent equipment for the manufacture of yoghurt are well explained in the first chapter. Most of the latest packaging machines for yoghurt also find good description therein. Chapter two and three detail the origin and classification of soft, semi-hard and hard cheese. They also include the modern techniques for improving the nutritional and other qualitative attributes of cheeses. Description of novelty frozen products found in chapter four makes the text lively and interesting. The trend for latest frozen product development has been beautifully brought out in this chapter. This book is the first of its kind to compile the physical properties of milk products and their role in the process. Chapters six and seven on chemical and microbial analysis discuss all the latest techniques employed for quality control. Also, the last chapter has usefully highlighted the importance of milk processing in the tropical countries. An attempt is made to project existing situation and possible suggestions to improve milk production, processing and marketing. Excellent as the book is, it could be more valuable if recent photographs other than those taken in 1957 were included.

Journal of Food Processing and Preservation 11(1987)91–94.

This book will be very useful to the dairy scientist and the planners interested in elevating the concept of milk product manufacturing technique. It will also set the future trend for adopting the most accurate and more advanced technologies, especially for the new dairy plants.

S.P. AGRAWALA

Food Science, 4th edition, Norman N. Potter, Avi Publishing Co., Inc., P.O. Box 831, Westport, Conn. 06881, 735 pp. 1986. $38.00.

Instructors of introductory courses in food science should consider the 4th edition of *Food Science* as a text. Potter states his purpose is to "introduce and survey the complex and fascinating interrelationships between the properties of food materials and the changing methods of handling and manufacturing them into an almost unlimited number of useful products." The book accomplishes this through a fairly comprehensive coverage of food processing. Potter was conscientious in updating dated information presented in the previous edition of the book.

Very few texts cover the range of food subject matter which is contained in Potter's book. In the first chapter, he acquaints the student with the field and advocates food science as a career. Educational requirements and activities in food science are described. The next chapter describes the food industry in terms of size and components. Material acquisition, manufacture and distribution are exemplified by production of bread and orange juice concentrate. Two chapters briefly allude to the chemical composition of food and the nutritional aspects of food constituents. Considering the later emphasis on food chemistry in most food science curricula, this subject deserves more attention. There remains a need for texts in food chemistry at this level.

Potter is traditionally strong in unit operations for food processing and preservation. There is a good discussion of food quality. Thermal processing, cold preservation, dehydration, food irradiation, microwave heating, and fermentation are covered in detail.

Eight of the 25 chapters are "field trips" through the major food commodities (i.e., milk, seafood, beverages, confectionery, etc.). Chemical and physical properties, quality controls, standards and the unit operations involved in converting raw into finished food products are covered. The chapter on food packaging is up to date, but seems out of place sandwiched between the chocolate and water/waste chapters. Nonetheless, it is good to see a chapter on waste processing. Chapters on food additives, food safety, food laws, nutrition labelling, and world food needs close the text, and have been updated as needed (e.g. the 1980 USRDA is used).

This book requires a freshman knowledge of biology, chemistry, physics and math but does not presume a background in food science. Thus it is ideal for the major's introductory course in food science. It may not be suitable for a course intended for nonmajors since these students may lack a background in the sciences. The book is well written, broad in coverage, and well indexed. These factors make the book a food reference for most food scientists.

Tables and figures are informative and are well coordinated with concepts discussed in the text. For example, illustrations of processing equipment and flow charts are a help to students new to food science. A major difference between the 4th edition of *Food Science* and its previous edition is that some of the unnecessary or unclear illustrations were eliminated.

Potter did a thorough job in updating the book. For example, the sweetener section ends with the approval of aspartame in soft drinks. Tabular data such as the USRDA'S have also been updated. The format of the book is essentially unchanged, with less than 5% of the book on new subject matter not seen in previous editions. There is expanded coverage of nutrient bioavailability, food safety, genetic engineering, and improvement of food quality through changes in processing or preservation. Newly added is a discussion of hypertension, cancer and dietary guidelines. References are extensive, enabling the reader to persue a subject in depth. About half of the references are post- 1980, with the most recent dated 1984.

Potter's *Food Science* 4th edition is highly recommended as an entry level text in food science, and is a worthwhile reference in a food professional's library.

L.S. JACKSON, K. LEE

Engineering Properties of Foods. M.A. Rao and S.S.H. Rizvi, (eds.). Marcel Dekker, Inc., New York. pp. 416, $69.75.

In this book, there are seven chapters on properties of foods, each written by established researchers in the field. These chapters include:

1) Rheological Properties of Fluid Foods by M.A. Rao,
2) Thermal Properties of Foods by V.E. Sweat,
3) Mass Transfer Properties of Foods by G.D. Saravacos,
4) Thermodynamic Properties of Foods in Dehydration by S.S.H. Rizvi,
5) Rheological Properties of Solid Foods by V.N.M. Rao and G.E. Skinner,
6) Physiochemical and Engineering Properties of Food in Reverse Osmosis and Ultrafiltration by T. Matsuura and S. Sourirajan and
7) Electrical Properties of Food by R.E. Mudgett.

Each chapter is generally organized so that the definition and theoretical background of the engineering property is discussed first. Experimental methods of measuring these values are then discussed. A reasonable compilation of the values of the engineering properties for various foods are presented througout the chapters along with extensive reference listings. This format presents pertinent information in a high quality, readable fashion.

This book will be a welcome addition to the book collection of food engineering researchers. It is an excellent collection of reviews on food properties of importance to both research and design engineers. In addition, it will serve as a resource text for an upper level food engineering course as well as a primary text for a course in engineering properties of foods.

RICHARD W. HARTEL

Foodbourne Microorganisms and their Toxins: Developing Methodology. M.D. Piersen and N.J. Stern, (eds.) Marcel Dekker, Inc., New York pp. 475. $59.75.

The information presented in this textbook is drawn from a symposium sponsored by the Institute of Food Technologists and the International Union of Food Science and Technology. This symposium was held June 7–8, 1985, immediately prior to the 45th annual IFT meeting. The book, as was the symposium, is organized to provide an up-to-date analysis and discussion on the methods for analysis of foods for microorganisms and their metabolic products. The benefit of a textbook such as this for the working food microbiologists is it's thorough coverage of the most current methodologies and recommended procedures. This textbook, through the eyes of experts in the field, highlights the need to get away from the "worship of numbers" philosophy; one author attributes this as having been a hindrance to the development of food microbiology in recent years.

The specific content of this textbook is best described by chapter title and associated author. The chapters are:

Developing Methodology for Foodborne Microorganisms, Fundamentals of Analytical Techniques by D.A.A. Mossel; Regulatory Aspects of Microbiological Methodology by C.S. Custer; Methodology and Microbiological Criteria by D.L. Collins-Thompson and O.B. Allen; Predictive Modeling of Food Deterioration and Safety by J.M. Farber; Membrane Filtration Systems by P. Entis; Plating Systems by S. Schalkowsky; Electrical Impedence for Determining Microbial Quality of Foods by R. Firstenberg-Eden; The Bioluminescent ATP Assay for Determining the Microbial Quality of Foods by K.A. La Rocco, K.J. Littel and M.D. Pierson; New Methods for Indicator Organisms by P.A. Hartman, J.P. Petzel and C.W. Kaspar; Microbial Spoilage Indicators and Metabolites by J.M. Jay; Newer Developments in Hybridoma Technology by R.A. Goldsby; Immunoassays for Detecting Foodborne Bacteria and Microbial Toxins by B. Swaminathan and R.L. Konger; Detection of Foodborne Microorganisms by DNA Hybridization by R.A. Fitts; Virulence Assessment of Foodborne Microbes by J.M. Madden, B.A. McCardell and D.L. Archer; Detection and Quantitation of Foodborne Pathogens and Their Toxins: Gram-Negative Bacterial Pathogens by M.P. Doyle; Detection and Quantitation of Gram-Positive Nonsporeforming Pathogens and Their Toxins by R.W. Bennet; Detection and Quantitating Sporeforming Pathogens and Their Toxins by P.M. Foegeding; Analysis of Foods for Mycotoxins by D.L. Park and A.E. Pohland; Detection, Quantitation and Public Health Significance of Foodborne Viruses by E.P. Larkin; and Detection of Foodborne Microorganisms and their Toxins: The Future by A.N. Sharpe.

Most of the chapters are easy to read, some are very technical. All of the chapters contain valuable information on their respective subject. This textbook is an excellent reference for the laboratory or library.

MARY K. WAGNER

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PUBLICATIONS IN FOOD SCIENCE AND NUTRITION

Journals

JOURNAL OF SENSORY STUDIES, M.C. Gacula, Jr.
JOURNAL OF FOOD SERVICE SYSTEMS, O.P. Snyder, Jr.
JOURNAL OF FOOD BIOCHEMISTRY, J.R. Whitaker, N.F. Haard and H. Swaisgood
JOURNAL OF FOOD PROCESS ENGINEERING, D.R. Heldman and R.P. Singh
JOURNAL OF FOOD PROCESSING AND PRESERVATION, D.B. Lund
JOURNAL OF FOOD QUALITY, M.P. De Figueiredo
JOURNAL OF FOOD SAFETY, M. Solberg and J.D. Rosen
JOURNAL OF TEXTURE STUDIES, M.C. Bourne and P. Sherman
JOURNAL OF NUTRITION, GROWTH AND CANCER, G.P. Tryfiates

Books

THE SCIENCE OF MEAT AND MEAT PRODUCTS, 3RD ED., J.F. Price and B.S. Schweigert
HANDBOOK OF FOOD COLORANT PATENTS, F.J. Francis
ROLE OF CHEMISTRY IN THE QUALITY OF PROCESSED FOODS, O.R. Fennema, W.H. Chang and C.Y. Lii
NEW DIRECTIONS FOR PRODUCT TESTING AND SENSORY ANALYSIS OF FOODS, H.R. Moskowitz
PRODUCT TESTING AND SENSORY EVALUATION OF FOODS, H.R. Moskowitz
ENVIRONMENTAL ASPECTS OF CANCER: ROLE OF MACRO AND MICRO COMPONENTS OF FOODS, E.L. Wynder *et al.*
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GUIDE FOR

Typewritten manuscripts in triplicate should be submitted to the editorial office. The typing should be double-spaced throughout with one-inch margins on all sides.

Page one should contain: the title, which should be concise and informative; the complete name(s) of the author(s); affiliation of the author(s); a running title of 40 characters or less; and the name and mail address to whom correspondence should be sent.

Page two should contain an abstract of not more than 150 words. This abstract should be intelligible by itself.

The main text should begin on page three and will ordinarily have the following arrangement:

Introduction: This should be brief and state the reason for the work in relation to the field. It should indicate what new contribution is made by the work described.

Materials and Methods: Enough information should be provided to allow other investigators to repeat the work. Avoid repeating the details of procedures which have already been published elsewhere.

Results: The results should be presented as concisely as possible. Do not use tables *and* figures for presentation of the same data.

Discussion: The discussion section should be used for the interpretation of results. The results should not be repeated.

In some cases it might be desirable to combine results and discussion sections.

References: References should be given in the text by the surname of the authors and the year. *Et al.* should be used in the text when there are more than two authors. All authors should be given in the References section. In the Reference section the references should be listed alphabetically. See below for style to be used.

DEWALD, B., DULANEY, J. T. and TOUSTER, O. 1974. Solubilization and polyacrylamide gel electrophoresis of membrane enzymes with detergents. In *Methods in Enzymology*, Vol. xxxii, (S. Fleischer and L. Packer, eds.) pp. 82–91, Academic Press, New York.

HASSON, E. P. and LATIES, G. G. 1976. Separation and characterization of potato lipid acylhydrolases. Plant Physiol. *57*, 142–147.

ZABORSKY, O. 1973. *Immobilized Enzymes*, pp. 28–46, CRC Press, Cleveland, Ohio.

Journal abbreviations should follow those used in *Chemical Abstracts*. Responsibility for the accuracy of citations rests entirely with the author(s). References to papers in press should indicate the name of the journal and should only be used for papers that have been accepted for publication. Submitted papers should be referred to by such terms as "unpublished observations" or "private communication." However, these last should be used only when absolutely necessary.

Tables should be numbered consecutively with Arabic numerals. The title of the table should appear as below:

Table 1. Activity of potato acyl-hydrolases on neutral lipids, galactolipids, and phospholipids

Description of experimental work or explanation of symbols should go below the table proper. Type tables neatly and correctly as tables are considered art and are not typeset.

Figures should be listed in order in the text using Arabic numbers. Figure legends should be typed on a separate page. Figures and tables should be intelligible without reference to the text. Authors should indicate where the tables and figures should be placed in the text. Photographs must be supplied as glossy black and white prints. Line diagrams should be drawn with black waterproof ink on white paper or board. The lettering should be of such a size that it is easily legible after reduction. Each diagram and photograph should be clearly labeled on the reverse side with the name(s) of author(s), and title of paper. When not obvious, each photograph and diagram should be labeled on the back to show the top of the photograph or diagram.

Acknowledgments: Acknowledgments should be listed on a separate page.

Short notes will be published where the information is deemed sufficiently important to warrant rapid publication. The format for short papers may be similar to that for regular papers but more concisely written. Short notes may be of a less general nature and written principally for specialists in the particular area with which the manuscript is dealing. Manuscripts which do not meet the requirement of importance and necessity for rapid publication will, after notification of the author(s), be treated as regular papers. Regular papers may be very short.

Standard nomenclature as used in the scientific literature should be followed. Avoid laboratory jargon. If abbreviations or trade names are used, define the material or compound the first time that it is mentioned.

EDITORIAL OFFICE: Dr. D. B. Lund, Editor, Journal of Food Processing and Preservation, University of Wisconsin, Department of Food Science, 1605 Linden Drive, Madison, Wisconsin 53706 USA.

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