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# A HIGH PROTEIN PRODUCT FROM CHICKPEAS (*Cicer arietinum L.*) BY ULTRAFILTRATION. PREPARATION AND FUNCTIONAL PROPERTIES

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Accepted for Publication May 26, 1995

## ABSTRACT

*Using a flat plate ultrafiltration system, Direct Ultrafiltration (DU) and Discontinuous Diafiltration (DD) were used to produce a High Protein Product (HPP) from chickpeas* (Cicer arietinum L.). *The chickpea extract (3.3% total solids) was concentrated up to 65% of protein by DD mode. Chickpea flour and spray-dried HPP were analyzed for proximate analysis and functional properties having a Commercial Soybean Isolate (SBI) as a control. The average water absorption found for the HPP (97.4%) was relatively low compared to the raw material, chickpea flour (121.2%) and SBI (115.2%). HPP had a higher fat absorption (52.2%) than flour (39.6%) and SBI (34.0%). Foam capacity and stability of the HPP were similar to those of the SBI and both were more stable than the flour. The HPP, SBI and flour had their lower nitrogen solubility within the pH range of 4–6. Recovery of 72.8% total nitrogen and removal of 59.3% Nonprotein Nitrogen (NPN), from chickpea extracts, were achieved by this system.*

## INTRODUCTION

Among the world's food legumes, chickpea (*Cicer arietinum* L.), bengal gram or garbanzo bean is the second to dry beans (*Phaseolus vulgaris*) in total area grown, and the third in production to dry beans and dry peas (*Pisum sativum*). Over 90% of the world production of chickpea is cultivated in less

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developed countries such as India, Turkey, Pakistan, Mexico, Burma and Ethiopia (Singh 1985).

In Mexico, excellent quality chickpea is cultivated in the northwest part of the country. Eighty percent of the total production meets the quality standards for the national and international market. The twenty percent left over is considered as a low commercial grade chickpea, even though the nutritive value remains quite acceptable. Chickpea is a very good source of carbohydrates and proteins, both making about 80% of the total dry seed weight. Also, it is a very good source of minerals and vitamins (Singh 1985). Chickpeas like most legumes are deficient in methionine, but contain more than adequate levels of the essential amino acids, such as lysine, which is deficient in most cereals (Bodwell 1981; Singh 1985).

In Mexico chickpeas are not commonly consumed by the population, despite its nutritional value, and considerable amounts are used as animal feed. However, chickpeas could be utilized as a good source of protein, in the form of protein concentrates for human consumption (Ulloa *et al.* 1988). The production of legume protein concentrates and isolates using ultrafiltration, seems to be an attractive alternative to the conventional acid precipitation methods, because most of the flour soluble proteins are recovered without generating whey-like by product. A substantial increase in protein recovery and enhanced nitrogen solubility is also achieved. Thus, protein isolates obtained by this process have highly desirable functional and nutritional properties (Manak *et al.* 1980).

The objective of this research was to study the use of a flat plate ultrafiltration system to prepare a High Protein Product (HPP) from low commercial grade chickpeas, which could be added to popular cereal based foods, increasing their nutritive value, for human consumption.

## MATERIALS AND METHODS

### Sample Preparation

Chickpea (*Cicer arietinum* L.) var. Surutato 77, of a low commercial grade was used in this study. The grain was cleaned of dust and foreign material by hand. Flour passed through U.S. Standard 200 mesh (Tyler Co. Cleveland, OH 44114, U.S), was prepared using an Alpine (fine impact mill, model B 160 UPZ) and stored, properly packed in a cold room (5C).

## Extracts Preparation

Aqueous extracts (45 L batch size) were prepared, for each run, as follows: flour-water ratio 1: 12 (w/v); extraction time 30 min; pH 8.0; temperature 25C (Romero 1989). A wet sifter system (Model LR 2262) equipped with 80 and 100 mesh sieves was used to separate the cellulose and other fibrous materials from the aqueous extract. Starch was removed after 24 h cool sedimentation (5C), and centrifuged at 1000 X g for 15 min at 10C. Both supernatants, from sedimentation and centrifugation, were mixed and fed to the ultrafiltration unit (Fig. 1).

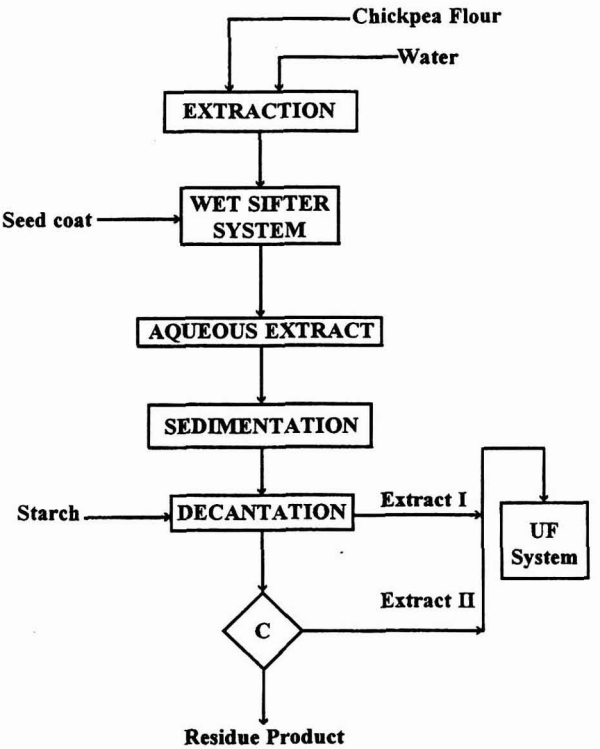


FIG. 1. FLOW DIAGRAM OF EXTRACTION AND ULTRAFILTRATION PROCESSES FOR CHICKPEA FLOURS

## Ultrafiltration Process

Ultrafiltration (UF) experiments were performed on a laboratory scale flat plate unit (Model OM-141, Millipore Co. Bedford, MA), equipped with a Pellicon cassette system of tangential flow. The membrane (catalog No. PTTK 000 05) had a nominal molecular weight exclusion limit of 30,000 and a total surface area of 4600 $cm^2$. Initial water flux, at a particular temperature and pressure, was recorded prior to each run and used to monitor cleaning efficiency. The UF membrane was cleaned by flushing with filtered tap water to displace feed solution, recirculating an enzyme detergent solution (150 g Tergazyme per 20 L of water at 50C for about 30 min, Alconox Inc, NY), and displacing the detergent solution with filtered tap water. The entire cleaning cycle was accomplished within a 1 h period. The water permeation rate was checked after each cycle to verify that the flux had been restored.

Two UF procedures were tested: Direct Ultrafiltration (DU), where all the solutes were concentrated at a Volume Concentration Ratio (VCR) of 5, and Discontinuous Diafiltration (DD) using 3 fold dilution and concentrated up to VCR of 5. Re-ultrafiltrations (RE-UF) in DD mode were performed at VCR of 2. The DD procedure was selected based on their frequency of use to purify the protein retentate in this type of process (Lawhon *et al.* 1978, 1981; Tzeng *et al.* 1988).

The High Protein Products (HPP) obtained from the different runs were dried in a spray-drier (A/S Anhydro APV, Ostmarken 8, DK-2860) using an inlet temperature of 135 $\pm$ 5C and outlet temperature of 75 $\pm$ 5C. Protein and nonprotein nitrogen balances were made on the UF system for each run, including both procedures (DU and DD) to determine the system efficiency.

## Chemical and Functional Analysis

Proximate analyses and the nitrogen solubility index (NSI) were determined according to the standard recommended methods (AACC 1984). Nonprotein nitrogen (NPN) was determined by the modified Singh and Jambunathan (1981) technique. Water absorption was obtained according to the method of Anderson *et al.* (1969). Fat absorption was determined by the technique of Lin *et al.* (1974). Foam capacity and stability were measured based on the Hsu *et al.* (1982) methodology. These analyses were performed on the chickpea flour, the HPP and the commercial soybean isolate (SBI), used as a control, provided by Arancia Purina Proteinas de Mexico.

## RESULTS AND DISCUSSION

In order to establish the operational conditions of the UF unit, a preliminary work was made as follows: different runs were made to study the effect of average transmembrane pressure (ATP) and time, on the flux behavior, and the effect of processing time on the % of nitrogen and volume collected in the permeate and retentate fractions. The more adequate conditions were: recirculation rate of 6 L/min; Average Transmembrane Pressure (ATP) of 25 psi; flux of 5.58 Liters per square Meter per Hour (LMH); pH of the aqueous extract = 8.0 and temperature of 25 $\pm$ 3C.

### Operations Modes

Using the DU mode, an average of 10.8% and 70.6% of total nitrogen were recovered in the permeate and retentate fractions, respectively. These results indicated that 18.6% of the nitrogen was retained by the membrane. The HPP obtained in this way had a protein content of 57.5 $\pm$ 0.6% (dry basis).

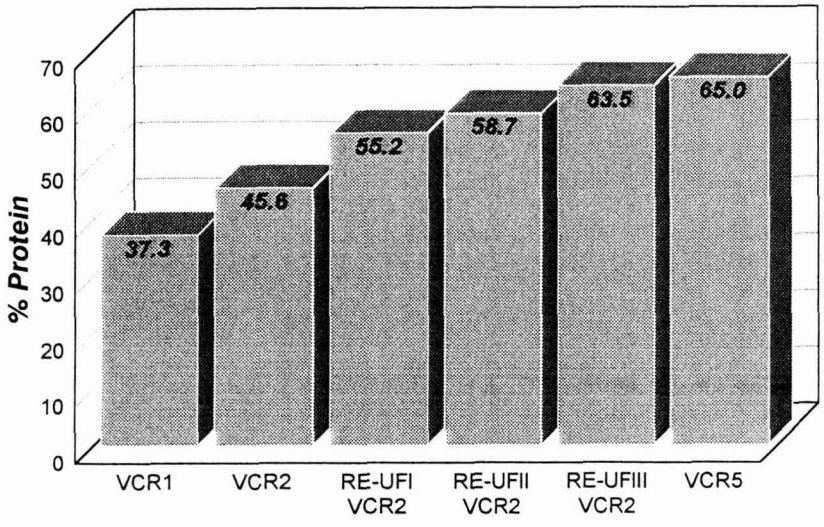


FIG. 2. RETENTATES PROTEIN CONTENTS (% D.B.) DURING DISCONTINUOUS DIAFILTRATION OF CHICKPEA EXTRACTS
Data are means of four determinations (2 for each run).

Results from the DD mode are shown in Fig. 2. A higher protein content was obtained in the retentate (65$\pm$1.5%) when a DD mode was used, in

comparison with DU (57.5±0.6%). Others studies done in this field assume that the dilutions used on the DD mode reduce the solute-solute interactions in the solution, reducing or retarding the membrane polarization phenomenon, thus the permeable solutes are favored to pass through the membrane, and greater purity in the protein is obtained (Omosaiye and Cheryan 1979; Nichols and Cheryan 1981).

A nitrogen balance made in the DD mode showed permeate and retentate nitrogen recoveries of 14.8 and 72.8%, respectively, in relation to the total nitrogen fed to UF system. A 12.4% nitrogen was retained in the membrane. This value is lower than the one obtained by using the DU mode(18.6%). This result is quite logical because the use of dilutions, as mentioned before, decreases or retards the membrane polarization phenomenon, resulting in a less solute retention in the cassette membrane.

## Chemical Composition

Proximate analyses results from the chickpea flour, HPP and SBI are shown in Table 1. Chickpea protein was concentrated 2.8 times, from 23.4% in the flour to 65% in the final product, with a flat plate UF system.

TABLE 1.
CHEMICAL COMPOSITIONS OF CHICKPEA FLOUR, CHICKPEA EXTRACT, HIGH PROTEIN PRODUCT AND COMMERCIAL SOYBEAN ISOLATE[a]

| Product | Protein[b] | Fat | Crude Fiber | Ash | Carbohydrate[c] |
|---|---|---|---|---|---|
| Chickpea flour | 23.4 | 8.4 | 1.68 | 3.02 | 63.50 |
| Chickpea extract | 37.3 | - | - | - | - |
| High protein product | 65.0 | 14.8 | - | 3.19 | 17.01 |
| Commercial soybean isolate | 90.5 | 2.3 | - | 3.00 | 4.20 |

[a] Expressed as % dry weight basis ( g/100g of dry solids)
[b] Determined as (N x 6.25)
[c] Determined by difference

In this study the NPN from the chickpea flour was 12.4% of the total nitrogen (Table 2). This value is similar to the one found by Singh and Jambunathan (1981), who reported NPN values ranging from 5.84 to 16.48% of the total protein for chickpea flours. The NPN content from the HPP is 0.57% in comparison with 1.4% of the extract, showing that it is possible to remove 59.3% of NPN during the UF process.

**TABLE 2.**
**NITROGEN DISTRIBUTION OF CHICKPEA FLOUR, CHICKPEA EXTRACT, HIGH PROTEIN PRODUCT AND COMERCIAL SOYBEAN ISOLATE**

| Product | Total Nitrogen[a] | Protein Nitrogen[b] | Non-Protein Nitrogen[a] |
|---|---|---|---|
| Chickpea flour | 3.74 | 3.28 | 0.46 |
| Chickpea extract | 5.97 | 4.57 | 1.40 |
| High protein product | 10.40 | 9.83 | 0.57 |
| Comercial soybean isolate | 14.48 | 13.96 | 0.52 |

[a] Expressed as % dry weight basis (g/100g of dry solids)
[b] Determined by difference (TN - NPN)

## Functional Properties

Functional properties measured on chickpea flour, HPP and SBI are shown in Table 3. The average percentage of the HPP water absorption (97.4%) was relatively low in comparison with chickpea flour (121.2%) and SBI (115.2%). Thompson *et al.* ( 1981) reported similar results on flour, concentrate and isolate from rapeseed, where the concentrated protein had the lowest water absorption in comparison with the flour and the isolate. Fat absorption of 52.2% was found for the HPP, which was higher than those found for chickpea flour (39.6%) and SBI (34.0%). Similar results were obtained by Thompson *et al.* (1981), when studying the fat absorption capacity of protein concentrate over the flour and isolate, in that order. They suggested that the concentrate behaves in this way due to the presence of a higher number of hydrophobic groups, in comparison with the flour and the isolate. Sosulski *et al.* ( 1976) also studied the flour, concentrate and isolate from rapeseed, comparing them with soy products, and found that soybean had lower fat absorption capacities than rapeseed products. Foam capacity and stability of the chickpea HPP were similar to those of SBI. Studies done by Lawhon and Cater (1971), Hsu *et al.* (1982) and Johnson and Brekke (1983), reported foam capacities in cottonseed isolates and other legumes lower than those found in this study for HPP. The percentage of foam volume increment of SBI was relatively higher than the one found for HPP and chickpea flour. Kinsella (1979) reported similar results, finding that soy isolates showed higher foam capacities than flours and concentrates.

Nitrogen solubility was higher on chickpea flour followed by HPP and less soluble SBI (Fig. 3). This behavior is probably due to chickpea proteins being more hydrophilic than soybean proteins. The HPP nitrogen solubility curve

TABLE 3.
FUNCTIONAL PROPERTIES OF CHICKPEA FLOUR, HIGH PROTEIN PRODUCT (HPP) AND COMMERCIAL SOYBEAN ISOLATE (SBI)

| Component | Water Absorption (%) | Fat Absorption (%) | Volume Increase (%) | Foam Capacity and Stability | | |
|---|---|---|---|---|---|---|
| | | | | Foam Leakage (%) | | |
| | | | | 30 min | 60 min | 120 min |
| Chickpea flour | 121.2 ± 3.3 | 39.6 ± 0.34 | 140.0 ± 0.0 | 47.0 ± 0.0 | 53.0 ± 0.0 | 60.0 ± 0.0 |
| HPP | 97.4 ± 0.4 | 52.2 ± 0.15 | 143.0 ± 0.0 | 23.0 ± 0.6 | 23.0 ± 0.6 | 29.0 ± 0.7 |
| SBI | 115.2 ± 5.3 | 34.0 ± 0.15 | 148.0 ± 1.5 | 23.0 ± 1.6 | 23.0 ± 1.6 | 23.0 ± 1.6 |

Data are means of triplicates

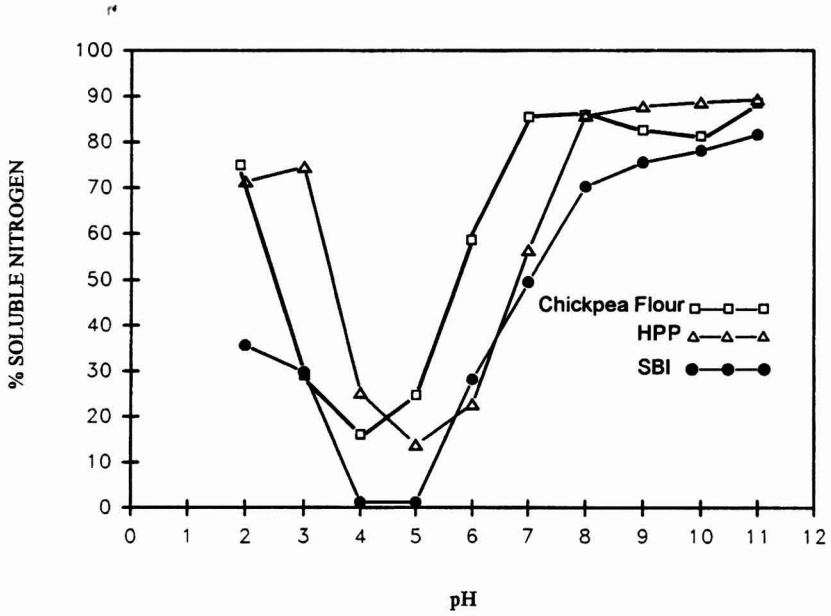


FIG. 3. EFFECT OF pH ON THE NITROGEN SOLUBILITY OF THE CHICKPEA FLOUR, HIGH PROTEIN PRODUCT (HPP) AND COMMERCIAL SOYBEAN ISOLATE (SBI)
Data are means of two replicates.

showed that 75% of the nitrogen was solubilized at pH of 2.0 and pH higher than 7.0. The isoelectric point was pH 5.0. The SBI nitrogen solubility curve showed the lowest solubility in a pH range of 4.0 to 5.0. These results are

similar to those reported by Fan and Sosulski (1974), Coffman and Garcia (1977), Thompson (1977) and Hsu *et al.* (1982), where flours and isolates from several legumes had isoelectric points in the pH range of 4.0 to 6.0.

## CONCLUSIONS

Results from this work showed that it is possible to obtain an HPP (65% protein) from chickpeas by the DD mode, using a flat plate UF system. A recovery of 72.8% of the total nitrogen was achieved and 59.3% of NPN was removed. HPP functional properties were acceptable, finding some of them similar to those of soybean isolate. The HPP may represent a potential alternative for the utilization of low commercial chickpea protein, which could be used as fortificant ingredient in the preparation of food products, especially those based on cereals.

The application of this product as a fortificant could not only increase the nutritional value of cereal based foods but also could improve other product sensory characteristics, such as color and flavor. Finally the UF equipment, using a flate plate unit, could be recommended as a useful system in the food area to obtain legume protein concentrates. The importance of this system could be based on obtaining protein concentrates from grains or their by-products, which until now are subutilized in their potential for human consumption. Further studies have to be conducted in terms of sensory evaluations, large scale production capabilities and marketing considerations in order to prove the feasibility of the method.

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## REFERENCES

AACC. American Association of Cereal Chemist. 1984. *Approved Methods*. (7 ed.) St. Paul, Minn.

ANDERSON, K.A., CONWAY, H.F., PFEIFER, V.F. and GRIFFIN, JR, E.L. 1969. Roll and extrusion-cooking of grain sorghum grits. Cereal Sci. Today. *14*, 372.

BODWELL, C.E. 1981. *Evaluation of Proteins for Humans*. Van Nostrand Renihold/Avi, New York.

COFFMAN, C.W. and GARCIA, V.V. 1977. Functional properties and amino acid content of a protein isolate from mung bean flour. Food Tech. *12*, 473.

FAN, T.Y. and SOSULSKI, F.W.1974. Dispersiblility and isolation of protein from legume flours. Can. Inst. Food Sci. Technol. J. *7*(4), 256.

HSU, D.L., LEUNG, H.K. MORAD, M.M., FINNEY, P.L. and LEUNG, C.T. 1982. Effect of germination on electrophoretic, lentil, and faba bean protein isolates. Cereal Chem. *59*(5), 344.

JOHNSON, E.A. and BREKKE, C.J. 1983. Functional properties of acylated pea protein isolates. J. Food Sci. *48*, 722.

KINSELLA, J.E. 1979. Functional properties of soy proteins J. Am. Oil Chem. Soc. *56*(3), 242.

LAWHON, J.T. and CATER, C.M. 1971. Effect of processing method and pH of precipitation on the yields and functional properties of protein isolates from glandless cottonseed. J. Food Sci. *36*, 372.

LAWHON, J.T., HENSLEY, D.W., MULSOW, D. and MATTIL, K.F. 1978. Optimization of protein isolate production from soy flour using industrial membrane systems. J. Food Sci. *43*, 361.

LAWHON, J.T., MANAK, L.J., RHEE, K. C . and LUSAS, E.W. 1981. Production of oil and protein food products from raw peanuts by aqueous extraction and ultrafiltration. J. Food Sci. *46*, 391

LIN, M.J., HUMBERT, E.S. and SOSULSKI, F.W. 1974. Certain functional properties of sunflower meal products. J. Food Sci. *39*, 368.

MANAK, L.K., LAWHON, J.T. and LUSAS, E.W. 1980. Functioning potential of soy, cottonseed and peanut protein isolates produced by industrial membrane systems. J. Food Sci. *45*(2), 236.

NICHOLS, D.J. and CHERYAN, M. 1981. Production of soy isolates by ultrafiltration: factors affecting yield and composition. J. Food Sci. *46*, 367.

OMOSAIYE, O. and CHERYAN, M.1979. Ultrafiltration of soybean water extracts: processing characteristics and yields. J. Food Sci. *44*, 1027.

ROMERO, A.L. 1989. Obtención de un material de alto contenido proteico a base de garbanzo de rezaga por ultrafiltración usando unidad de placa plana. Tesis de Maestria. DIPA, Universidad de Sonora. Hermosillo, Sonora, Mexico.

SINGH, U. 1985. Nutritional quality of chickpea (Cicer ariehnum L.): current status and future research needs. Qual. Plant Foods Hum. Nutr. *35*, 339.

SINGH, U. and JAMBUNATHAN, R. 1981. Relationship between nonprotein nitrogen and total nitrogen in chickpea (Cicer arietinum L.) seed J. Agric. Food Chem. *29*, 424.

SOSULSKI, F., HUMBERT, E.S. BUI, K. and JONES, J.D. 1976. Functional properties of rapeseed flour concentrates and isolate. J. Food Sci. *41*, 1349.

THOMPSON, L.U. 1977. Preparation and evaluation of mung bean protein isolates. J. Food Sci. *42*, 202.

THOMPSON, L.U., LIU, R.F.K. and JONES, J.D. 1981. Functional properties and food applications of rapeseed protein concentrate. J. Food Sci. *47*, 1172.

TZENG, Y.M., DIOSADY, L.L. and RUBIN, L.J. 1988. Preparation of rapeseed protein isolates using ultrafiltration, precipitation and diafiltration. Can. Inst. Food Sci. Technol. J. *21*(4), 419.

ULLOA, J.A., VALENCIA, M.E. and GARCIA, Z.H. 1988. Protein concentrate from chickpea: nutritive value of a protein concentrate from chickpea *(Cicer arietinum)* obtained by ultrafiltration and its potential use in an infant formula. J. Food Sci. *53*, 1396–1398.

# PARTICLE SIZE, SALT CONCENTRATION AND TEMPERATURE EFFECTS ON NITROGEN EXTRACTION OF CHICKPEA (Cicer arietinum) BY RESPONSE SURFACE METHODOLOGY

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## ABSTRACT

*This study was conducted to evaluate the effect of time, pH, particle size, %NaCl and temperature on total nitrogen (TN) extraction of low commercial grade chickpea* (Cicer arietinum) *grain, in order to find the optimum extraction conditions for further processing. Extraction times used were 30, 60, 90 and 120 min and the nitrogen extraction curve was carried out at a pH range of 2.0 to 11.0. Response surface methodology was used to evaluate the effect of particle size (100, 150 and 200 mesh), salt concentration (0, 0.3 and 0.6% NaCl) and temperature (25, 35 and 45C). No significant time effect was found on nitrogen extractability. However, a great pH effect on nitrogen extraction was observed. Results from the RSM analysis showed that the most adequate conditions for total nitrogen extraction were particle size, 200 mesh; 0.0% NaCl; pH 8.0; temperature, 25C; and time, 30 min. By using the above mentioned parameters a yield over 90% of nitrogen was obtained.*

## INTRODUCTION

Chickpea *(Cicer arietinum)* is a legume that besides its economic importance plays a significant role as a source of protein in the human diet of several countries, particularly India, Mexico, Ethiopia and Pakistan (Singh 1985). In Mexico the state of Sonora is one of the most important producers of chickpeas. In the last five years the average production has been around 23,121 tons.

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Ninety percent of this production was exported, and the rest was considered as a "low commercial grade" grain (SARH 1993). However, from the nutritional standpoint, the low commercial grade grain has the similar nutritional attributes as the grain exported (Lopez and Andrade 1973). Protein content in chickpea ranges from 18 to 27%. Globulins (56%) account for the most abundant storage proteins (Singh *et al.* 1982). Chickpea proteins could be incorporated into foods to fortify their nutritional value, mainly in cereal based diets. Studies focused on nitrogen extraction in legumes have demonstrated the importance of certain parameters (pH, extraction time, ionic strength of solvent, temperature and particle size) on the nitrogen or protein yield (Hang *et al.* 1970; Kazazis and Kalaissakis 1979; McWatters and Holmes 1979). Extraction conditions depend on the type of legume because of the differences in protein content and its characteristics. There are only a few studies on nitrogen extraction in chickpea (Fan and Sosulski 1974; Ulloa *et al.* 1988). A statistical method which involves several variables and their corresponding interactions could be used in order to determine the optimum extraction conditions of protein. Response Surface Methodology (RSM) is a technique that involves the minimum squares model to establish optimum conditions when more than one independent variable is being tested. The objective of this research was to study the influence of several factors such as: time, pH, particle size, salt concentration and temperature, on the protein extraction of low commercial grade chickpea using RSM technique.

## MATERIALS AND METHODS

### Sample Preparation

Low commercial grade chickpea var. Surutato 77 harvested in the coast of Hermosillo, Sonora, Mexico was used as raw material. Once collected, the sample was cleaned manually and milled in a hammer mill and Alpine Mill (Fine Impact Mill 100 UPZ, Alpine American Co., Massachusetts) to 100 and 200 mesh (U.S.A. standard). A chemical proximate analysis was performed on the flour, following recommended methods (A.A.C.C. 1984).

### Nitrogen Extraction

Five parameters were studied in order to determine their effect on the total nitrogen extraction (TN) of chickpea: time, pH, particle size, salt concentration

(% of NaCl) and temperature. These parameters were selected according to those results obtained in previous studies carried out on protein solubility of several legumes, including chickpea (Sosulski and Bakal 1969; Fan and Sosulski 1974; Miers *et al.* 1977; Chang and Satterlee 1979; Kazazis and Kalaissakis 1979; Sathe and Salunkhe 1981). TN in all the experiments was measured using the 46-13 method (AACC 1984).

## Extraction Time

Nitrogen extraction as a function of the extraction time was determined using a 1:12 ratio (100 mesh flour: 0.3% saline solution), at four different extraction times (30, 60, 90 and 120 min). The pH of the solution was adjusted to 10 with 1.0 and 0.1 N NaOH solutions. Temperature of extraction was 25C, with magnetic stirring. After the extraction, the mixture was centrifuged at 8800 × g for 30 min (CL, I.E.C., Damon, Co., U.S.A.) to separate the insoluble material. The supernatant was assayed for TN and the results expressed as % of TN recovery of the flour.

## pH of Extraction

The effect of pH on total nitrogen extraction was performed based on the technique developed by Fan and Sosulski (1974). The 2 g of flour (100 mesh) were dispersed in 24 ml of water. The pH of the solution was adjusted in the range of 2 to 11 with 1.0 and 0.1 N HCl or NaOH solutions. The extraction was carried out for 30 min using magnetic stirring at 25C. The mixture was then centrifuged at 8800 × g for 30 min, the supernatant was assayed for TN and the results expressed as % of TN recovery of the flour.

## Effect of Particle Size, % NaCl and Temperature

An extraction system with recirculation of water was designed and constructed to study these variables. An experimental design with three independent variables (X = temperature, Y = particle size and Z = % of NaCl) was used. The response variable was % of TN recovery. All possible combination of treatments are shown in Fig. 1. The flour-solvent ratio was 1:12, the time was 30 min and pH was 8.0; these conditions were maintained constant and were used based on previous results. The mixture was centrifuged for 30 min and the supernatant was assayed for TN. The results were expressed as % of TN recovery of the flour. Each combination of treatments had 3 replications.

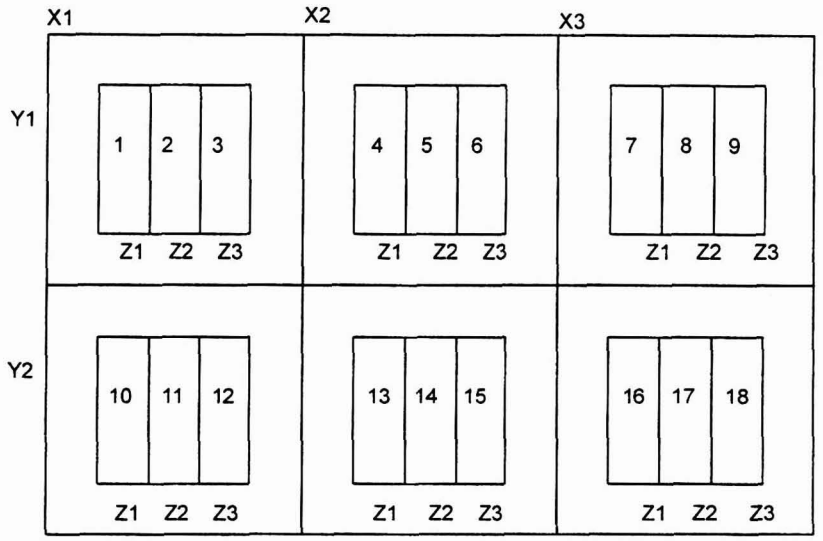


FIG. 1. POSSIBLE TREATMENTS FOR A RESPONSE SURFACE METHODOLOGY (RSM) EXPERIMENTAL DESIGN

RSM computer program was used for statistical analysis of the data. In general this program requires the data of at least half of the possible treatments. In this case, the possible combinations of treatments were 18, where 9 combinations were randomly selected. RSM program calculates multiple correlation coefficient, standard error and calculates an overall equation. Predictions for the combinations not tested experimentally are printed in a surface response map (Walker and Parhurst 1984).

## RESULTS AND DISCUSSION

### Effect of Time

Results of the effect of extraction time on the TN extraction are shown on Table 1. No significant effect was found ($p > 0.01$) on the percentage of TN recovery of the flour, when 30, 60, 90 and 120 min extractions times were used.

TABLE 1.
PERCENT OF NITROGEN EXTRACTION AS FUNCTION OF TIME

| Time (min) | % Extraction[a] | | F[b] |
|---|---|---|---|
| | Repetition 1 | Repetition 2 | |
| 30 | 91.34 | 90.93 | 0.50 |
| 60 | 91.34 | 92.63 | |
| 90 | 91.76 | 92.18 | |
| 120 | 91.76 | 90.51 | |

[a] Values are average of duplicates.
[b] $p > 0.01$, (DF= 3, 12), F= 3.29

## Effect of pH

In contrast with the extraction time, pH showed a great effect on the percentage of TN recovery of the flour (Fig. 2). The highest recoveries were found between pH 2.0–8.0, with 75 and 90%, respectively. The lowest recoveries were found between pH 4.0–5.0, with 16.5 and 25%, respectively. These results suggested that maximum TN extraction occurred when pH 8.0 was used. Results from this study agree with those of Fan and Sosulski (1974) and Ulloa *et al.* (1988), who found that the highest percentage of TN extraction was at pH 7.0.

## Effect of Particle Size, Percentage of NaCl and Temperature

Results of RSM analysis, based on the 9 combinations selected at random, are shown in Fig. 3. The percent TN extraction was over 90% for several combinations tested. In order to prove those results given by the RSM analysis, two sets of combination data were selected mainly based on the criteria of operation facility, cost and performance. These combinations were: (1) particle size = 200 mesh, percent of NaCl = 0.0, Temperature = 25C and (2) particle size = 200 mesh, percent of NaCl = 0.3, Temperature = 35C. Both combinations had yield NT extractions higher than 90%. The statistical design used in this study, apart from developing response surface maps, produces a multiple correlation equation that can be used to predict values for combinations of treatments that are not experimentally tested; the resulting equation was:

Percentage of Extraction of TN = 172.881659 + (-35.960366) x %NaCl + (-1.43133123) + 0.98147704 x Temp + ($1.97649918 \times 10^3$) x Particle Size x Temp + 1.31405561 x % NaCl x Temp + (-0.531383898) x (% NaCl)$^2$ + 4.75665 x (Particle Size)$^2$ + (0.0245065742) x (Temp)$^2$

with a 0.9 multiple correlation coefficient, 1.19 as an standard error estimate and a determination coefficient of 0.87.

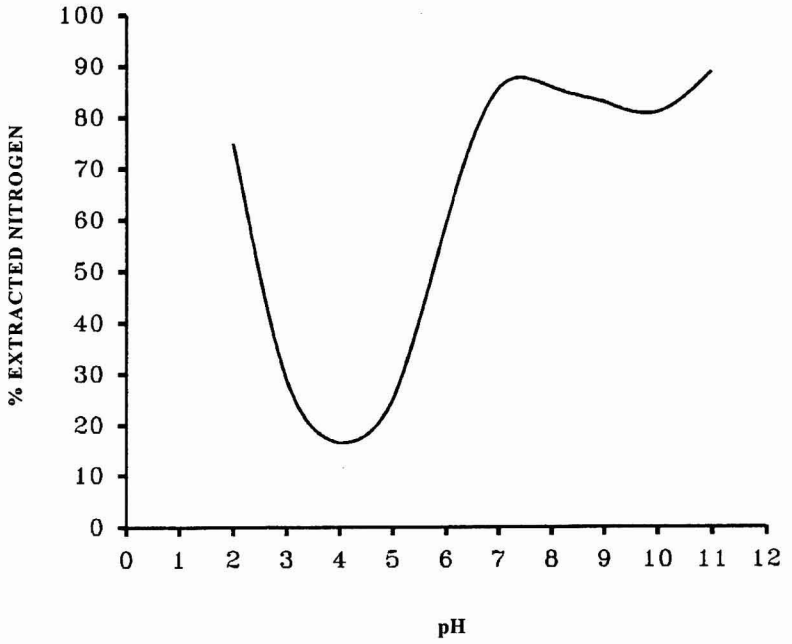


FIG. 2. EFFECT OF pH ON THE NITROGEN EXTRACTION OF CHICKPEA FLOUR

Results were compared to those of Kazazis and Kalaissakis (1979), who studied the effect of several concentrations of neutral and alkaline salts in *Vicia sativa*. They obtained 73% of soluble nitrogen in the extract, when NaCl in distilled water was used for nitrogen extraction. The same authors reported that particle sizes smaller than 0.2 mm gave better percent nitrogen extraction. This could be explained by the fact that with smaller particles there is more contact area for the solvent, and thus, more nitrogen is extracted.

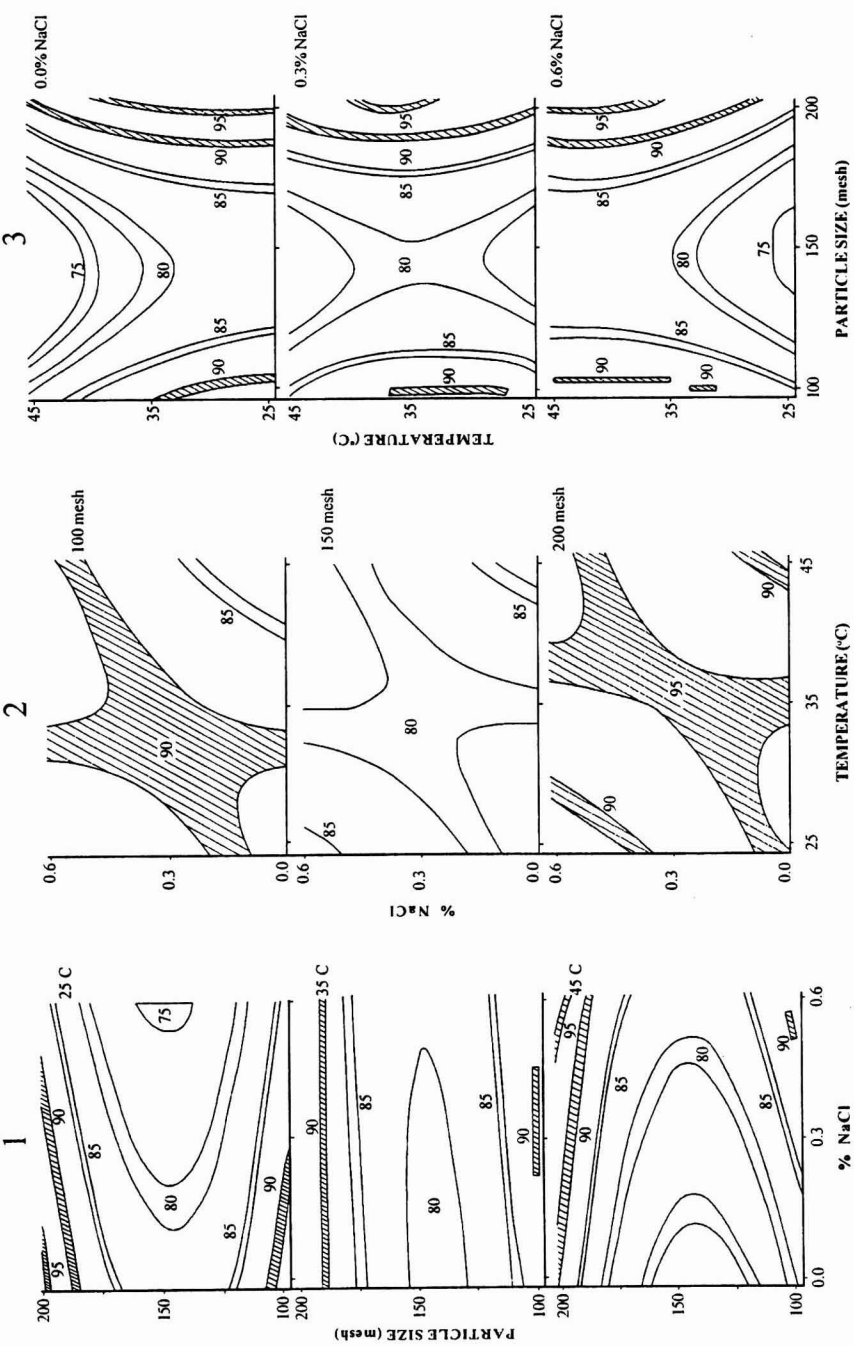


FIG. 3. RESPONSE SURFACE MAPS FOR PERCENTAGE TOTAL NITROGEN EXTRACTION FROM CHICKPEA FLOUR AS A FUNCTION OF: (1) % NaCl VS. FLOUR PARTICLE SIZE; (2) TEMPERATURE VS. NaCl; AND (3) FLOUR PARTICLE SIZE VS. TEMPERATURE

## CONCLUSIONS

Extraction time showed no significant ($p > .0\ 1$) effect on nitrogen extraction. In contrast pH had a great effect, with pH 7.0 having the highest percent TN extraction (90%) and with pH 4.0 the lowest (16.5%). The combination of particle size, percent NaCl and temperature showed a positive effect on percent TN extraction. RSM maps showed that several of these combinations give yields over 90%. From the RSM method it is possible to obtain maps, as well as a multiple correlation equation, that can be used to predict experimental values. Based on these results the following parameters were defined as the most convenient for TN extraction: 200 mesh, particle size; 0.0 % NaCl, salt concentration; pH of 8.0, temperature of 25C, with 30 min extraction time.

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## REFERENCES

A.A.C.C. American Association of Cereal Chemists. 1984. Approved Methods. (7 ed.) St. Paul, Minn. Methods: 08-01, 30-20, 32-15, 44-40 and 46-13.

CHANG, K.C. and SATTERLEE, L.D. 1979. Chemical, nutritional and microbiological quality of a protein concentrate from culled dry beans. J. Food Sci. *44*, 1589.

FAN, T.Y. and SOSULSKI, F.W. 1974. Dispersability and isolation of protein from legume flours. Can. Inst. Food Sci. Technol. J. *7*(4), 256.

HANG, Y.D., STEINKRAUS, K.H. and HACKER, L.R. 1970. Comparative studies on the nitrogen solubility of mung beans, pea beans and red kidney beans. J. Food Sci. *35*, 318.

KAZAZIS, I. and KALAISSAKIS, P. 1979. Extraction of nitrogenous constituents from leguminosae: solubility of nitrogen from *Vicia sativa*. J. Sci. Food Agri. *30*, 759.

LÓPEZ, G. and ANDRADE, A. 1973. El Garbanzo y su Cultivo en el Valle de Culiacan. Circular C.I.A.N.O. Num.30. Edición México.

MCWATTERS, K.H. and HOLMES, M.R. 1979. Salt concentration, pH, and flour concentration effects on nitrogen solubility and emulsifying properties of peanut flour. J. Food Sci. *44*, 765.

MIERS, J.C., OLSON, A.C. and GRAY, G.M. 1977. Bean protein separations using laboratory and continuous decanter centrifuges. J. Food Sci. *42*(2), 367.

SARH. Secretaría de Agricultura y Recursos Hidráulicos. 1993. Comunicación Personal, No Publicada. Hermosillo, Sonora, México.

SATHE, S.K. and SALUNKHE, D.K. 1981. Solubilization and electrophoretic characterization of the great northern bean *(Phaseolus vulgaris* L.*)* proteins. J. Food Sci. *46*, 82.

SINGH, U. 1985. Nutritional quality of chickpea (*Cicer arietinum* L.): Current status and future research needs. Qual. Plant Foods Hum. Nutr. *35*, 339.

SINGH, U., KHERDEKAR, M.S. and JAMBUNATHAN, R. 1982. Studies on desi and kaubuli chickpea (*Cicer arietinum* L.) cultivars. The levels of amylase inhibitors, leveles of oligosaccharides and in-vitro starch digestibility. J. Food Sci. *47*, 510.

SOSULSKI, F.W. and BAKAL, A. 1969. Isolates proteins from rapeseed, flax and sunflower meals. Can. Inst. Food Techno. J. *2*(1), 28.

ULLOA, J.A., VALENCIA, M.E. and GARCIA, Z.H. 1988. Protein concentrate from chickpea: nutritive value of a protein concentrate from chickpea (*Cicer arietinum* L.) obtained by ultrafiltration and its potential use in an infant formula. J Food Sci. *53*(5), 1396.

WALKER, C.F. and PARKHURST, A.M. 1984. Response surface analysis of bake-lab data with a personal computer. Cereal Food World. *29*(10), 662.

# EFFECT OF WHEAT GERM PROTEIN FLOUR ON THE QUALITY CHARACTERISTICS OF BEEF PATTIES COOKED ON A GRIDDLE[1]

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## ABSTRACT

*Patties with ground beef alone or extended with wheat germ protein flour (WGPF) at levels of 2.0, 3.5, and 5.0% were fabricated. WGPF was added as a slurry. Beef patties were cooked on a griddle to a temperature of 69±1C. With the addition of WGPF, water holding capacity decreased and pH increased. No difference was found in $a_w$. Yield increased and cooking losses decreased as extension level increased. Beef patties with WGPF added shrank less than all - beef patties. Protein and fat contents decreased, but moisture increased with the addition of WGPF. Extension with WGPF did not cause significant changes in amino acid content. Wheat-like aroma and flavor as well as juiciness and tenderness increased as extension level increased. No difference in lightness was found; however, redness decreased and yellowness increased with increasing WGPF. WGPF showed a potential use as a meat extender.*

## INTRODUCTION

Concern for improving the protein quality of meat products, while lowering cost of production, and attempts to develop new types of meat products have resulted in considering plant proteins as additives for such products. The germ portion of wheat is known for its high nutritive value. Wheat germ is separated as a by-product in flour milling operations. Several studies have indicated a superior nutritive value of wheat germ over the milling products. Wheat germ contains high levels of essential amino acids (Miladi *et al.* 1972), and its amino acid profile is comparable to that of egg and milk proteins and superior to that

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of corn germ proteins (Gnanasambandam 1993). The contents of carbohydrates in wheat germ were found to be: 1.58% reducing sugars, 15.89% nonreducing sugars, and 29.65% total carbohydrates. The main sugars were (mg/g): raffinose 52.70, sucrose 42.82, maltose 42.82, glucose 52.70, and xylose 52.70 (Osman *et al.* 1988). Wheat germ contains high levels of trace elements such as zinc, magnesium, copper, cobalt, iron, and selenium (Garcia *et al.* 1972). It is also a good source of thiamine, riboflavine, and niacin and the richest source of tocopherol (vitamin E) of plant origin, being almost exclusively $\alpha$-tocopherol and $\beta$-tocopherol (Gnanasambandam 1993). Wheat germ showed a capacity to reduce cholesterolemia in a study designed to investigate its long-term effects on the human diet (Cara *et al.* 1992a). Wheat germ fiber may reduce postprandial lipemia in humans (Cara *et al.* 1992b).

Wheat germ proteins have been used in a diversity of products. Appearance and flavor of muffins and shape and crumb structure of rolls were improved with the addition of wheat germ flour (Turnbough and Baldwin 1986; Godunova *et al.* 1986). Highly nutritious products such as cookies (Bajaj *et al.* 1991) and sweet high-protein bars (Ruales *et al.* 1989; Anon. 1981) have been obtained by adding wheat germ to the formulations. Gnanasambandam and Zayas (1994) studied the quality characteristics of meat batters and frankfurters containing wheat germ protein flour (WGPF). Batters with 5% WGPF added had higher scores for adhesiveness compared to the control. The emulsion-stabilizing capacity of sausage batters improved with addition of WGPF. The highest yields of frankfurters were observed in treatments containing WGPF.

Considering the advantages of WGPF and the need for low-cost and nutritious meat products, investigation on the utilization of WGPF in meat products is needed. Therefore, the objectives of this study were to develop a process to incorporate WGPF in beef patties at levels of 2.0, 3.5, and 5.0% and to investigate the effects of this additive on pH, water holding capacity, water activity, yield, cooking losses and shrinkage, proximate and amino acid composition, sensory characteristics, textural properties, and color of beef patties.

## MATERIALS AND METHODS

### Sample Preparation

A flow-diagram for preparation of samples is illustrated in Fig. 1. Samples were prepared from beef knuckles and beef plates. Lean (90/10) and fat (50/50) sources were ground separately through a 1/2 in. (1.27 cm) break plate. A fat content test (Foss-Let) was performed for both lean and fat sources. A Pearson

square calculation was used to determine the amounts of meat and fat portions needed to formulate ground beef with a 20% fat content. Meat and fat were homogenized by blending in a Master meat blender model 265407 (The Master Electric Co., Dayton OH) for 30 s. Then the meat mixture was ground through a 1/8 in. (0.32 cm) break plate. The Foss-Let test was used to ensure that the ground meat met the targeted fat level. The ground meat then was divided into three batches and vacuum packaged to correspond to the three replications of the project.

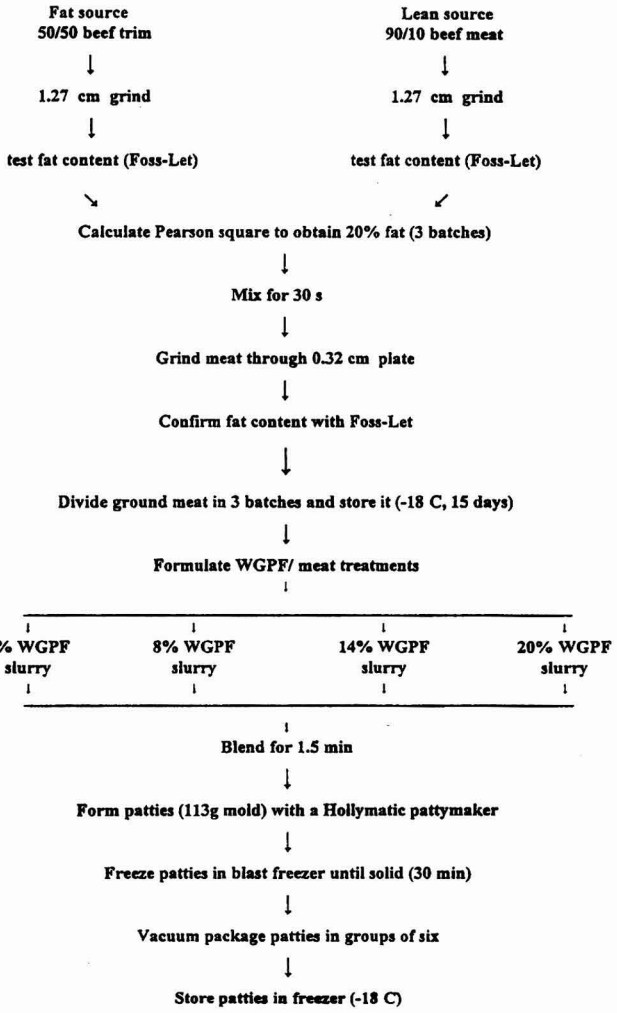


FIG 1. DIAGRAM FOR EXPERIMENTAL SAMPLE PREPARATION

## Treatments

Defatted WGPF was obtained from Vitamins, Inc., Chicago, IL. Beef patties were extended with WGPF at levels of 2.0, 3.5, and 5.0% of the dry weight of the total mix (8, 14, and 20% when rehydrated 1:3 with distilled water). Control samples were those prepared without WGPF. Formulations of patty treatments are presented in Table 1. To prepare WGPF slurries, dry WGPF was hydrated with distilled water at a ratio of 1:3 in plastic containers. These were covered with plastic lids and held at room temperature for 90 min. Slurries were mixed with the ground beef by blending for 90 s in a Hobart mixer. Patties were formed by a Hollymatic (Jet-Flow Super, Model 54) pattymaker (113g mold). The whole process was performed at a temperature of 4C. Formed patties were placed between squares of waxed paper, layered on metal trays, and frozen in a blast freezer for 30 min. Frozen patties were vacuum packaged in groups of six and were stored in a freezer (−18C) until needed for experimentation.

TABLE 1.
FORMULATION OF BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF)

| Ingredients | Treatment (% extension) | | | |
|---|---|---|---|---|
| | Control | 8 | 14 | 20 |
| Ground beef, g | 5580 | 5460 | 5100 | 4740 |
| Salt, g | 60 | 60 | 60 | 60 |
| Distilled water, g | 360 | 360 | 630 | 900 |
| WGPF, g | 0 | 120 | 210 | 300 |
| Total, g | 6000 | 6000 | 6000 | 6000 |

## pH, Water Holding Capacity, and Water Activity

Samples were prepared by blending a 10 g portion of ground beef patties with 100 ml of distilled water for 15 s at high speed in an Osterizer blender. The blended sample was placed in a 100 ml beaker. A Fisher Accumet pH

meter 50 (Denver Instrument Co.) was used for measuring pH. The electrode was rinsed between samples with a protein cleaner. Duplicate readings of six samples from each treatment were obtained.

Water holding capacity (WHC) was determined in the raw patties, and nine samples per treatment were taken. A centrifuge technique was utilized. Thawed patties were homogenized using an Oskar Jr mini food processor (Sunbeam). The weights of a 50 ml plastic centrifuge tube and its cover were recorded. Then each 10-g sample of patty was placed into the tube, and 40 ml of distilled water was added. Tubes were placed in a water bath at 25C for 30 min. Then the tubes were centrifuged at 1200g (3000 rpm) for 30 min at a constant temperature of 25C. After centrifugation water from each tube was removed carefully using a glass micropipette and the tube then was weighed to determine differences in weight. The following formula was utilized to determine WHC:

$$\% \text{ WHC} = \frac{\text{Hydrated wt. of sample} - \text{Wt. of sample before hydration}}{\text{Wt. of sample before hydration}} \times 100$$

Water activity ($a_w$) was measured with a Decagon CX-1 as an indicator of shelf life. Two samples were taken from each of three raw patties from each treatment. Randomized samples were placed in the plastic containers used for this equipment. Each container was filled to half of its capacity. Direct readings were taken from the instrument's screen.

## Heat Treatment

Before cooking, patties were thawed overnight in a refrigerator at 4C. Eight patties from each treatment were used in each cooking method. An electric Wells powerline griddle model G-15 (Wells Manufacturing Corporation, San Francisco, CA) was used for this purpose. The griddle was preheated for 15 min and coated with a nonstick spray. Beef patties were placed on the griddle's metal plate to be cooked at 177C (350F) for 4 min, turned over, and cooked to an internal endpoint temperature of $69 \pm 1$C, medium-well doneness. The internal temperature was monitored using thermocouples (Doric Minitrend 205) in one of the four patties cooked at the same time. The average cooking time to reach the selected internal temperature was 7 min.

## Cooking Losses, Yield and Dimensional Measurements

Patties were weighed before and after cooking to calculate cooking losses. Eight patties from each treatment were used. Cooked patties were at room

temperature when measurements were taken. Percent of total cooking losses (TCL) and yield were calculated by the following formulas:

$$\% \text{ TCL} = \frac{\text{Raw patty weight} - \text{Cooked patty weight}}{\text{Raw patty weight}} \times 100$$

$$\% \text{ Yield} = 100 - \% \text{ TCL}$$

A clear plastic ruler was used to measure the diameter in the same widest part of each patty before and after cooking, and measurements were reported in cm. A vernier caliper was used to measure the thickness of the patties before and after cooking. Four thickness measurements taken from each patty were averaged as an estimate of thickness. Cooked patties were at room temperature when measurements were taken. Data were reported as percent change in patty diameter and thickness, because patties can increase or decrease in dimensions depending on formulation. Percent change for both diameter and thickness was calculated with the following formula:

$$\% \text{ Change} = \frac{\text{Raw measure} - \text{Cooked measure}}{\text{Raw measure}} \times 100$$

**Proximate Analysis**

All analyses were performed on both raw and cooked patties. Three samples were taken from each treatment for each analysis. A modified semimacro-Kjeldahl method (Buchi) was utilized to determine protein content (method 981.10, AOAC 1990). Percent nitrogen was calculated. In order to obtain percent of protein, two conversion factors were used: 6.25 for the meat protein proportion and 5.85 for the wheat germ protein proportion. For the amino acid analysis, slices of patty were lyophilized (freeze dried) for 48 h to remove all moisture. A small amount of each sample was weighed and transferred to a hydrolysis tube. 0.5 ml of constant boiling HCL at 6N was added to each tube, and it was sealed under vacuum. Samples were hydrolyzed at approximately 110C for 24 h and were lyophilized to dryness. Dried samples were suspended in 0.5 ml of 50mg/ml potassium EDTA and transferred to an eppendorf tube. A dilution of 1: 100 was made for each sample, and an aliquot of this dilution

was loaded onto the amino acid analyzer. Amino acid concentrations were calculated on the basis of grams of amino acid per 100 g of sample.

Fat determination was made by the Foss-Let fat Analyzer (A/S N. Foss Electric, Denmark) according to method 976.21 (AOAC 1990). Patties were homogenized in a Oskar Jr mini food processor (Sunbeam). A 22.5-g sample was reacted with 120 ml tetrachloroethylene and 50 g plaster of paris for 2.5 min. The extracted filtrate was analyzed, and a direct reading of percent of fat content was taken. This reading was multiplied by 2, because half of the recommended sample was used.

Moisture content was determined by drying a 5-g sample for 8 h in an oven at 105C (method 950.46, AOAC 1990).

## Sensory Evaluation

**Training of panelists.** Panelists were trained to become familiar with the product and its characteristics. Beef shank broth and cooked t-bone steak were used as references for meaty aroma and meaty flavor. These were defined as the aroma and the flavor of cooked beef. WGPF cooked in distilled water at a ratio 1:3 was used as a reference for wheat-like aroma and wheat-like flavor, which were defined as the aroma and the flavor of WGPF cooked in water. For intensity of meaty and wheat-like attributes (aroma and flavor), the control and 36% WGPF-extended beef patties were used as references, respectively. The texture attributes of firmness and juiciness were evaluated. Firmness was defined as the amount of force required to bite through a sample with the incisors. A standard hardness scale (Szczesniak *et al.* 1962) was utilized to train the panelists for this attribute. Juiciness was defined as the degree to which moisture was released from the sample after seven chews between the molars. WGPF-extended (20% extension level) medium-well cooked and overcooked patties were used as references for the extremes of very and none, respectively.

**Evaluation.** Double boilers containing hot water (90±2C) were used to keep samples warm before being served. Four samples per session were presented to panelists in a randomized order. Panelists evaluated two samples, had a recess of 8 min, and then evaluated two more samples. Each sample was formed by two 1/8-wedges of warm cooked patty (36±2C) and presented to panelists in custard cups covered with watch glasses. Evaluation of aroma, flavor, and texture was done under red light to minimize the panel's perception of color differences caused by different composition of the beef patties. Parameters were scored on a 15-cm, semistructured, line scale with anchors at each endpoint. By measuring the distance of the line score from the left end of the line scale, results were converted into numerical values.

## Texture Analysis

A TA-XT2 Texture Analyzer was used to measure resistance to compression and shear force. Eight cooked patties from each treatment were utilized, four for each measurement. Each patty was made uniform in thickness with a miter box. Samples were prepared with patties at room temperature. For compression force, three cores of 18mm diameter were removed from each patty. A flat-headed plunger was attached to the texture analyzer. Compression then was registered as the kg of force required to compress the sample 50% of its height. Samples for shear force were prepared according to the guidelines of AMSA (1983) for ground beef. A blade (89×70×3mm) and special base were used. Shear force was registered as the kg of force required to cut the sample in half. The highest peak from the graph was taken for this purpose.

## Color Measurement

A HunterLab D54 spectrophotometer was used to measure L, a, and b values. Illuminant C light was utilized. Equipment was calibrated using the calibrating devices wrapped in crystal clear polyethylene. Thawed raw patties were wrapped in crystal clear polyethylene, and readings were taken. Cooked patties were cut in half, and a round sample (52mm diameter) was wrapped in crystal clear polyethylene, and readings were taken. For both raw and cooked samples, three patties from each treatment were used and three readings per sample were taken, with the angle of the sample changed before the next measurement was taken. Hue angle and saturation index were calculated as follows:

$$\text{Hue angle: } H = \tan^{-1} b/a$$
$$\text{Saturation index: } S = (a^2 + b^2)^{1/2}$$

## Statistical Design

Three replications were conducted. A randomized complete block design was used, treating each replication as a block. Data were analyzed for differences caused by level of extension with WGPF, using analysis of variance and mean separations calculated by the General Linear Model (GLM) Procedure of the Statistical Analysis System (SAS 1988). Sensory analysis was performed using a split-plot design. For each source of variation for which the F-value was significant, the least significant difference (LS means) at the 5% level of probability was calculated.

## RESULTS AND DISCUSSION

### pH, Water Holding Capacity, and Water Activity

The lowering of pH in muscle from the accumulation of lactic acid is observed during postmortem changes. The normal pH of beef meat has been reported to be in the range of 5.5–5.7 (Gill and Penney 1988; Rousset and Renerre 1991). The pH of raw beef patties increased with the addition of the WGPF slurry. All treatments were significantly higher in pH ($P<0.05$) when compared to the control and were also different from each other (Table 2). The effect of the WGPF on the pH values probably influenced water retention in the cooked patties. However, in this experiment, a correlation coefficient of 0.10 was found. Nevertheless, when correlation coefficients were calculated within each treatment, factors of 0.58, 0.55, 0.52, and 0.16 were found for control and 8, 14, and 20% extension levels, respectively. When percent of WHC was analyzed, differences among treatments were found. Addition of 8% WGPF slurry slightly increased WHC; however, it was not significantly different from that of the control treatment. Treatments with 14 and 20% extension were not different from each other, but were different from the control and 8%-extension treatments. This means that factors other than pH affected the WHC of the patties extended with WGPF. Proteins were not capable of binding more water than that already added to the different treatments during formulation. No differences in water activity occurred among treatments.

### Yield, Cooking Losses, and Dimensional Changes

Yield and cooking losses were calculated by the difference in weight between the raw patty and the cooked patty. In beef patties extended with WGPF, yield increased and cooking losses decreased as the level of extension increased (Table 3). Patties with the 20% extension level had the highest yield and the lowest cooking losses ($P<0.05$), whereas control and 8%-extension treatments resulted in the lowest yield and the highest cooking losses, but were not different from each other. Other investigators have shown that the addition of plant proteins increases yields of cooked ground beef patties. Brown and Zayas (1989, 1990) reported an overall trend for reduction in cooking losses as the level of added corn germ protein increased in beef patties either heated in a microwave oven or broiled in a conventional oven. Berry *et al.* (1985) found that patties processed with soy flour produced the highest cooking yields compared to all-beef patties, which were the lowest.

The cooking process causes several changes in food. One of them is the change in diameter and thickness, better known as shrinkage. In food service

TABLE 2.
pH, WATER HOLDING CAPACITY (WHC), AND WATER ACTIVITY ($a_w$) OF RAW BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF)

| Treatment [1] (% extension) | pH | WHC (%) | $a_w$ |
|---|---|---|---|
| 0 | 5.57 [a] | 11.87 [a] | 0.996[a] |
| 8 | 5.67 [b] | 11.98 [a] | 0.998[a] |
| 14 | 5.74 [c] | 9.77 [b] | 0.996[a] |
| 20 | 5.76 [d] | 8.26 [b] | 0.996[a] |

[a,b,c,d]Means in the same column with different superscripts are significantly different ($P<0.05$).
[1]Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.

TABLE 3.
YIELD, COOK LOSSES AND DIMENSIONAL CHANGES OF BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF) AND COOKED ON A GRIDDLE

| Treatment (% extension) | Yield (%) | TCL[2] (%) | Decrease in diameter (%) | Increase in thickness (%) |
|---|---|---|---|---|
| 0 | 73.30[a] | 26.70[a] | 15.31[a] | 10.68[a] |
| 8 | 75.50[a] | 26.50[a] | 14.61[a] | 6.14[a,b] |
| 14 | 76.59[b] | 23.42[b] | 12.65[b] | 5.39[a,b] |
| 20 | 79.53[c] | 20.47[c] | 10.26[c] | 1.59[b] |

[a,b,c,d]Means in the same column with different superscripts are significantly different ($P<0.05$).
[1]Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.
[2]Total cooking losses.

establishments, maintaining quality standards of beef patties is important. Therefore, shrinkage is an important parameter to measure when an additive is being investigated. As a general trend, addition of WGPF decreased changes in diameter and thickness of the patties when they were cooked (Table 3). Control and 8%-extended patties were smaller in diameter when compared to 14 and 20%-extended patties ($P<0.05$). Patties extended at 20% showed less decrease in diameter. Significantly thicker patties ($P<0.05$) were obtained from the control treatment when compared to patties extended at 20%. Patties extended at 8 and 14% were not different from each other and were similar to the control and 20%extended patties. Because meat proteins were diluted with the addition of the WGPF slurry to the patty formulation, less myofibrillar protein network was present to shrink during the cooking process. At the same time swelling increased. Other researchers also have reported that plant proteins added to meat decreased shrinkage (Judge *et al.* 1974; Bowers and Engler 1975; Kotula and Rough 1975; Brown 1988).

## Proximate Analysis

Experimental data showed that the protein content of raw and cooked patties decreased with the addition of WGPF. Raw control patties had a higher protein content ($P<0.05$) than the extended patties, which were not different among themselves (Table 4). Cooked control and 8%-extended patties had similar protein contents. The protein content of patties extended with 14% WGPF was similar to that of 8%-extended patties, but different from that of control patties. Patties extended at 20% had lower protein content ($P<0.05$) as compared with the rest of the treatments. WGPF contains about 30% protein, and beef contains 19–23% protein, depending on the leanness of the meat (Judge *et al.* 1989). However, WGPF also contains carbohydrates, fiber, and some other minor nutrients that may have been caused a decrease in protein content. Moreover, the protein experienced a dilution effect because the added WGPF was hydrated to three times its weight. Therefore, the reduction in protein content resulted from the higher retention of water. Nevertheless, it is important to consider that extension of meat products with WGPF will result in products containing increased levels of carbohydrates, fiber, and minerals.

Usage of WGPF as an extender in ground meat products is related to the nutritive value of the protein components. Amino acid analysis showed that the amino acid composition in beef patties was not affected significantly by the addition of WGPF, with the exception of methionine, which decreased as the level of extension increased (Table 5). Extension treatment with 8% WGPF slurry was not significantly different compared to all the other treatments. Extension treatments with 14 and 20% WGPF slurry resulted in a significantly

TABLE 4.
PROXIMATE COMPOSITION OF RAW AND COOKED BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF)

| Treatment[1] | Protein (%) | | Fat (%) | | Water (%) | | Carbohydrates[2] (%) |
|---|---|---|---|---|---|---|---|
| (% extension) | Raw | Cooked | Raw | Cooked | Raw | Cooked | |
| 0 | 17.34[a] | 21.39[a] | 21.04[a] | 21.24[a] | 49.61[a,c] | 43.47[a] | 0 |
| 8 | 15.77[b] | 20.90[a,b] | 20.29[a] | 20.19[b] | 47.64[a] | 42.45[a] | 1.06 |
| 14 | 15.41[b] | 20.03[b] | 18.89[b] | 18.71[c] | 51.86[b] | 44.31[a] | 1.86 |
| 20 | 14.86[b] | 18.43[c] | 17.48[c] | 17.76[d] | 50.71[b,c] | 45.27[a] | 2.65 |

[a, b, c, d] Means in the same column with different superscripts are significantly different ($P<0.05$).

[1] Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.

[2] The percent of carbohydrates was determined from the content of carbohydrates in WGPF.

TABLE 5.
AMINO ACID COMPOSITION (g/100) OF WHEAT GERM PROTEIN FLOUR (WGPF) AND WGPF-EXTENDED BEEF PATTIES COOKED ON A GRIDDLE

| Amino acid | Treatment (% extension) [1] | | | | WGPF |
|---|---|---|---|---|---|
| | 0 | 8 | 14 | 20 | |
| Asn (D+N)[2] | 3.391 | 2.917 | 2.650 | 2.513 | 1.593 |
| Glx (E+Q)[3] | 4.997 | 3.325 | 3.971 | 3.874 | 1.068 |
| Serine | 1.551 | 1.410 | 1.280 | 1.229 | 0.931 |
| Glycine | 1.206 | 0.962 | 0.931 | 0.853 | 0.573 |
| Histidine | 0.845 | 0.785 | 0.747 | 0.678 | 0.559 |
| Arginine | 2.012 | 1.707 | 1.519 | 1.515 | 1.692 |
| Threonine | 1.636 | 1.382 | 1.206 | 1.184 | 0.856 |
| Alanine | 2.244 | 1.975 | 1.878 | 1.753 | 1.167 |
| Proline | 1.747 | 1.365 | 1.285 | 1.244 | 1.053 |
| Tyrosine | 1.159 | 1.114 | 1.014 | 0.886 | 0.511 |
| Valine | 1.216 | 1.027 | 0.851 | 0.850 | 0.743 |
| Methionine | 1.866 [a] | 1.557 [a,b] | 1.293 [b] | 1.130 [b] | 0.163 |
| Isoleucine | 1.190 | 0.851 | 0.691 | 0.644 | 0.634 |
| Leucine | 3.283 | 2.755 | 2.277 | 2.236 | 1.190 |
| Phenylalanine | 1.333 | 1.262 | 1.077 | 1.058 | 0.787 |
| Lysine | 2.907 | 2.453 | 2.129 | 2.124 | 1.012 |

[a, b] Means in the same column with different superscripts are significantly different ($P<0.05$).

[1] Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation [2] Aspartic acid and asparagine. [3] Glutamic acid and glutamine.

lower content ($P<0.05$) of methionine compared to the control treatment. Gnanasambandam (1993) reported no difference in the amino acid content of frankfurters extended with WGPF.

The addition of WGPF slurry to the formulation caused a significant decrease ($P<0.05$) in fat content for both raw and cooked patties (Table 4). Raw control patties were not different from patties extended at 8%. Patties extended with 14 and 20% WGPF were significantly lower ($P<0.05$) in fat content than control and 8% treatments and were different from each other. The

reduction in fat content was due to the dilution effect caused by the utilization of water to hydrate WGPF, and the fact that the WGPF was defatted. In the cooked patties, a significant decrease ($P<0.05$) in fat content occurred as the level of extension increased. All treatments were different from each other.

The water content of raw patties was affected by the addition of WGPF slurries (Table 4). A general trend indicated that moisture content increased as the level of extension increased. Extension treatments with 14 and 20% WGPF slurry showed the highest water content ($P<0.05$) compared to the control and 8% extension level. As discussed earlier, this was due to the addition of water in the formulation and to the effect of the water binding capacity of the proteins contained in WGPF. Cooked patties showed the same trend as raw patties; however, no significant difference occurred in moisture content among the different treatments. Anderson and Lind (1975), who studied beef-soy patties having fat contents of 15, 20, 25 or 35%, reported that the addition of textured soy protein increased moisture retention and decreased fat retention in patties during cooking to an internal temperature of 70C.

## Sensory Evaluation

Although statistically, no significant difference was found in any of the attributes among the treatments, sensory characteristics of the experimental samples were affected by added WGPF. Meaty aroma decreased and wheat-like aroma increased as the percent of WGPF increased in the formulation of the patties. The same phenomenon was noticed in attributes for flavor. Meaty flavor decreased and wheat-like flavor increased as the level of WGPF extension increased (Table 6). Gnanasambandam (1993) reported trends that suggested an increase in wheaty aroma and flavor when WGPF was used to extend frankfurters. As perceived by panelists, there was no difference ($P>0.05$) in the firmness of the beef patties with the addition of WGPF (Table 7). As measured by shear force and compression values, softness of patties increased ($P<0.05$) with increase in extension levels. Berry *et al.* (1985) found higher values for juiciness in patties formulated with iron- and zinc-fortified soy flour when compared to all-beef patties. Brown and Zayas (1990) reported a significant increase in juiciness of broiled beef patties with the addition of 30% corn germ protein flour slurry.

## Textural Characteristics

Numerous changes in protein and physical structure resulting from heating are related to meat texture. The ability of proteins to retain water and bind fat

TABLE 6.
AROMA AND FLAVOR OF BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF) AND COOKED ON A GRIDDLE

| Treatment [1] (%extension) | Aroma [2] | | Flavor [2] | |
|---|---|---|---|---|
| | Meaty | Wheat-like | Meaty | Wheat-like |
| 0 | 9.39 | 4.37 | 10.33 | 3.08 |
| 8 | 10.03 | 4.69 | 8.75 | 5.09 |
| 14 | 8.65 | 4.71 | 8.40 | 5.02 |
| 20 | 9.08 | 5.21 | 7.40 | 6.57 |

No significant difference ($P > 0.05$) found among means within the same attribute.
[1]Percent extension: slurry of WGPF and distilled water in ratio 1:3 added to formulation.
[2]Based on a 15 cm semistructured line scale anchored on opposing ends "none" (0) and "intense" (15).

TABLE 7.
TEXTURAL PROPERTIES OF GRIDDLED BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF) AND COOKED ON A GRIDDLE

| Treatment [1] (% extension) | Firmness [2] | Juiciness [2] | Shear force (kg) | Compression (kg) |
|---|---|---|---|---|
| 0 | 9.54[a] | 6.69[a] | 3.47 [a] | 1.53 [a] |
| 8 | 8.00[a] | 7.09[a] | 3.03 [b] | 1.52 [a] |
| 14 | 6.76[a] | 8.79[a] | 2.36 [c] | 1.24 [b] |
| 20 | 4.28[a] | 10.88[a] | 2.00 [d] | 1.10 [b] |

[a,b,c,d]Means in the same column with different superscripts are significantly different ($P < 0.05$).
[1]Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.
[2]Based on a 15 cm semistructured line scale anchored on opposing ends "none" (0) and "very" (15).

determine texture, juiciness, and structural binding characteristics. However, carbohydrates contained in WGPF also contributed to these quality characteristics. Hardness of beef patties was determined as kg force for both shear and compression. Instrumental measurements showed that less force was required to either shear or compress the samples as the level of extension increased in the patty formulation (Table 7). Control patties required more kg of force to be sheared ($P<0.05$) than WGPF-extended patties, and all treatments were different. A correlation coefficient of $r = 0.97$ was found between firmness measured by panel and shear force measured by instrument. A similar trend was observed when compression (50% of sample's height) was measured. Patties extended with 14 and 20% WGPF slurry required significantly less ($P<0.05$) force to be compressed than control and 8% extension patties. Huffman and Powell (1970), Kotula and Rough (1975), and Cross *et al.* (1975) reported that all-beef patties were less tender than patties with soy added.

## Color

Color is the single most important factor considered by the consumer when selecting meat. Therefore, color evaluation was performed in order to detect any effect from extension with WGPF. No difference was observed in lightness of the raw patties (Table 8). A significant increase in redness ($P<0.05$) was found when the raw extended patties were compared to control raw patties. The control patties had a higher degree of metmyoglobin formation than extended patties. This may have been the cause for the decrease in redness. A significant increase ($P<0.05$) in yellowness occurred as the level of extension increased. Differences among treatments were observed for hue angle. Purity of the color was measured by the saturation index. An increase in purity occurred with the addition of WGPF, and the extended patties were not different from each other.

Cooking of the patties resulted in color value changes (Table 9). Patties extended with 20% WGPF slurry were significantly lighter than control patties. Patties extended with 8 and 14% WGPF slurry were not different from each other and were similar in lightness to the control and 20%-extended patties. A significant reduction in redness was found for the extended cooked patties. The control treatment was significantly higher ($P<0.05$) in redness compared to the extended treatments, which did not differ among themselves. Similar data were found when broiled beef patties were extended with corn germ protein flour (Brown and Zayas 1990). This suggests that a dilution of meat pigments was caused by the extension with hydrated WGPF, resulting in a decrease of redness. Gnanasambandam (1993) reported that Hunter Lab b values were higher for frankfurters containing WGPF in the formulation compared to all-meat frankfurters. However, in this experiment, no differences among the

TABLE 8.
COLOR VALUES OF RAW BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF)

| Treatment [1] (% extension) | L | a | b | Hue angle | Saturation index |
|---|---|---|---|---|---|
| 0 | 40.92[a] | 10.59[a] | 8.86[a] | 40.48[a,b] | 13.86[a] |
| 8 | 40.53[a] | 11.55[b] | 9.15[b] | 38.56[c] | 14.75[b] |
| 14 | 40.42[a] | 11.53[b] | 9.47[c] | 39.50[b,c] | 14.92[b] |
| 20 | 40.24[a] | 11.22[b] | 9.58[c] | 40.54[a] | 14.76[b] |

[a,b,c]Means in the same column with different superscripts are significantly different ($P<0.05$).
[1]Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.

TABLE 9.
COLOR VALUES OF BEEF PATTIES EXTENDED WITH WHEAT GERM PROTEIN FLOUR (WGPF) AND COOKED ON A GRIDDLE

| Treatment [1] (% extension) | L | a | b | Hue angle | Saturation index |
|---|---|---|---|---|---|
| 0 | 45.14[a] | 5.83[a] | 7.22[a] | 50.73[a] | 9.62[a] |
| 8 | 45.68[a,b] | 5.18[b] | 7.24[a] | 53.14[b] | 9.26[b] |
| 14 | 45.49[a,b] | 5.38[b] | 7.51[a] | 53.71[b,c] | 9.67[a] |
| 20 | 45.97[b] | 5.25[b] | 7.47[a] | 54.18[c] | 9.49[a,b] |

[a,b,c]Means in the same column with different superscripts are significantly different ($P<0.05$).
[1]Percent extension = slurry of WGPF and distilled water in ratio 1:3 added to formulation.

various patty treatments were found for yellowness ($P<0.05$). Extended patties had a greater hue angle compared to the control patties. The hue angle of patties extended with 8% WGPF slurry was similar to that of patties extended with 14%, but different from that of 20%-extended patties. The two latter treatments were not different from each other. Control patties had a more pure color than the 8% extended patties. Patties extended with 14 and 20% WGPF slurry did not differ in purity and were similar to the control.

## CONCLUSIONS

Utilization of WGPF increased the yield and decreased cooking losses as a result of increasing water retention of beef patties cooked on a griddle. Protein and fat contents of both raw and cooked patties decreased with increasing levels of WGPF in the formulations. This was due to a dilution effect caused by the addition of hydrated WGPF. Amino acid content of the patties was not severely affected, except that methionine content decreased in WGPF-extended patties. A decrease in redness was caused by a dilution of meat pigments by addition of the WGPF slurry. Although no significant difference was found, wheat-like aroma and flavor and juiciness tended to increase as the level of WGPF increased. Tenderness, as measured by panelists and instrument, increased with the addition of WGPF. Therefore, WGPF can be recommended for use as an extender in ground beef patties.

## REFERENCES

AMSA. 1983. Guidelines for sensory, physical and chemical measurements in ground beef. Amer. Meat Sci. Assoc. and National Live Stock and Meat Board, Chicago, IL.

ANDERSON, R.H. and LIND, K.D. 1975. Retention of water and fat. Food.Tech. *29*, 44–45.

Anon. 1981. "Food bar" offers high protein content. Food Prod. Dev. *15*, 30.

AOAC 1990. Official Methods of Analysis, 15th ed. Vol. II. Association of Official Analytical Chemists, Arlington, VA.

BAJAJ, M., KAUR, A. and SIDHU, J.S. 1991. Studies on the development of nutritious cookies utilizing sunflower kernels and wheat germ. Plant Foods for Human Nutr. *41*, 381–387.

BERRY, B.W., LEDDY, K.F. and BOWDELL, C.E. 1985. Sensory characteristics, shear values and cooking properties of ground beef patties extended

with iron- and zinc-fortified soy isolate, concentrate or flour. J. Food Sci. *50*, 1556–1559.

BOWERS, J.A. and ENGLER, P.P. 1975. Freshly cooked and cooked, frozen reheated beef and beef-soy patties. J. Food Sci. *40*, 624–625.

BROWN, L.M. 1988. Application of corn germ protein in beef patties. MS Thesis. Kansas State University, Manhattan, KS.

BROWN, L.M. and ZAYAS, J.F. 1989. Effect of corn germ protein on the quality characteristics of beef patties heated by microwave. J. Food Processing Preservation *13*, 155–170.

BROWN, L.M. and ZAYAS, J.F. 1990. Corn germ protein flour as an extender in broiled beef patties. J. Food Sci. *55*, 888–892.

CARA, L. *et al.* 1992a. Long-term wheat germ intake beneficially affects plasma lipids and lipoproteins in hypercholesterolemic human subjects. J. Nutr. *122*, 317–326.

CARA, L. *et al.* 1992b. Effects of oat brand, rice brand, wheat fiber, and wheat germ on postprandial lipemia in healthy adults, Am. J. Clin. Nutr. *55*, 81–88.

CROSS, H.R., STANFIELD, M.S., GREEN, E.C., HEINEMEYER, J.M. and HOLLICK, A.B. 1975. Effect of fat and TVP content on consumer acceptance of ground beef. J. Food. Sci. *40*, 1331–1332.

GARCIA, W.J., BLESSING, G.W. and INGLETT, G.E. 1972. Mineral constituents in corn and wheat germ by atomic absorption spectroscopy. Cereal Chem. *49*, 158–162.

GILL, O.C. and PENNEY, N. 1988. The effect of the initial gas volume to meat weight ratio on the storage life of chilled beef packaged under carbon dioxide. Meat Sci. *22*, 53–63.

GNANASAMBANDAM, R. 1993. Functionality and utilization of wheat germ proteins in comminuted meat products. Ph.D Dissertation. Kansas State University, Manhattan, KS.

GNANASAMBANDAM, R. and ZAYAS, J.F. 1994. Quality characteristics of meat batters and frankfurters containing wheat germ protein flour. J. Food Quality. *17*, 129–142.

GODUNOVA, L.Y., DEMCHUK, A.P., CHUMECHENKO, N.A., MARKIANOVA, L.M. and ROITER, I.M. 1986. New products enriched with wheat germ. Pishcheavaya Promyshlennost *3*, 34 [as cited in FSTA (1987) 12 M 57].

HUFFMAN, D.L. and POWELL, W.E. 1970. Fat content and soy level effect on tenderness of ground beef patties. Food Tech. *24*, 100–101.

JUDGE, M., ABERLE, E., FORREST, J., HEDRICK, H. and MERKEL, R. 1989. Principles of meat processing. Meat for food service. Palatability and cookery of meat. In *Principles of Meat Science*, 2nd Ed., p. 160, 267–268, 275. Kendall/Hunt Publishing Co., Dubuque, IA.

JUDGE, M.D., HAUGH, G.L., ZACHARIAH, C.E., PARMELEE, C.E. and PYLE, R.L. 1974. Soya additives in beef patties. J. Food Sci. *39*, 137–139.

KOTULA, A.W. and ROUGH, D.K. 1975. Cooking losses and tenderness of beef soy protein patties. 21st European Meeting of Meat Research Workers, pp. 168–169, Bern, Switzerland.

MILADI, S., HEGSTED, D.M., SAUNDERS, R.M. and KOHLER, G.O. 1972. The relative nutritive value, amino acid content and digestibility of the protein of wheat mill fractions. Cereal Chem. *49*, 119–127.

OSMAN, M., DOAS, H.A. and EL-SAKR, A.S. 1988. Carbohydrates in cereal germs. Grasas y Aceites *39*: 207–209.

ROUSSET, S. and RENERRE, M. 1991. Effect of $CO_2$ or vacuum packaging on normal and high pH meat shelf-life. Int. J. Food Sci. Tech. *26*, 641–652.

RUALES, J., POLIT, P., and NAIR, B.M. 1989. Nutritional evaluation of a sweet bar produced for supplementary feeding of undernourished school children. Nutri. Rep. Int. *40*, 113–121.

SAS, 1988. *SAS User's Guide: Basic Statistical Analysis*. SAS Institute Inc., Cary, NC.

SZCZESNIAK, A.S., BRANDT, M.A. and FRIEDMAN, H.H. 1962. Development of standard rating scale for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. p. 397–403. General Foods Corporation, Technical Center, Tarrytown, NY.

TURNBOUGH, J.M. and BALDWIN, R.E. 1986. Enhancing the nutritive value and appearance of microwave-baked muffins. Microwave World *7*, 7.

# PHYSICAL PROPERTIES OF VARIOUS STARCH BASED FAT-SUBSTITUTES

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## ABSTRACT

*Physical properties—rigidity modulus (RM), water solubility, gel strength (GS), water holding capacity (WHC), electrical conductivity (EC), apparent viscosity (AV), and pH of 8 starch-based fat-substitutes were determined. These fat-substitutes provide a wide variation in physical properties. Some form strong gels when heated, others provide good cold water solubility. In some cases, freezing treatment improved gelling ability. All fat-substitutes had good hot water solubility. The EC increased with the increase in fat-substitute concentration. pH at 30% concentration ranged from 4.8 to 6.6. The samples with lower concentrations resulted higher pH. Both pseudoplastic and dilatant behaviors were observed.*

## INTRODUCTION

In response to consumer's demands, a number of fat-substitutes have been developed. The overriding consideration in developing fat-substitutes was to provide flavor comparable to traditional products. Summerkamp and Hesser (1990) classified fat-substitutes into four categories, i.e., protein based, synthetic compounds, carbohydrate-based, and combination products. Further, Glicksman (1991) classified fat-substitutes in many categories such as synthetic replacers, hydrocolloids, starch-derivatives, hemicelluloses, $\beta$-Glucans, soluble bulking agents, micro-particulates, composite materials, and gums.

Physical and chemical properties of fat-substitutes are important to final quality of food products. The following properties are often used to describe a

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fat-substitute: gel strength, rigidity modulus, gelatinization temperature, water solubility, particle size, apparent viscosity, flavor/aroma, water absorption, water holding capacity, pH, electrical conductivity, color, etc. These properties, represent gelling ability (first 3), water- and fat-binding abilities (4th one), slicing characteristics (next 2), flavor enhancement (next 1) as well as the ability to improve cooking yields (next 2). Out of these, gelling ability is the most important property because it helps to form a gel that has smooth, fat-like texture (Giese 1992). Several fat-substitutes are currently being used in food products. One of them is iota-carrageenan. It retains moisture based on its ability to form a complex with water and protein. It gels strongly with calcium ions to form a clear, elastic, syneresis-free gel (Giese 1992). In addition, its good cold water solubility and freeze/thaw capability can enhance machinability during processing (Egbert *et al.* 1991).

Isolated soy protein is also widely used in many food products. Isolated soy protein, containing 90% protein, is easy to use and provides nutritious protein (McMindes 1991). Oat bran and oat fiber provide textural enhancement by increasing moisture retention. LeanMaker™, a specially processed oat bran mixed with flavorings and seasonings, enhances the textural ability and provides improved mouth-feel (Pszczola 1991). Starch derivatives such as Sta-Slim™ 171, Amalean™I, Remyline® AC, LeanBind™, Paselli™ SA2, Rice* Complete®, SlenderLean™, and TrimChoice™ can be used (as recommended by their manufacturers) as binders to maintain juiciness and tenderness in low-fat meat products. The starches are used to bind water. The advantages of food starches are their low cost, familiar ingredient technology, and positive acceptance by consumers (Berry 1991; Giese 1992). Oatrim™ is a maltodextrin produced by the conversion of oat starch to maltodextrins by alpha-amylase enzymes (Inglett and Grisamore 1991). Thermostable gels made from this exhibited a smooth, fat-like texture, and a bland flavor (Summerkamp and Hesser 1990; Giese 1992).

Although a number of fat-substitutes have been developed, criteria to select a proper fat substitute for processing a specific low-fat product are unknown. Therefore, in this paper physical properties such as rigidity modulus, water solubility, gel strength, water holding capacity (WHC), electrical conductivity, apparent viscosity, and pH of 8 starch-based fat-substitutes which are recommended for ground meat products are investigated. In another study, this data were used to develop criteria to select fat-substitutes for ground meat products.

## MATERIAL AND METHODS

The selected (8) fat-substitutes are all starch-based (Table 1). Some of them are modified starches from corn and potato, others are starch derivatives from rice,

TABLE 1.
SELECTED FAT-SUBSTITUTES

| Name | Type | Supplier |
|---|---|---|
| Amalean™ I | modified high-amylose corn starch | American Maize Products Co., Hammond, IN, USA |
| LeanBind™ | specialty modified food starch | National starch and Chemical Company, Bridgewater, NJ, USA |
| Paselli™ SA2 | enzymatically modified potato starch | AVEBE America Inc., Princeton, NJ, USA |
| Remyline™ AC | rice starch derivative | REMY Industries, Brussel, Belgium |
| Rice*Complete® 3 | complete rice solids with the starch fraction hydrolysed to 3 dextrose equivalent | Zumbro Inc., Hayfield, Minnesota, USA |
| SlenderLean™ | modified food starch derived from tapioca | National Starch and Chemical Company, Bridgewater, NJ, USA |
| Sta-Slim™ 171 | potato starch derivative | A. E. Staley Manufacturing Company, Decatur, IL, USA |
| TrimChoice™ | oats starch derivative | Specialty Grain Products Company, Omaha, NE, USA |

oat, potato and tapioca. These fat-substitutes are used for meat and dairy products to reduce fat levels. Their major components are carbohydrate, and protein. The following measurements of the properties of each fat-substitutes were replicated six times.

## Shear Rigidity Modulus (SRM)

Continuous evaluations of the rigidity modulus during thermal processing of the fat substitutes were conducted by using a thermal scanning rigidity monitor (TSRM) (Correia and Mittal 1991). The shear rigidity monitor consisted of a cylindrical stainless steel water-jacketed sample holder (35 mm inner-diameter, 90 mm height); a base plate through which the sample holder was set on the platform of a universal testing machine (Model 4204, Instron Canada Ltd., Burlington, Ontario, Canada) fitted with a 1 kN load cell; a rectangular 80 × 16 mm shearing screen (45 × 45 mesh, 0.254 mm in wire diameter) attached with a connecting bolt, through which, the shearing screen was assembled on the load cell of the universal testing machine.

The thermal processing device consisted of a water bath with a heater and pump (Model G, Haake Mess Technik u. Co., Berlin, Germany); two rubber tubes were used to connect the water bath with the water-jacketed sample holder; an automatic temperature controller (Model PG20, Haake Mess Technik u. Co., Berlin, Germany) was used to control the temperature change rate of the water in a bath. Data acquisition consisted of two devices: a chart recorder connected to the universal testing machine, and a data logger (Model 3020T, Electronic Controls Design Inc., Toronto, Canada). The former was used to obtain a hard copy of the shear forces versus displacement during the thermal processing of the sample. The latter was used to record the temperature variation of a sample near the geometric center of the sample using a T-type thermocouple.

A 100 g sample containing 30% fat-substitute and 70% distilled water was well mixed in a 250 ml beaker. Then, the sample was transferred into the water-jacketed holder. The thermal processing device circulated water through the water-jacket. The increasing temperature of the circulating water was automatically controlled at a rate of 0.5C/min from 20 to 80C by a temperature controller. Before gelling (around 20 to 50C), the sample was stirred intermittently to insure the uniformity of the sample. A thermocouple was inserted into the sample at the point near the geometric center of the sample holder. The data logger recorded the temperature every 2 min. The rectangular screen, mounted on the load cell of the universal testing machine, was immersed in the sample at a depth of 72 mm. In 2 min time intervals, a $\pm 0.5$ mm cyclic movement of the rectangular screen was applied to the sample at a crosshead speed of

1 mm/min to produce sample deformation. The shear force was recorded on a chart recorder at a speed of 5 mm/min. The load ranges of the universal testing machine were set to different levels based on the samples tested. The sample rigidity modulus was calculated by:

$$G = \frac{\text{maximum shear stress}}{\text{maximum shear strain}} = \frac{g.F/(2A)}{d/H}$$

where, G = rigidity modulus, Pa, g = acceleration due to gravity, $m/s^2$, F = force amplitude, kg, A = average area of the screen immersed in the sample = 1.152E-03 $m^2$, d = displacement amplitude of the screen = 5E-03 m, H = thickness of the sample on both side of the screen, m.

The experimental data were analyzed by using the SAS-GLM and Duncan's ranking procedures (SAS 1990). There were no significant differences between the replicates for all the fat-substitutes tested. Thus, the data were combined and G versus temperature curves for the fat substitutes were plotted. Several parameters such as the peak force, the peak force temperature, the slope and the intercept of the linear portion of the curve, were recorded.

## Gel Strength

A 40 g mixture of fat-substitute and distilled water (at 20C) was prepared at the moisture content of 70% (wet basis, WB) in a water-jacketed cup (Brookfield Engineering Lab. Inc., Stoughton, MA). A heating bath/circulator (Model D1-G, Haake Mess-Technik u. Co., Firma, Germany) was connected to the cup by two rubber tubes. The aqueous-fat-substitute system in the cup was stirred intermittently during the first 3 min while the 70C hot water recirculated through the outer jacket. The gel strength of a fat-substitute was defined as the maximum force per unit cross section area of the testing probe (15.8 mm in diameter), when the cylindrical probe with a flat end penetrated the 10 mm thick gel sample, maintained at 70C, by 5 mm. The test was conducted on the universal testing machine fitted with an 1 kN load cell. The penetrating speed of the puncture was 100 mm/min. The chart speed of the recorder connected to the testing machine was set to 100 mm/min. Force versus displacement plots for the samples were obtained and their peak forces were calculated.

## Cold Water Solubility

A 14 g sample containing 10% fat-substitute (1.4 g) and 90% distilled water (12.6 g) at 20C was prepared. The aqueous-fat-substitute system was stirred

manually in a V-bottom shaped polyethylene tube with a glass rod for thorough mixing. The sample was centrifuged (Model GS6R, Spinco Division of Beckman Instruments, Inc., Palo Alto, CA) at a speed of 4000 rpm for 15 min at room temperature (around 20C). Then, the mass of the supernatant liquid was recorded. Five grams was transferred into an aluminum cup and dried in a vacuum oven (Model 282A, Fisher Scientific Instrument Division, Pittsburgh, PA) at 100C for 8 h. Then, the mass of the solid left in the aluminum cup was weighed and the total fat-substitute mass in the supernatant liquid was calculated as follows:

$$\text{Total mass of solid in the supernatant liquid} = \frac{\text{mass of the solid in the aluminum cup}}{5} \times \text{total mass of the supernatant liquid} \quad (2)$$

The water solubility for each fat-substitute was determined as the ratio of the mass of the solid present in the supernatant liquid to the total mass of the dry fat-substitute in the aqueous fat-substitute system.

## Hot Water Solubility

The procedure of measuring hot water solubility was similar to the one for cold water solubility except for the sample preparation. While stirring with a glass rod intermittently, the sample was heated to 70C before centrifugation.

## Apparent Viscosity

A 400 g sample containing 20% fat-substitute and 80% distilled water was prepared in a 500 ml beaker. The beaker was placed in a water bath (Model W13, Haake Mess-Technik u. Co., Firrna, Germany). A heating/circulator (Model D1, Haake Mess-Technik u. Co., Firma, Germany) was used to keep the water in the bath at the desired temperature. A rotational viscometer (Model RVTD, Brookfield Engineering Lab. Inc., Stoughton, MA) was used for measurement. The spindle was placed at the center of the cylindrical beaker. The sample in the beaker was stirred intermittently to keep its uniformity. A T-type thermocouple connected with a recording meter (MicroMite™, Thermo-Electric, Saddle Brook, NJ) was inserted into the sample at its geometric center to monitor its temperature. For different fat-substitutes, different spindles were used to get proper readings. The readings were taken at

four spindle speeds (10, 20, 50, and 100 rpm) and two temperatures (30 and 60C). The readings obtained were converted into apparent viscosities (cP) by multiplying with proper factors according to the spindle number and the rotational speeds.

## Water Holding Capacity (WHC)

WHC of the aqueous samples containing 10% and 30% of fat-substitutes were measured by using a centrifugal method. The aqueous samples of the fat-substitutes were prepared by adding distilled water at 20C. Five grams of the sample was placed in a tube and centrifuged (Model J2-21, Beckman Instruments, Canada, Inc., Mississauga, Canada) at a speed of 7500 rpm for 15 min at 20C. The free water from the tubes was removed and weighed. WHC was then calculated using the following equation:

$$\text{WHC} = \frac{\text{mass of water added to the sample} - \text{mass of water removed from the sample}}{\text{mass of fat-substitute}} \times 100 \qquad (3)$$

## Electrical Conductivity

Samples (each weighing 80 g) of aqueous-fat-substitute system with two concentrations (10% and 30% of fat-substitutes) were prepared in 100 ml beakers. The aqueous-fat-substitute system was stirred manually using a glass rod for thorough mixing. Then, electrical conductivity was measured at 20C using a conductivity meter (Model HI 8033, Hanna Instruments, Bedok Industrial Estate, Singapore).

## pH

pH values of the fat-substitutes were measured with an Accumet® pH meter (Model 925, Fisher Scientific Ltd., Toronto, Canada). The aqueous samples containing 10% and 30% of fat substitutes were used at 20C.

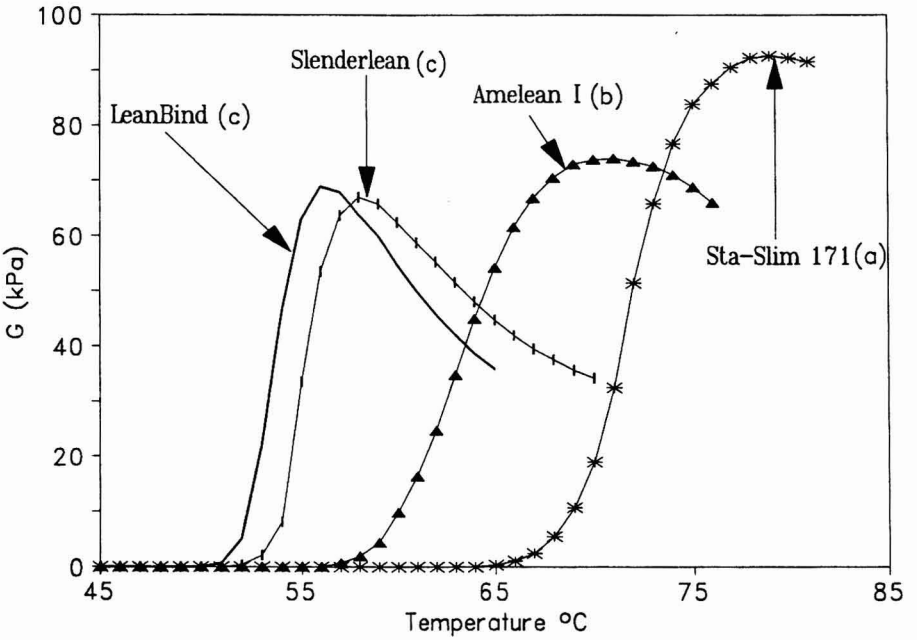


FIG. 1. RIGIDITY MODULI (G) OF FAT-SUBSTITUTES (GROUP 1)
Letters in parentheses represent Duncan's ranking for peak G.

## RESULTS AND DISCUSSION

### Gelation Properties

The rigidity modulus (G, kPa) versus temperature (T, C) curves are plotted in Fig. 1 and 2. All fat-substitutes provided different gelation behaviors and properties. During heating (Fig. 1), there was no increase in G up to a certain characteristic temperature (51 to 66C) for these four fat-substitutes. After this transition temperature, there were rapid increases in G exhibiting peaks from 66 to 92 kPa at temperatures from 56 to 79C, followed by no increase in G with further increase in temperature. Their transition temperatures, peak G values and other behaviors were dependent on the nature of fat-substitutes. Rest of the fat-substitutes except Paselli SA2 (PS) (Fig. 2) showed very similar G-temperature relationships. In all these cases there was no change at low temperature, followed by a rapid increase in G to a specific temperature where G peaks are reached. The peak G values indicate the formation of stable, stiff, and elastic matrix structures of typical heat-induced protein gels. With the further increase in temperature, there was a decrease or no change in G.

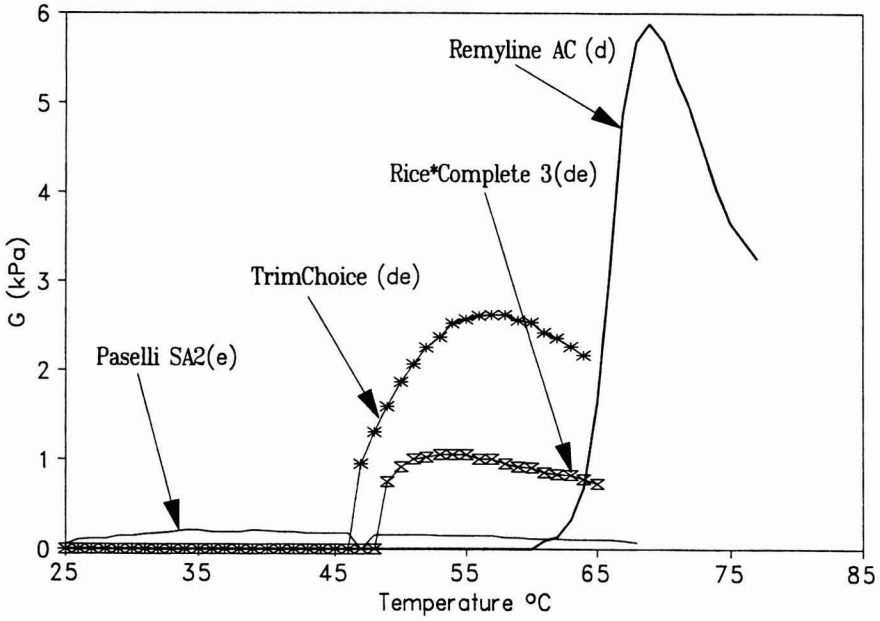


FIG. 2. RIGIDITY MODULI (G) OF FAT-SUBSTITUTES (GROUP 2)
Letters in parentheses represent Duncan's ranking for peak G.

Table 2 lists the gelation parameters including peak rigidity moduli, the temperature corresponding to the peak rigidity modulus, slope of the initial linear portion of the curve and the corresponding intercept for the fat-substitutes. These fat-substitutes can be divided into 2 groups based on G values, with Sta-Slim 171 (ST), Amalean I (AL), SlenderLean (SL), LeanBind (LB) having higher peak G values (65 to 92 kPa) than the rest of four (0.2 to 6 kPa). Among the first group, the peak G value of LB occurred at a temperature of 56C (minimum) while for ST, it was at 79C (maximum). In the second group, it was noticed that Rice*Complete® 3 (RC) did not gel until the temperature rose to 51C (Fig. 2), at which point, an abrupt change increased G to its highest value in a 3C temperature interval and remained close to peak value with further increase in temperature. Similar behavior was noted for TrimChoice (TC). On the other hand, for Remyline AC (RL), the peak G was noted at 70C, however, with the further increase in temperature, G decreased at a higher rate. The gelling ability of PS was found to be very poor as its peak G was only 0.2 kPa. SAS procedure GLM showed that both peak G and the corresponding slope of the initial linear portion of the curves were significantly different at 5% level.

TABLE 2.
DUNCAN'S RANKING FOR MEAN VALUES OF GELATION PROPERTIES OF SELECTED FAT-SUBSTITUTES

| Fat Substitute | Peak | | Slope (kPa/°C) | Intercept (kPa) | Temperature at which gel initiated (°C) |
|---|---|---|---|---|---|
| | G (kPa) | T (°C) | | | |
| Amelean™ I | 73.9b | 71 | 8.35d | -487.6 | 57 |
| LEANBIND™ | 69.0c | 56 | 16.85b | -875.4 | 51 |
| Paselli™ SA2 | 0.2e | 37 | 0.02f | -0.4 | None |
| Remyline™ AC | 5.9d | 70 | 1.32e | -73.9 | 62 |
| Rice*Complete® 3 | 1.1de | 56 | 0.09f | -2.8 | 51 |
| Slenderlean™ | 65.7c | 58 | 18.27a | -984.6 | 54 |
| Sta-Slim™ 171 | 92.5a | 79 | 13.97c | -839.7 | 65 |
| TrimChoice™ | 2.6de | 60 | 0.22f | -9.8 | 48 |

Each value is a mean of six replications. Means in the same column followed by identical letter are not significantly different at the 5% level. G = rigidity modulus, and T = temperature.

Wu *et al.* (1985) studied transitions occurring during the gelation of meat batters using a constant heating rate of 1C/min by a similar method. Three transition temperatures were observed at 38, 46, and 60C. Rigidity which increased beyond 46C was related to the formation of a stable network and a strong gel structure. Schweid and Toledo (1981) also reported transition points in meat batters to occur at 33-36C and at 57-67C. They suggested that these temperatures correspond to points where insolubilization and solubilization of collagen occur, respectively. Foegeding and Ramsey (1987) determined the rigidity changes during heating of meat batters containing various carrageenans and xanthan gum. There was a slight variation of G from 34 to 58C but major variation in rigidity developed from 58-70C due to the gums. Our study also showed a similar trend for fat-substitutes except PS. However, G values and transition ranges are different probably due to the different material.

## Gel Strength

The results of gel strength of fat-substitutes varied considerably under different test conditions. Figure 3 shows the gel strength at room temperature, and of the samples initially frozen at -2C for 24 h and then thawed at room temperature for 8 h.

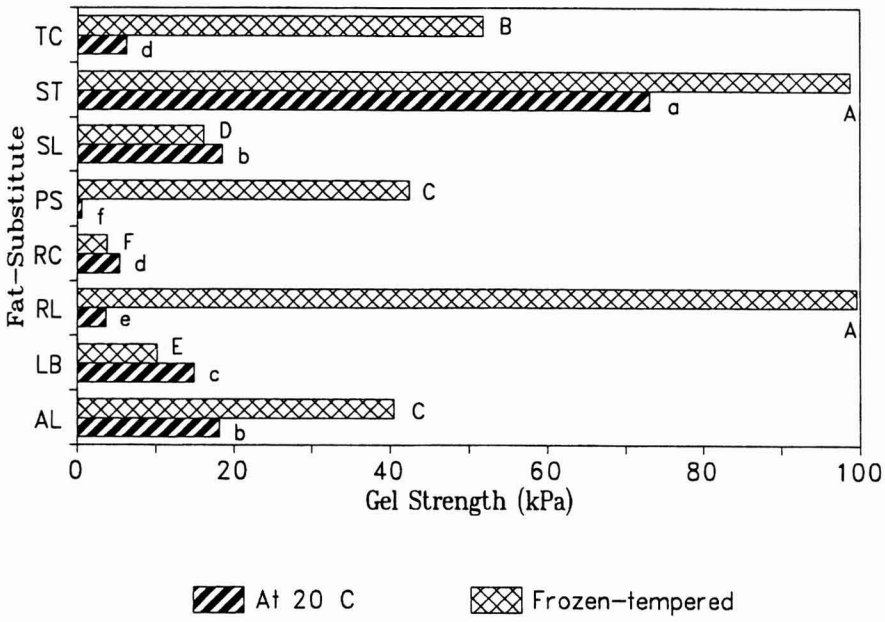


FIG. 3. GEL STRENGTH OF FAT-SUBSTITUTES AT TWO CONDITIONS
Bars with the same letters are not significantly different at 5% level.
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

Fat-substitute PS, when mixed with distilled water became swollen and formed a smooth, creamy fat-like gel, with very low gel strength (~0.4 kPa). When heated to 70C, it became a low-viscosity solution. However, when cooled down to room temperature, its gel strength recovered (0.6 kPa). This confirms the supplier's description that PS can form a "thermoreversible" gel (AVEBE 1992). In addition, after being frozen at -2C and tempered at room temperature (20C), PS had a great increase in gel strength (42.5 kPa).

According to the supplier, the gel strength of TC will increase with time (from 20 to 80 h). The lowest value of gel strength was obtained (penetration force = 10 g) if the sample with 25% solid was heated to 75C, cooled at 4C for 20 h and measured at 4C. Similar to PS, TC can also form a thermo-reversible gel (ConAgra 1992). This characteristic gives ground meat products containing these fat-substitutes good freeze/thaw capability (i.e., reduced thaw losses). Since, thermo-reversible gels provide increase in gel strength at low temperatures, they retain more water during freeze/thaw process. After keeping the

fat-substitutes at -2C for 24 h and thawing at room temperature, the gel strength of TC increased 8.2 times from 6.3 kPa to 51.8 kPa (Fig. 3). Besides, RL and AL also showed significantly larger values after freeze-thaw treatment. On the contrary, the gel strength values after freeze-thaw treatment for other fat-substitutes SL, RC and LB, were lower than the ones at room temperature (Fig. 3). According to the supplier, RL has microwave stability i.e., no change in gel structure after gelatinization and reheating in a microwave oven. Its gelatinization temperature is 70C (at 25% concentration). However, our results showed that RL at 30% concentration started gelling at 62.5C, probably due to the higher concentration used.

ST had the highest gel strength while RC had the lowest, whether the samples were frozen or not. The gel strengths measured under room temperature had better correlation with the corresponding rigidity of moduli ($r = 0.83$) compared with the ones under freeze-thaw condition. This is probably because of the no freezing treatment for the samples used for gelation evaluation. Softer gels at 70C were formed due to the swelling of starch during gelatinization (Comer 1979).

## Water Solubility

Cold water solubilities at 10% concentration of the fat-substitutes can be divided into two groups, with RC, PS, and TC in the first group providing large solubility values (53, 77 and 84%, respectively), and the rest (AL, LB, RL, SL, and ST) in the second group exhibiting very low solubility (<2%) (Fig. 4). Among the second group, ST showed the lowest value (0.8%).

On the other hand, hot water solubility of all the fat-substitutes could not be determined because of the complete gelation of the samples when they were heated to 70C. Thus, no supernatant water existed in the centrifuge tubes after centrifugation of the samples. Therefore, all the fat-substitutes provided 100% hot water solubility. These fat-substitutes are designed to provide maximum solubility when heated to certain temperature (48 to 65C). On the basis of their hot water solubility, these fat-substitutes can not be differentiated.

However, since RC, PS, and TC have good water solubility under room temperature, they can be used at 20C, but the rest require higher temperature for better solubility.

## Water Holding Capacity

The results obtained at 30% concentration of the fat-substitutes may not be reasonable because PS - the potato starch maltodextrin, RC, the whole-rice

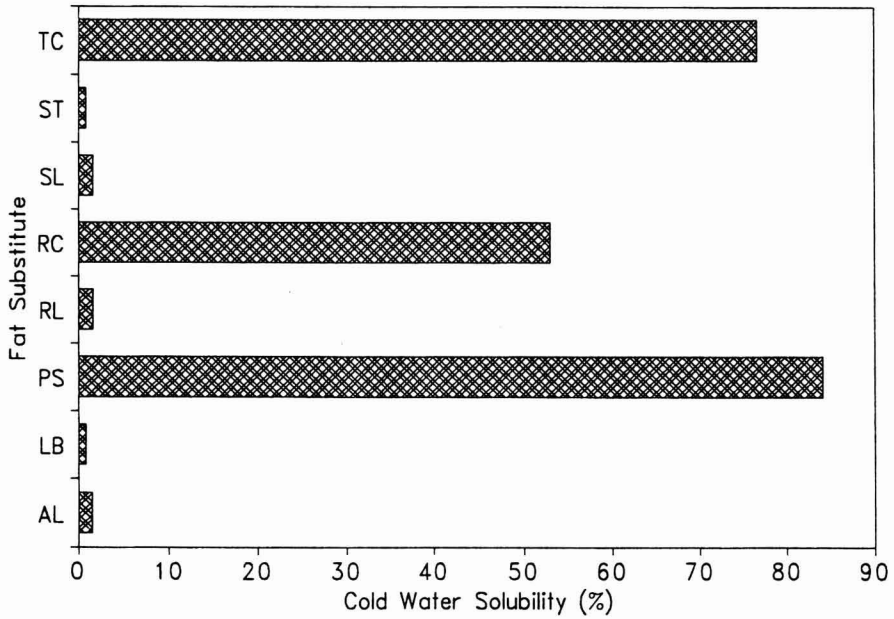


FIG. 4. COLD WATER SOLUBILITY OF FAT-SUBSTITUTES
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

maltodextrin, and TC, oat starch maltodextrin absorbed all the added water (Fig. 5). There was no supernatant water left in the tubes containing these three samples after centrifugation. Thus, over-concentrated samples misled WHC results to the maximum value (233%). It is because these maltodextrins remained swollen when mixed with water that they can entrap more water (Best 1991). Physically, at room temperature, the samples containing 30% of RC, PS, and TC were very sticky, so the centrifugal force could not separate the solids from water, thus, leading to a sharp increase in WHC. At reduced concentration (10%), difference in WHC among these 3 fat-substitutes could be observed (Fig. 5). WHC of PS and TC significantly decreased from 233% to 69% and 66%, respectively. However, WHC of RC was reduced to only 220% which indicated that this modified rice starch has a stronger swelling ability than PS and TC. Beside RC, PS, and TC, modified high-amylose corn starch (AL) appeared to have higher WHC than the rest of 4 fat-substitutes (LB, RL, SL and ST).

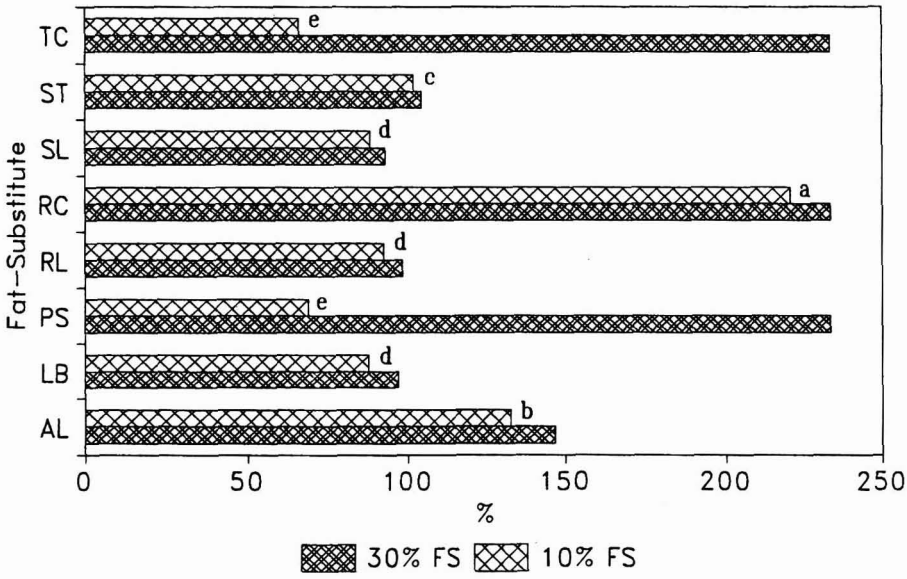


FIG. 5. WATER HOLDING CAPACITY (%) OF FAT-SUBSTITUTES
Bars with the same letters are not significantly different at 5% level.
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

## Electrical Conductivity (EC)

EC of solutions result from the mobility of ions. Electrolytic conductors become better conductors if the apparent viscosity is decreased or there is a less solvation of the ions. Thus, the EC values will indicate the mobility of ions of the fat-substitute in solutions. In meat emulsions, EC influences stability of the emulsions. The electrical conductivities of fat-substitute, aqueous systems increased about 100% when the sample concentration increased to 30% from 10% (Fig. 6). TC had a very high EC compared with the rest of fat-substitute - aqueous systems. This indicated that the modified oat starch, once mixed with distilled water, formed insoluble or slightly dissociated compounds whose conductivity was much higher in comparison with that of distilled water. There was no significant difference between the samples containing i.e., PS and ST , or those with RL and SL. Significant differences were found among the samples containing LB, ST and RC.

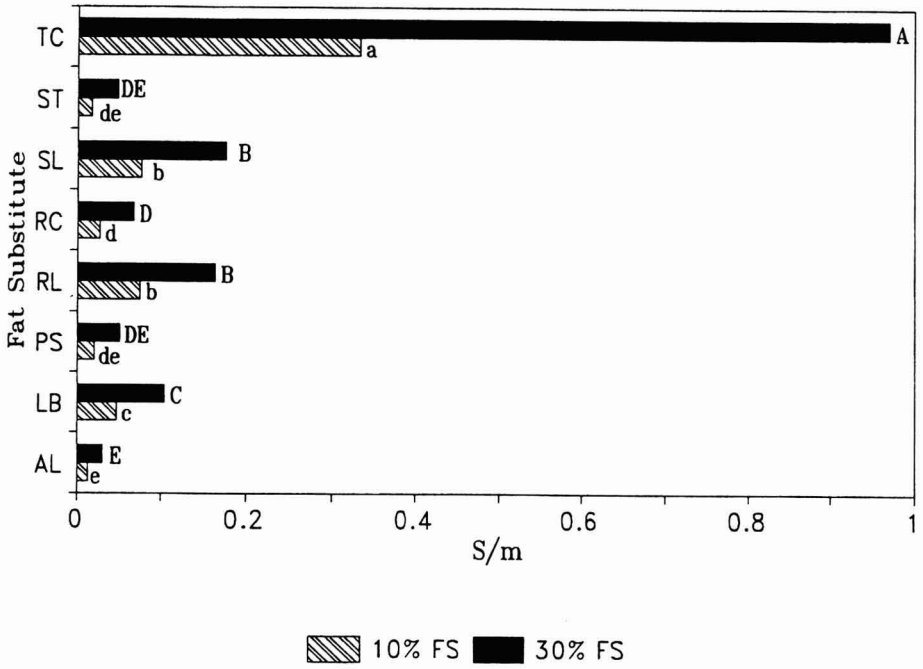


FIG. 6. ELECTRICAL CONDUCTIVITY OF FAT-SUBSTITUTES AT TWO CONCENTRATIONS

Bars with the same letters are not significantly different at 5% level.
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

## pH

pH values of samples containing 30% of fat-substitutes ranged from 4.8 to 6.6 with RC the highest and AL the lowest (Fig. 7). The samples with lower concentration (10%) resulted in higher pH values. Most results of the samples containing 30% fat-substitutes were closer to supplier's specifications. Slight differences might be caused by different test conditions i.e., (temperature, sample concentrations).

## Apparent Viscosity

The Apparent viscosities of fat-substitutes at 30 and 60C, with four levels of shear rates (10, 20, 50, 100 rpm) were measured. The corresponding plots

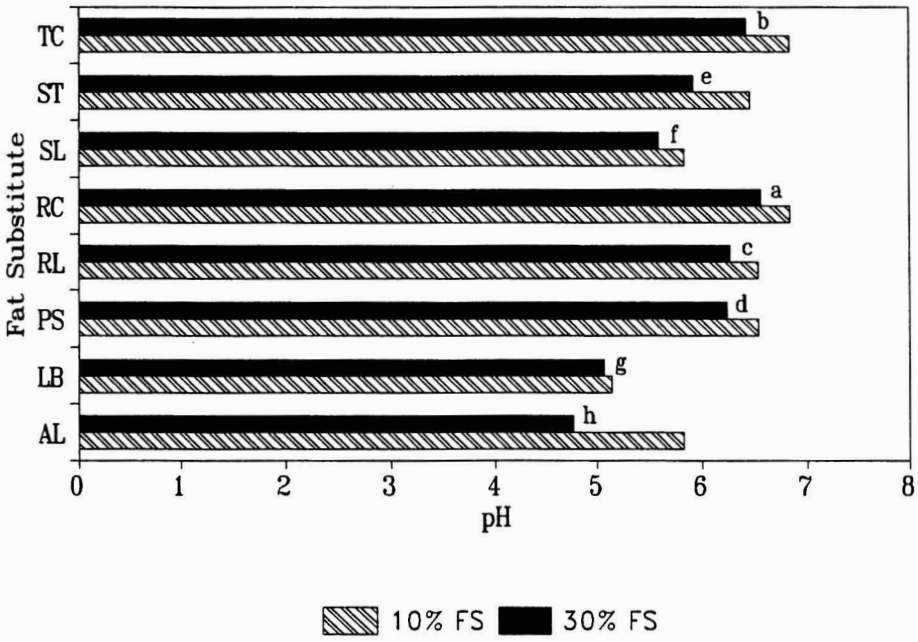


FIG. 7. pH OF FAT-SUBSTITUTES AT TWO CONCENTRATIONS
Bars with the same letters are not significantly different at 5% level.
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

of apparent viscosity are shown in Fig. 8 to 8.5. Fat-substitutes RC and TC exhibited their shear thinning (pseudoplastic) behavior at both 30 (Fig. 8.1) and 60C (Fig. 8.5). This agreed with supplier's conclusion for these two fat-substitutes i.e., a slower shear rate results in higher apparent viscosity. On the other hand, fat substitutes RL, PS, and ST exhibited dilatant behaviors at 30 (Fig. 8.2) and 60C (Fig. 8.3). The fat-substitutes SL and LB exhibited the characteristics of dilatant fluid at 30C (Fig. 8.2), but at 60C, they showed pseudoplastic behavior (Fig, 8.4). When temperature increased from 30 to 60C, the apparent viscosities of most fat-substitutes increased except for RC, whose apparent viscosity decreased by about 80% (Fig. 8.1 and 8.5). However, the viscosity was recorded when the temperature was reduced to 30C. This confirmed the results reported by Pszczola (1991). Duxbury (1990) stated that AL is a psuedoplastic fluid, but our study showed different behavior. At 30C, it exhibited a dilatant behavior (Fig. 8.2); when temperature increased to 60C, its apparent viscosity dropped between shear rates of 10 and 50 rpm, and rose

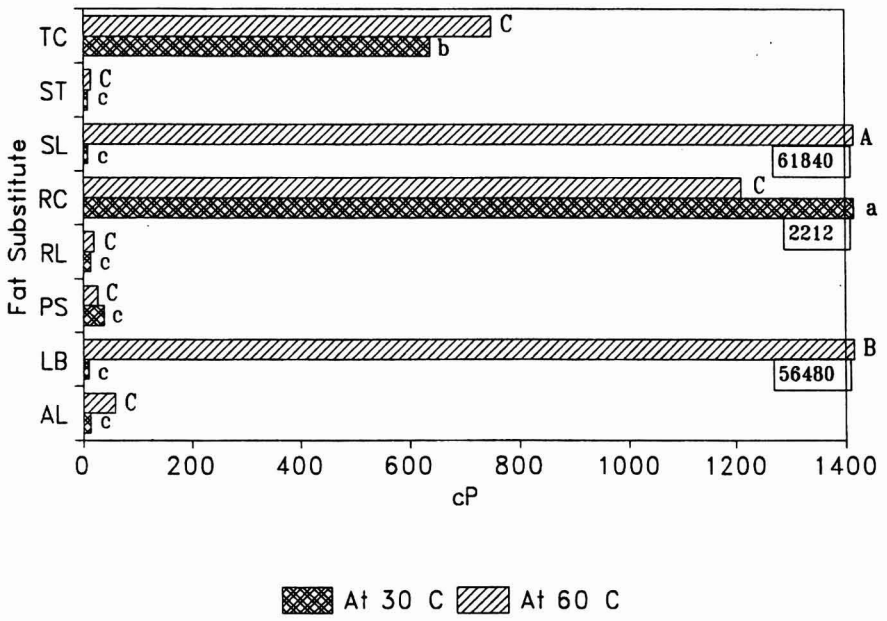


FIG. 8. APPARENT VISCOSITY OF FAT-SUBSTITUTES AT TWO TEMPERATURES
Bars with the same letters are not significantly different at 5% level.
Numbers in boxes are apparent viscosity values. AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RC = Rice-Complete-3, RL = Remyline-AC, SL = SlenderLean, ST = Sta-Slim-171, and TC = TrimChoice.

thereafter. Lewis (1987) concluded that non-newtonian fluids are more difficult to classify experimentally, as the apparent viscosity will depend on the experimental conditions selected.

From shear stress and shear rate plots, it was found that the rice based starches RC and TC are shear thickening as shear stress increases with the increase in shear rate at both 30 and 60C. Similar behavior was noted for other fat-substitutes to a certain extent. Because apparent viscosity is a function of protein type (molecular size, shape, surface charge, type, concentration), pH, temperature, heat treatment, shear rate, ion type and ion concentration (Kinsella 1982), the causes of above apparent viscosity changes with different shear rate and temperature are hard to determine.

Duncan analyses for the properties of fat-substitutes are listed in Table 3 for comparison.

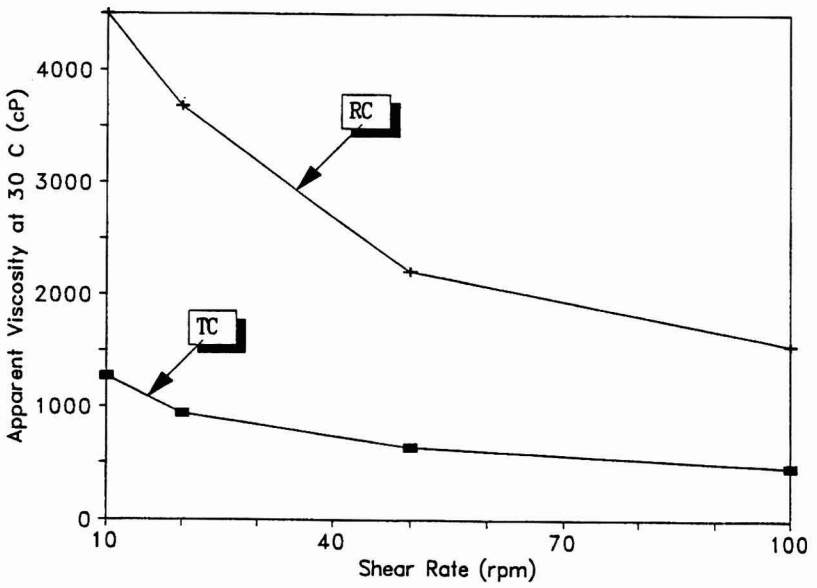


FIG. 8.1. APPARENT VISCOSITY OF FAT SUBSTITUTES VERSUS SHEAR RATES AT 30C (GROUP 1)
RC = Rice-Complete-3 and TC = TrimChoice.

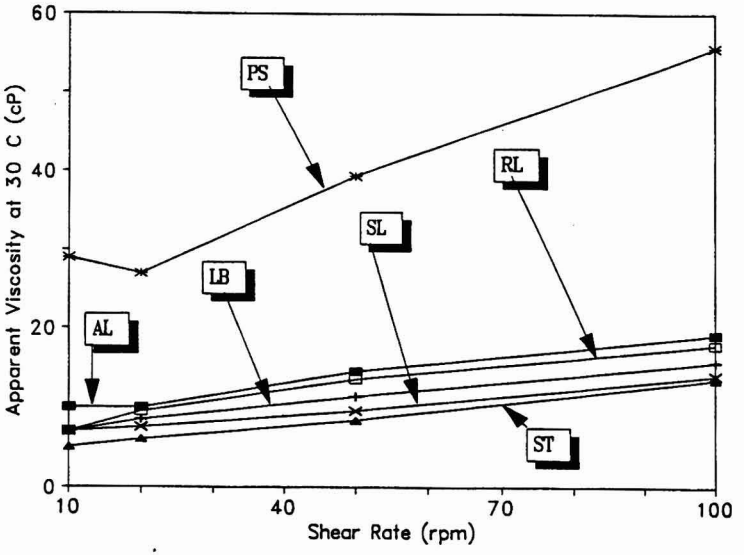


FIG. 8.2. APPARENT VISCOSITY OF FAT-SUBSTITUTES VERSUS SHEAR RATES AT 30C (GROUP 2)
AL = Amalean-I, LB = LeanBind, PS = Paselli-SA2, RL = Remyline- AC, SL = SlenderLean, and ST = Sta-Slim-171.

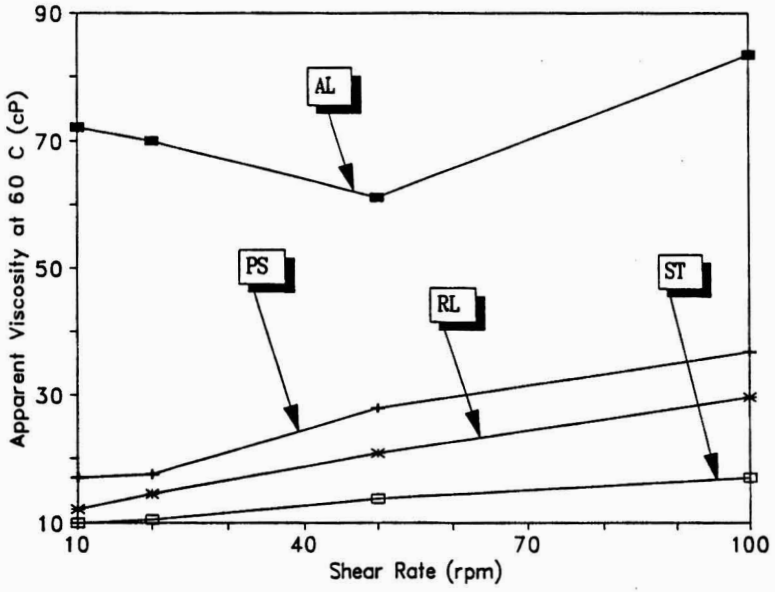


FIG. 8.3. APPARENT VISCOSITY OF FAT-SUBSTITUTES VERSUS SHEAR RATES AT 60C (GROUP 1)
AL = Amalean-I, PS = Paselli-SA2, RL = Remyline- AC, and ST = Sta-Slim-171.

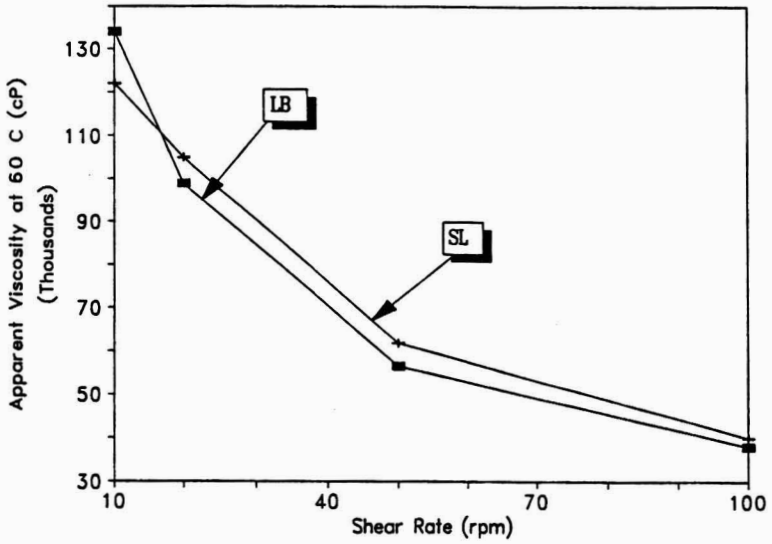


FIG. 8.4. APPARENT VISCOSITY OF FAT-SUBSTITUTES VERSUS SHEAR RATES AT 60C (GROUP 2)
LB = LeanBind, and SL = SlenderLean.

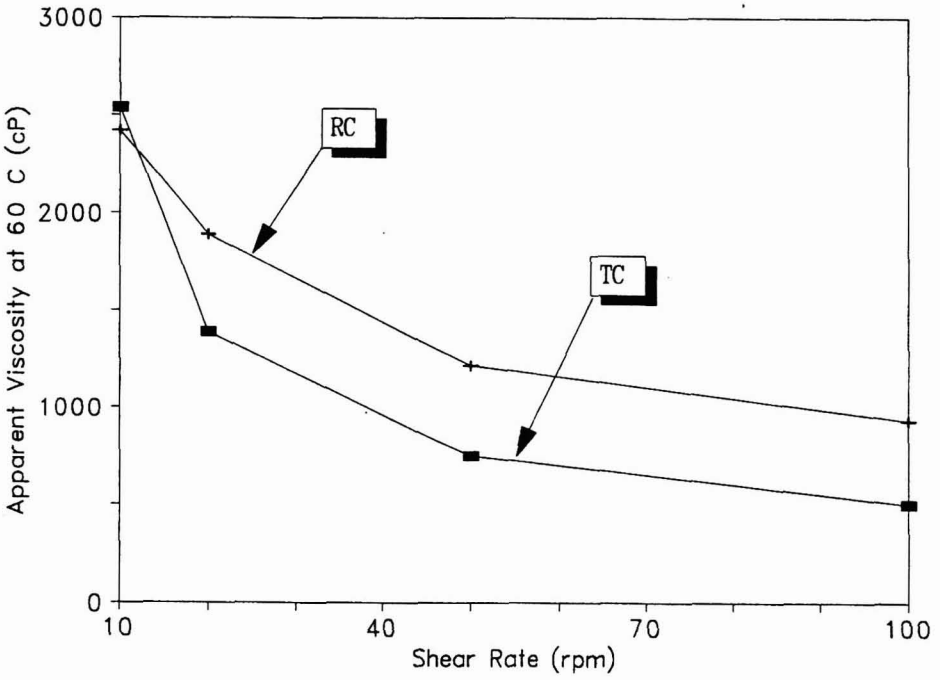


FIG. 8.5. APPARENT VISCOSITY OF FAT-SUBSTITUTES VERSUS SHEAR RATES AT 60C (GROUP 3)
RC = Rice-Complete-3, and TC = TrimChoice.

## CONCLUSIONS

Four fat-substitutes (ST, AL, SL and LB) provided higher peak G values (65 to 92 kPa) compared to others (PS, RC, RL and TC) (0.2 to 6 kPa). The gelling ability of PS was the poorest. Similarly, five fat-substitutes (AL, PS, RL, ST and TC) formed thermo-reversible gels, while others (SL, RC and LB) provided lower gel strengths after freeze-thaw treatment compared to ones at room temperature. ST had the highest gel strength while RC had the lowest.

Three fat-substitutes (PS, RC and TC) showed larger cold-water solubility values (53 to 84%), while the rest (AL, LB, RL, SL and ST) exhibited very low solubility (<2%). On the other hand, all the fat-substitutes provided 100% hot water solubility. Similarly, RC, PS, TC, and AL have higher water holding capacity than the rest of the 4 fat-substitutes. Electrical conductivity of all the fat-substitutes increased by 100% when the sample concentration was increased to 30% from 10%. pH ranged from 4.8 to 6.6 with RC the highest and AL the

TABLE 3.
DUNCAN'S RANKING FOR MEAN VALUES OF THE PROPERTIES OF FAT-SUBSTITUTES

| Fat-Substitute | Property | | | | | | |
|---|---|---|---|---|---|---|---|
| | AV30 (cP) | AV60 (cP) | EC30 (S/m) | GSR (kPa) | pH30 | WHC10 (%) | WS10 (%) |
| Amalean™ I | 14.6c | 61c | 0.03e | 18.1b | 4.8h | 133.6b | 1.5d |
| LEANBIND™ | 11.4c | 56480b | 0.10c | 14.9c | 5.0g | 87.9d | 0.8d |
| Paselli™ SA2 | 39.4c | 27.8c | 0.05de | 0.6f | 6.2d | 69.3e | 84.1a |
| Remyline™ AC | 13.6c | 20.8c | 0.16b | 3.7e | 6.3c | 92.9d | 1.6d |
| Rice*Complete® 3 | 2212a | 1212c | 0.07d | 5.5d | 6.6a | 220.7a | 53.0c |
| SlenderLean™ | 9.6c | 61840a | 0.18b | 18.5b | 5.6f | 88.6d | 1.6d |
| Sta-Slim™ 171 | 8.4c | 13.6c | 0.05de | 73a | 5.9e | 102.1c | 0.8d |
| TrimChoice™ | 640b | 750c | 0.97a | 6.3d | 6.4b | 66.4e | 76.7b |

Values are the averages of six replications. Means in the same column with identical letters are not significantly different at 5% level.

AV30 (60) = apparent viscosity at 30°C (60°C), EC30 = electrical conductivity of samples containing 30% fat-substitute, GSR = gel strength at room temperature, pH30 = pH value of samples containing 30% fat-substitute, WHC10 = water holding capacity of samples containing 10% fat-substitute, WS10 = water solubility of samples containing 10% fat-substitute.

lowest. The samples with lower concentration resulted in higher pH. RC and TC exhibited pseudoplastic behavior, while RL, PS and ST exhibited dilatant behaviors both at 30 and 60C. SL and LB showed dilatant characteristics at 30C and pseudoplasticity at 60C.

## ACKNOWLEDGMENTS

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## REFERENCES

AVEBE. 1992. Catalogue for fat-substitute PaselliTM SA2. AVEBE America Inc., Princeton, NJ.

BERRY, B.W. 1991. Summary of USDA low-fat ground beef meeting. Gaithersburg, MD. Agric. Res. Service, U.S. Dept. of Agriculture, Washington, DC.

BEST, D. 1991. Technology fights the fat factor. Prepared Foods. *160*(2), 48–48.

COMER, F.W. 1979. Functionality of fillers in comminuted meat products. Can. Inst. Food Sci. Technol. J. *12*,157–165.

CON-AGRA.1992. Catalogue for fat-substitute TrimChoiceTM. ConAgra Specialty Grain Products Company, Omaha.

CORREIA, L.R. and MITTAL, G.S. 1991. Gelation kinetics of meat emulsions containing various fillers during cooking. J. Food Process Eng. *14*,35–49.

DUXBURY, D.D. 1990. Modified food starches partially replace fats, oils and provide smooth texture. Food Proc. *51*(11),85–88.

EGBBERT, W.R., HUFFMAN, D.L., CHEN, C. and DYEWSKI, D.P. 1991. Development of low fat ground meat. Food Technol. *45*(6),64–73.

FOEGEDING, E.A. and RAMSEY, S.R. 1987. Rheological and water holding properties of gelled meat batters containing iota carrageenan, kappa carageenan or xanthan gum. J. Food Sci. *52*,549–553.

GIESE, J. 1992. Developing low-fat meat products. Food Technol. *46*(4), 100–108.

GLICKSMAN, M. 1991. Hydrocolloids and the search for the "oily grail". Food Technol. *45*(10),94–103.

INGLETT, G.E. and GRISAMORE, S.B. 1991. Maltodextrin fat-substitute lowers cholesterol. Food Technol. *45*(6),104.

KINSELLA, J.E. 1982. Relationships between structure and functional properties of food protein. In *Food Proteins*, (P.F. Fox and J.J. Condon, eds.) Applied Science Publishers, London, England.

LEWIS, M.J. 1987. Dielectrical Properties of Foods. In *Physical Properties of Foods and Food Processing Systems*. p. 402, Ellis Horwood Ltd., Chichester, England.

MCMINDES, M.K. 1991. Applications of isolated soy protein in low-fat meat products. Food Technol. *45*(12),61–64.

PSZCZOLA, D.E. 1991. Oat-bran-based ingredient blend replaces fat in ground beef and pork sausage. Food Technol. *45*(11),60–66.

SAS. 1990. SAS *User's Guide: Statistics*. SAS Institute, Cary, NC.

SCHWEID, J.M. and TOLEDO, R.T. 1981. Changes in physical properties of meat batters during heating. J. Food Sci. *46*,850–859.

SUMMERKAMP, B. and HESSER, M. 1990. Fat-substitute update. J. Food Tech. *44*(3),92–97.

WU, M.C., LANIER, T.C. and HAMANN, D.D. 1985. Rigidity and viscosity changes of croaker actomyosin during thermal gelation. J. Food Sci. *50*,14–19.

# TEMPERATURE PROFILES AT SUSCEPTOR/PRODUCT INTERFACE DURING HEATING IN THE MICROWAVE OVEN

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## ABSTRACT

*The temperature of dough at susceptor/dough interface was measured as a function of heating time, dough weight and diameter using fluoroptic fiber probes. Applying the time-temperature superposition principle, a generalized equation was found that enables one to predict reasonably well the dough temperature, at the interface, during heating.*

## INTRODUCTION

Utilization of the domestic microwave oven for reheating and preparation of foods is common in the USA (Ho and Yam 1992) and is spreading very rapidly over the rest of the Western World (Zuckerman and Miltz 1992). The major cause for the rapid heat up of foods in the microwave oven are the polar water molecules (which most foods are composed of) that align in the direction of the electric field, when applied. This field that changes direction at a frequency of $2.45 \times 10^9$ Hz in the domestic microwave oven, causes the water molecules and ions to vibrate and move, respectively. As the relaxation time of water is $8.85 \times 10^{-12}$ s ($\tau = 1/(2\pi f)$ where $\tau$ is the relaxation time and f is the frequency), water molecules are able to relax in this changing field and absorb the microwave energy. The friction between molecules during this relaxation causes the food to heat up (Lorenson 1990).

The interaction between microwaves and food is a very complex phenomenon. When a moving electromagnetic wave encounters an interface or a boundary, the nature of this boundary imposes certain conditions on the behavior

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of the wave. The result is that part of the incident energy is reflected, another part is transmitted and the rest is absorbed. Thus, one change in the propagation of the waves occurs at the air/package boundary and another occurs at the package/product interface due to the large difference in the dielectric properties between air, package and food. The fact that food products are often nonuniform in their shape, structure, texture and surface, complicates the reflection and refraction patterns of the microwaves even more.

While passing through the food, the power is attenuated and the power, P, at a distance d from the surface is described by (Ayappa *et al.* 1991):

$$P = Po \exp(-2\alpha d) \tag{1}$$

Where Po is the microwave power at the surface and $\alpha$ is the attenuation coefficient that can be calculated from the dielectric constant, $\epsilon'$, the dielectric loss factor, $\epsilon''$, and the wavelength in vacuum, $\lambda o$, according to Nykvist *et al.* (1976):

$$\alpha = (\pi\sqrt{2}/\lambda o)\left[\sqrt{(\varepsilon'^2 + \varepsilon''^2)} - \varepsilon'\right]^{1/2} \tag{2}$$

The major advantage of the microwave oven is speed of food preparation. One disadvantage of this oven is the inability to crisp and brown a product. In order to achieve significant browning and crisping reactions, food surfaces must be raised above 150C (Miltz *et al.* 1992, Turpin 1989). In the normal mode of operation, the food temperature in the microwave oven does not exceed 110C and therefore no crisping and browning can occur (Harrison 1988). To overcome this problem, one proposed solution is to use microwave interactive heating elements (known as thin layer susceptors). The susceptors are placed inside the package (or are part of it) and come in contact with the product; they rapidly absorb the microwave energy, heat up to a high temperature and transmit this energy to the product (by conduction) and thus cause crisping and browning during the food preparation.

The purpose of the present work was to study the parameters affecting the temperature profile at the susceptor/product interface during microwave heating.

## MATERIALS AND METHODS

The susceptor was made of metallized (on an industrial vacuum metallizer) PET (polyethylene terephthalate) film laminated (on a semi-industrial laminator) to a 250 g/m$^2$ paperboard using a polyurethane based adhesive. The average

resistivity of the film was 90±20 Ohm/square (measured by a Multimeter No:75, Fluke Mnfg. Co. Inc., USA).

An industrially prepared dough ("short crust pastry") was chosen as product for the present study. The dough was cut into cylinders of 4 diameters (6, 10, 14 and 18 cm, identical to the diameters of the susceptors), and three different heights. For temperature measurements at different dough locations with and without a susceptor, dough samples of weight $W_0$ = 400 g, radius of r = 5 cm and height of h = 4.5 cm were chosen. In Table 1, the locations at which temperature measurements were made are given. The dough weights, diameters and heights for which temperatures at dough/susceptor interface were studies are summarized in Table 2. The radial locations where temperatures were measured are the same as given in Table 1. The cylindrical dough samples were placed on top of the susceptor, and heated for predetermined time intervals in a domestic microwave oven (Amana Model RS) set at 100% power (nominal output - 700 Watt). The microwave oven was allowed to cool down between runs.

Temperatures were measured using a Luxtron 755-4 Model instrument (Luxtron, Corp. Mountain View, CA) containing four fluoroptic probes. Measured temperature data were collected at intervals of 1 s by the four channels of the data acquisition system and transferred to a computer via a RSC-232 serial port. The probes were inserted into several predetermined locations (given in Table 1) through special pyrex holders.

TABLE 1.
LOCATIONS AT WHICH TEMPERATURES WERE MEASURED

| | | | | |
|---|---|---|---|---|
| r(cm) | 0 | 1.1 | 3.5 | 4.4 |
| h (cm) | 0.1 | 0.1 | 0.1 | 0.1 |
| | 1.6 | 1.6 | 1.6 | 1.6 |
| | 3.4 | 3.4 | 3.4 | 3.4 |
| | 4.4 | 4.4 | 4.4 | 4.4 |

The height, h, was measured from the bottom of the dough.
The radial distance, r, was measured from the center of the cylindircal dough sample.

## RESULTS AND DISCUSSION

Figure 1 demonstrates the temperature distribution profile in the dough, at several elevations, during its heating in the microwave oven without a susceptor for different time periods. The reported values are averages of temperatures measured in five dough samples. The distance was measured from the dough

TABLE 2.
DOUGH WEIGHTS, DIAMETERS AND HEIGHTS FOR WHICH TEMPERATURE AT DOUGH/SUSCEPTOR INTERFACE WERE STUDIED

| $W_o$ (g) | d (cm) | h( cm) |
|---|---|---|
| 60 | 6.0 | 1.5 |
| 120 | 6.0 | 3.1 |
| 180 | 6.0 | 4.8 |
| 100 | 10.0 | 1.2 |
| 200 | 10.0 | 2.4 |
| 300 | 10.0 | 3.5 |
| 140 | 14.0 | 0.7 |
| 280 | 14.0 | 1.4 |
| 420 | 14.0 | 2.1 |
| 180 | 18.0 | 0.6 |
| 360 | 18.0 | 1.1 |
| 540 | 18.0 | 1.7 |

$W_o$ - dough weight; d- dough diameter, h - dough height.

bottom namely, from the susceptor/dough interface when a susceptor is used. In Fig. 2, the same profile is shown for the dough heated on top of a susceptor for the same time periods. It can be seen that in the dough heated without a susceptor the maximum temperature of about 108C was reached after 220 s of heating and that during the initial stages of heating, the bottom and top were colder than the center. In the dough heated on top of the susceptor, the temperature at the susceptor/dough interface was significantly higher than in the rest of the dough. This temperature reached 150C and 200C after 150 and 220 s of heating respectively. Thus crisping and browning of this dough sample could be achieved only when a susceptor was used and start only after 150s of heating.

In Fig. 3, the temperature rise at the susceptor/dough interface during heating of 100, 200 and 300 grams of dough (corresponding to dough heights of 1.2, 2.4 and 3.5 cm) on top of a 10 cm, in diameter, susceptor is shown. All reported temperatures at the susceptor/dough interface are averages of 20 values measured in five dough samples at four different locations of the interface. The maximum temperature deviation from the average was 3C. In Fig. 4, 5 and 6 the same temperature rise is shown for dough placed on top of 6, 14 and 18 cm in diarneter susceptors respectively, with similar dough weight/area ratios as

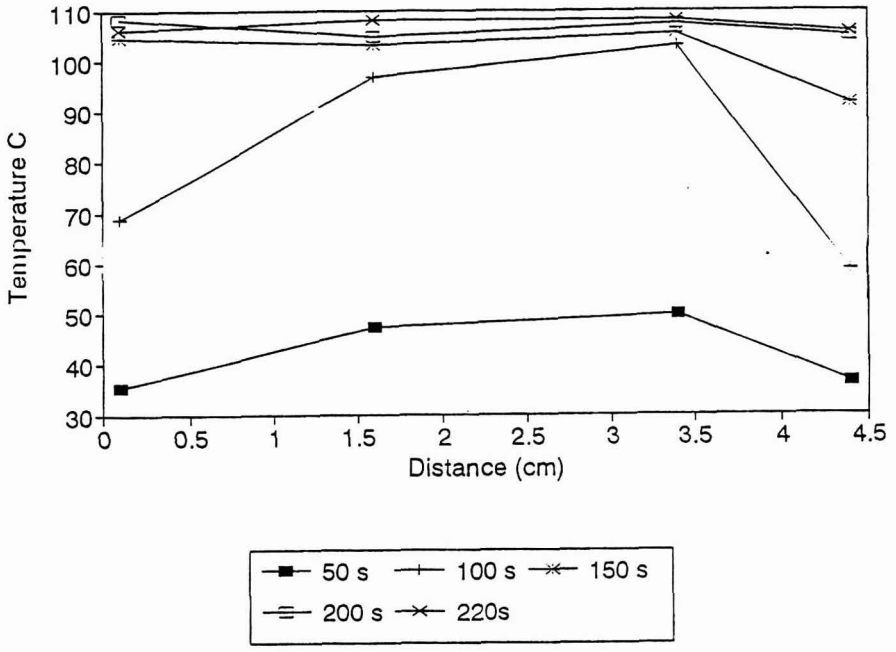


FIG. 1: TEMPERATURE PROFILES IN THE DOUGH, AT DIFFERENT ELEVATIONS (DISTANCES) FROM THE BOTTOM DURING HEATING IN MICROWAVE OVEN WITHOUT A SUSCEPTOR
(the marks stand for the heating periods, in seconds).

those shown in Fig. 3 (the actual weights are shown in the figures). It is evident that for each susceptor diameter, the more dough is placed on top of it, the less is its temperature rise.

An initial analysis of the results showed that the temperature, T, at the susceptor/dough interface is proportional to the logarithm of time in the form:

$$T = C + a \log t \quad (1)$$

Where C is a constant, t, is time and a is the slope of the line T vs. logt. The slope, a, depends on the dough weight, $W_0$, surface in contact with susceptor, A, and dough diameter, d. Thus:

$$a = f(W_o, A, d) \quad (2)$$

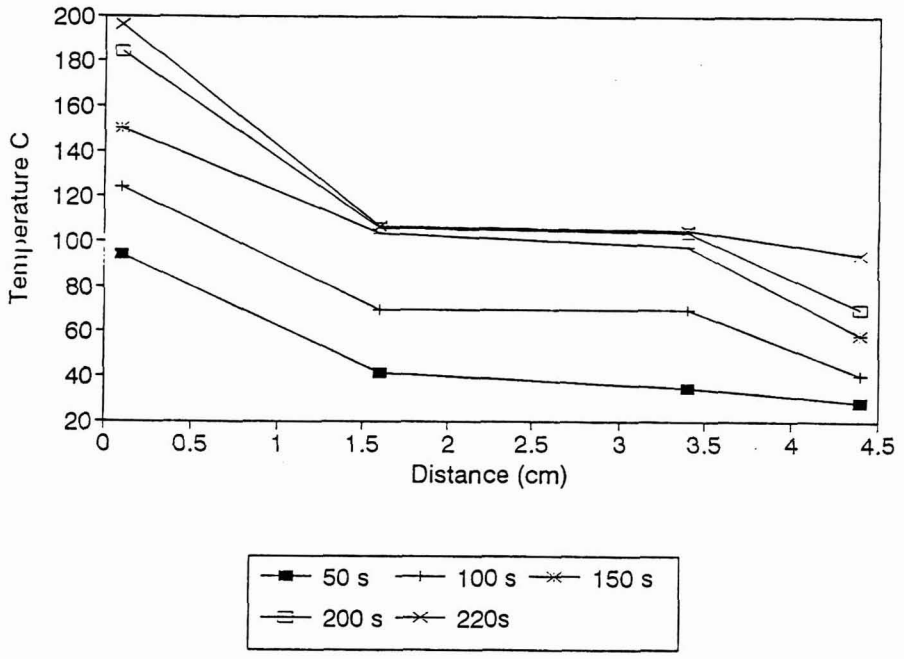


FIG. 2. TEMPERATURE PROFILES IN THE DOUGH AT DIFFERENT ELEVATIONS (DISTANCES) FROM THE BOTTOM WHEN PLACED ON TOP OF A SUSCEPTOR AND HEATED IN THE MICROWAVE OVEN
(the marks stand for heating periods in seconds).

If this relationship is correct, then a general relationship between temperature and logt could be found (which is in principle a time-temperature superposition) and a master curve constructed in the following way:

$$K=\frac{T-C}{f(W_o,A,d)}=\log t \tag{3}$$

and all measured temperatures, normalized and expressed in the form of the left side of Eq. 3 (designated as K), should be linearly related to logt.
A statistical analysis, provided by the procedures in SAS/STAT software, using stepwise regression was used to determine which of the parameters affects the temperature significantly. The method of least squares was then used to fit a general linear model (GLM). When only the significant parameters were taken into account, two relationships were obtained. For the relatively simple relationship, the following equation was found:

$$a = 46.8 - 2.5 \times 10^{-3} W_0 d \tag{4}$$

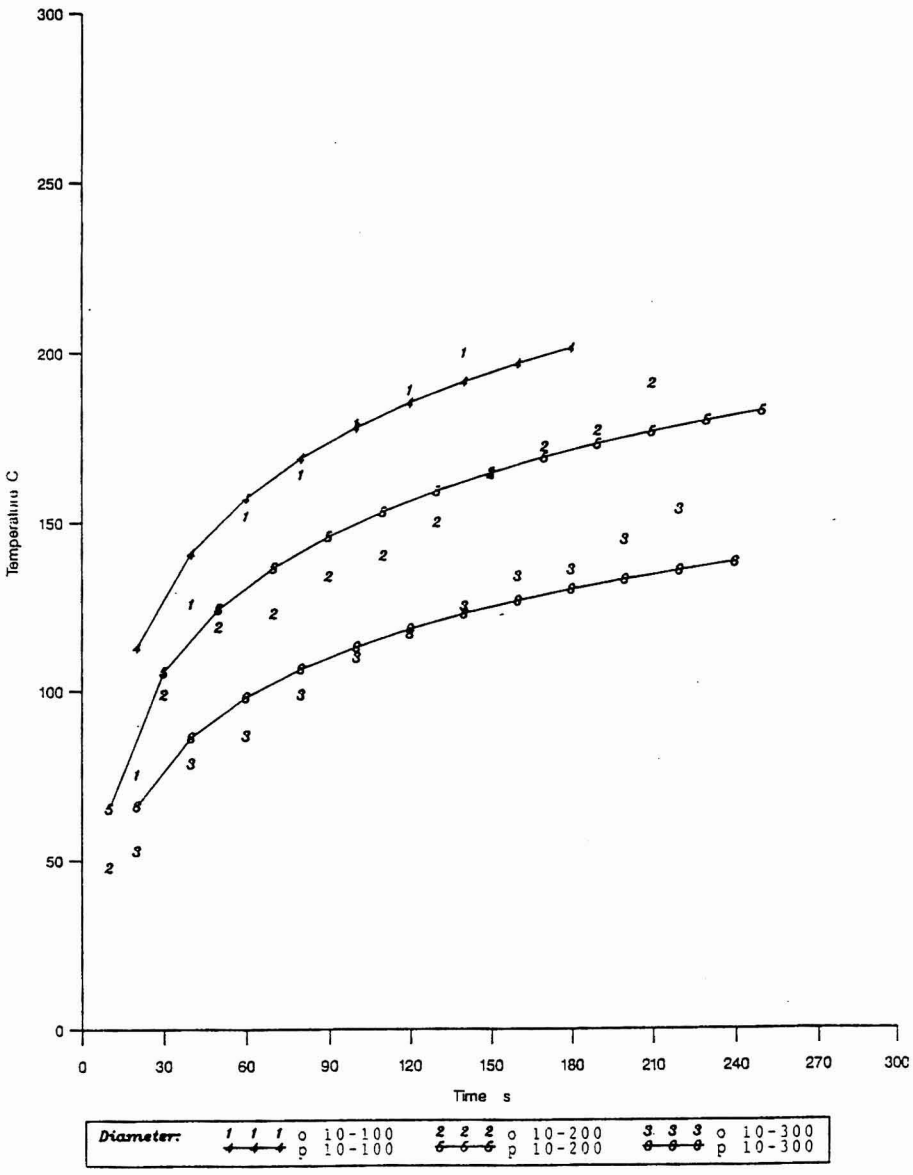


FIG. 3. EXPERIMENTAL (OBSERVED) AND PREDICTED ("O" AND "P" RESPECTIVELY, IN THE LEGEND) TEMPERATURE PROFILES AT THE DOUGH/SUSCEPTOR INTERFACE (the first and second numbers after "o" or "p" in the legend stand for dough diameter, in cm and dough weight, in o, respectively).

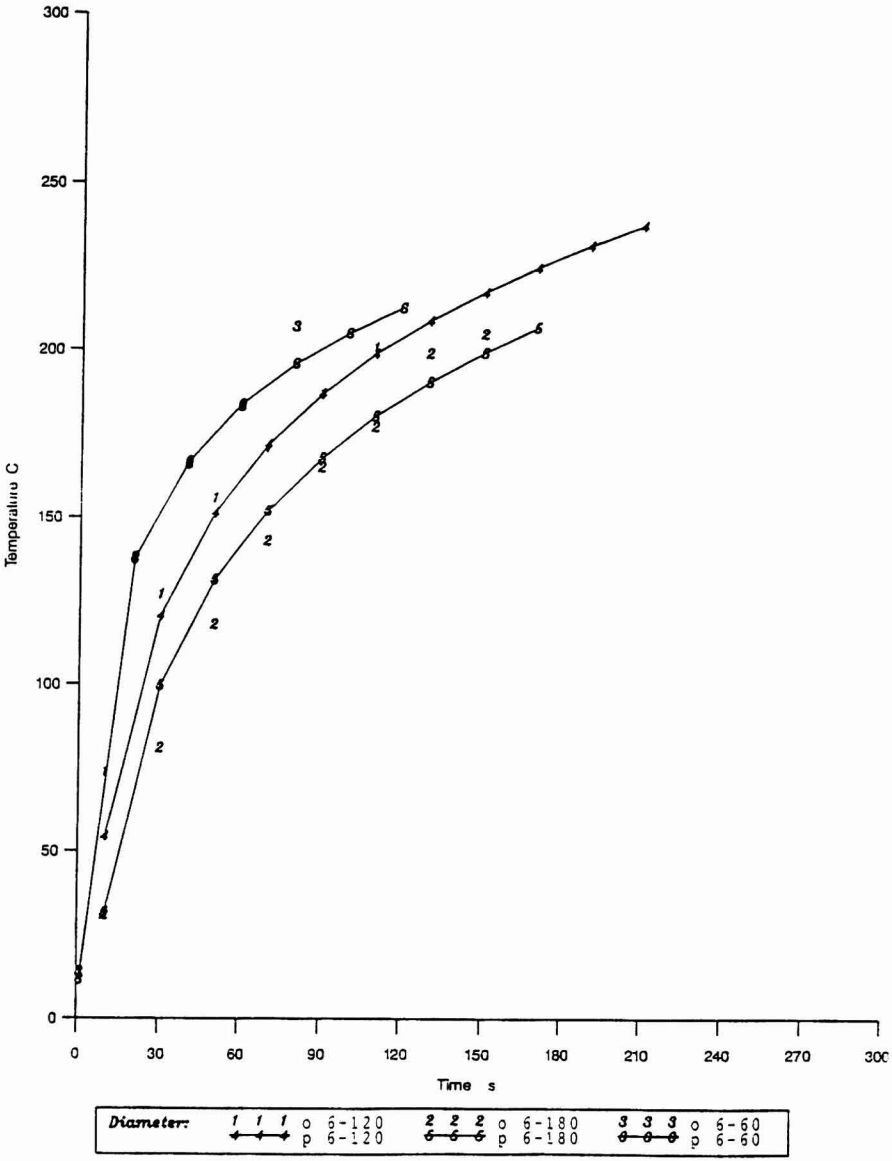


FIG. 4. EXPERIMENTAL (OBSERVED) AND PREDICTED ("O" AND "P" RESPECTIVELY, IN THE LEGEND) TEMPERATURE PROFILES AT THE DOUGH/SUSCEPTOR INTERFACE (the first and second numbers in the legend after "o" and "p" stand for dough diameter, in cm. and dough weight, in g, respectively).

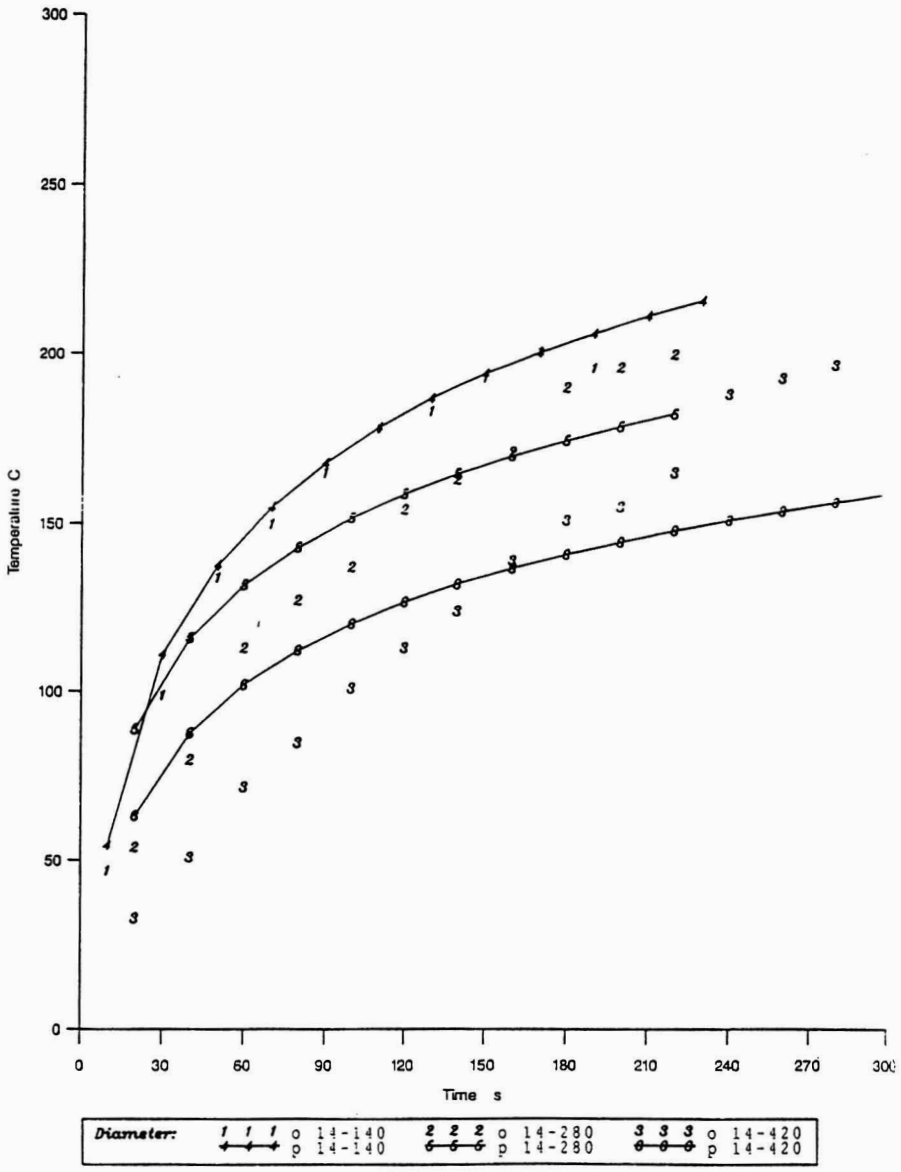


FIG. 5. EXPERIMENTAL (OBSERVED) AND PREDICTED ("O" AND "P" RESPECTIVELY, IN THE LEGEND) TEMPERATURE PROFILES AT THE DOUGH/SUSCEPTOR INTERFACE (the first and second numbers after "o" or "p" in the legend stand for dough diameter, in cm and dough weight, in g, respectively).

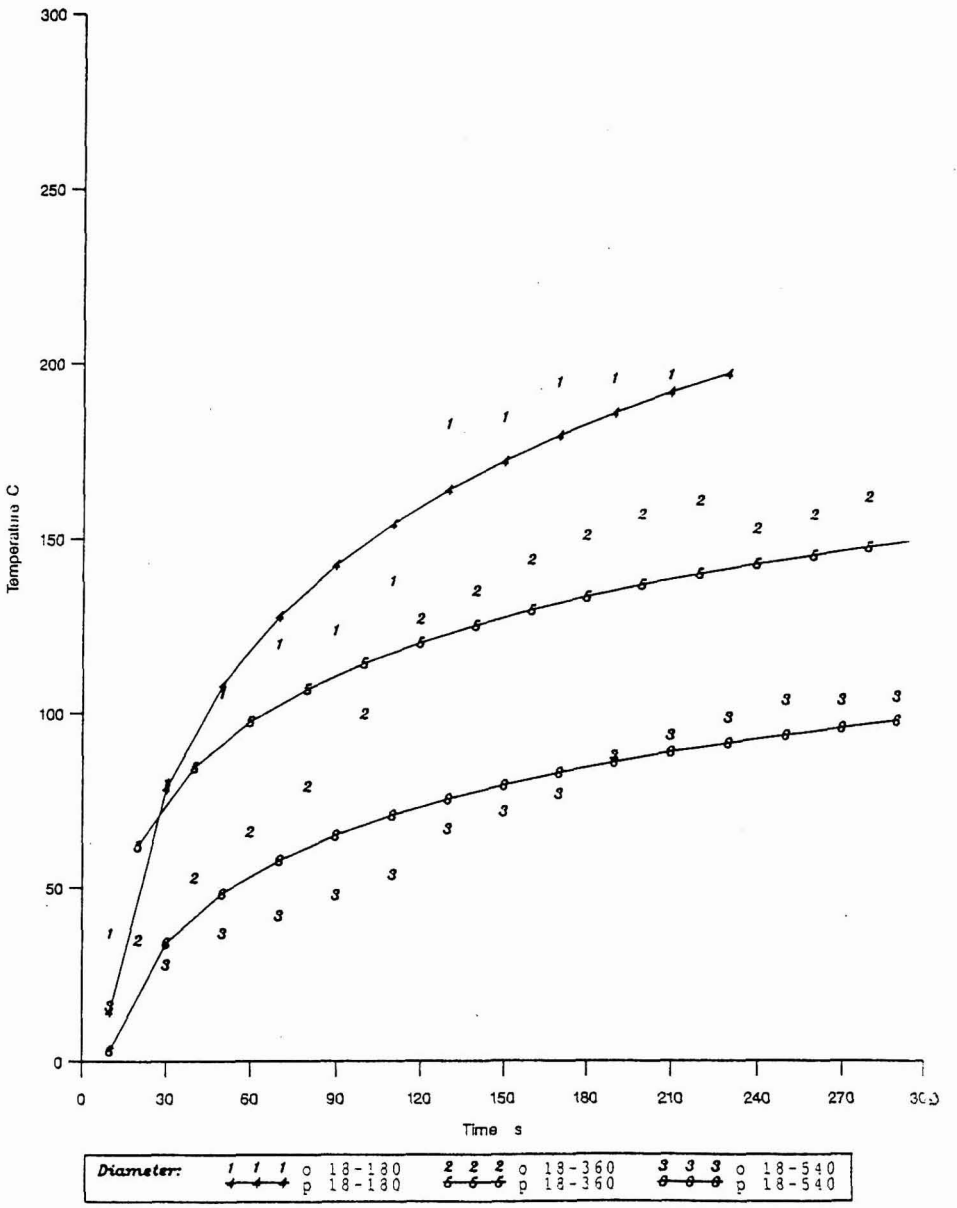


FIG. 6. EXPERIMENTAL (OBSERVED) AND PREDICTED ("O" AND "P" RESPECTIVELY, IN THE LEGEND) TEMPERATURE PROFILES AT THE DOUGH/SUSCEPTOR INTERFACE (the first and second numbers after "o" or "p" in the legend stand for dough diameter, in cm and dough weight, in g, respectively).

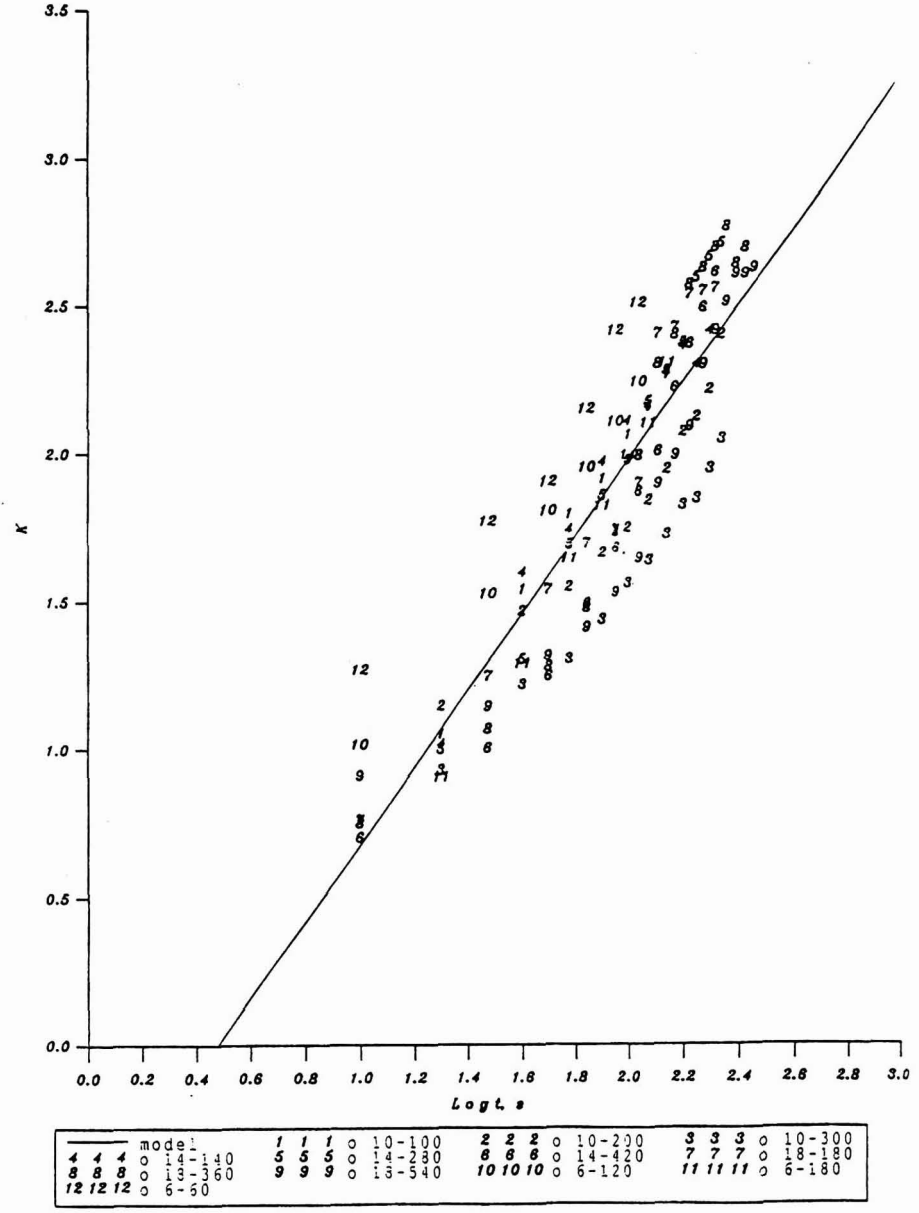


FIG. 7. VARIATION OF THE CALCULATED K VALUES FROM EXPERIMENTAL (OBSERVED - "O") RESULTS AND PREDICTED FROM THE SIMPLE GENERALIZED MODEL (EQ. 1 AND 4), WITH TIME, AND THE LEAST SQUARE, CONTINUOUS, LINE

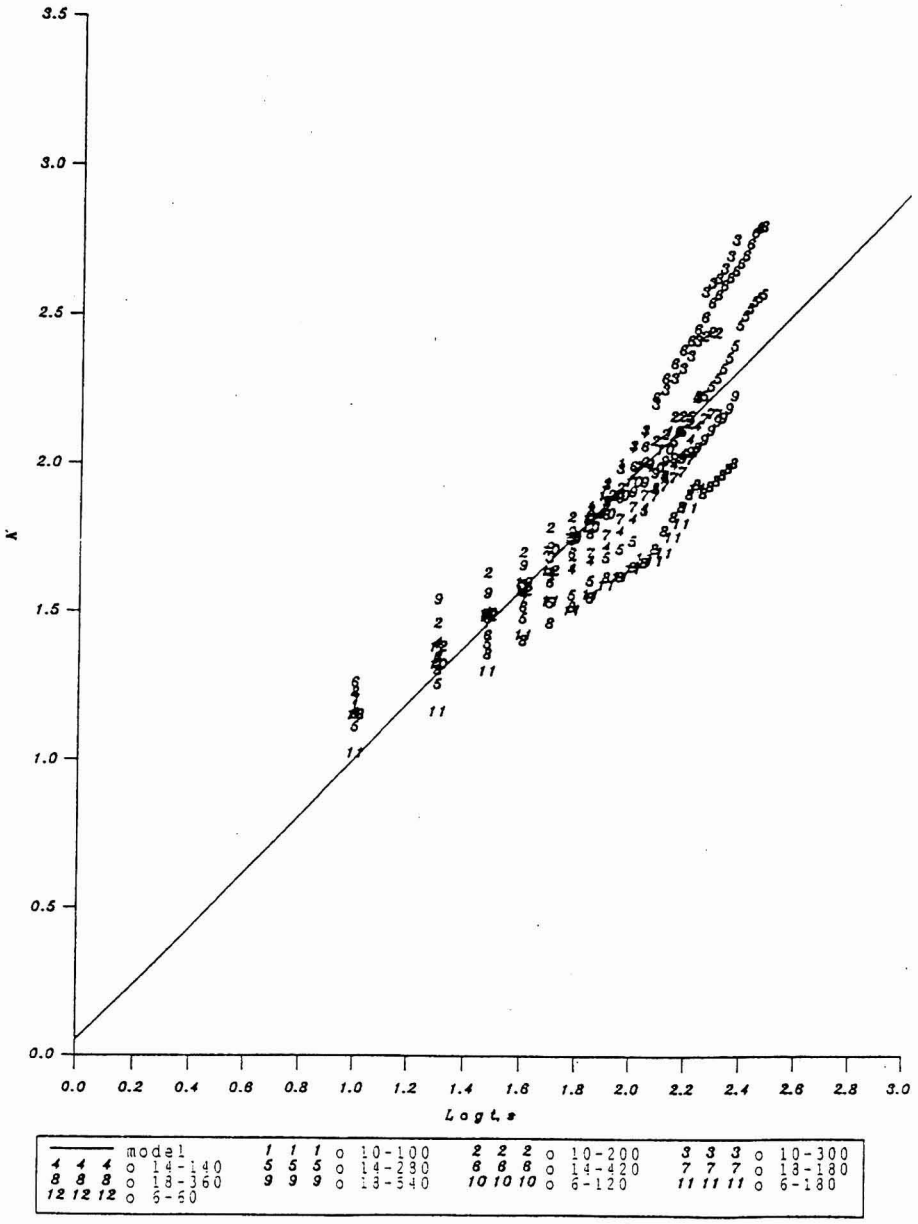


FIG. 8. VARIATION OF THE CALCULATED K VALUES, FROM EXPERIMENTAL (OBSERVED - "O") RESULTS FROM THE MORE COMPLEX GENERALIZED MODEL (EQ. 1 AND 6), WITH TIME, AND THE LEAST SQUARE, CONTINUOUS, LINE

In Fig. 7, K in Eq. 3 was plotted as a function of logt using all measured data points. Numbers were designated to the average of the different runs and they are shown in the legend of this figure. The first number (from left) in the legend is the experiment symbol. The second number, after the "o" (observed), stands for the susceptor diameter (in centimeters) and the third, for the dough weight (in grams). Thus, for example, **2** o 10-200 stands for runs for which the susceptor diameter was 10cm and the dough weight was 200g. The calculated least square line for this plot was:

$$K = -0.62 + 1.21 \log t(5)$$

with a correlation coefficient of $r^2 = 0.83$.

From Eq. 3 a slope of one and an intercept (at logt =0) of zero is expected. Both values differ however from the expected ones. The more complex relationship obtained is:

$$a = 68 - 3.9d + 2.8\frac{W_o}{A} - 0.9d\frac{W_o}{A} \tag{6}$$

In Fig. 8, K in Eq. 3 for this relationship is plotted as a function of logt using the same data points. The calculated least square line for this plot is:

$$K = 0.05 + 0.96 \log t \tag{7}$$

with a correlation coefficient of $r^2 = 0.86$. Thus, this correlation has a higher correlation coefficient. Moreover, in this more complex correlation, the intercept and slope are very close to the values expected from Eq. (3) while in the simpler correlation this agreement is much poorer. In Fig. 3-6, the predicted temperatures from the more complex model are superimposed (on the experimental points) as continuous lines.

Taking into consideration the fact that heating in the microwave oven is nonuniform, it can be concluded that the temperature at the dough/susceptor interface can be predicted reasonably well by using Eq. (3) together with Eq. (6). A somewhat poorer prediction could be obtained by using Eq. (3) together with the relatively simple Eq. (4).

## ACKNOWLEDGMENT

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## REFERENCES

AYAPPA, K.G., DAVIS, M.T., CRAPISTE, G., DAVIS, E.A. and GORDON, J. 1991. Microwave heating: An evaluation of power formulations. Chemical Engineering Sci. *46* (4), 1005–1006.

HARRISON, P. 1988. The role of packaging in achieving microwave browning and crisping. J. Packaging Technol. and Sci. *2*, 5–10.

HO, Y.C. and YAM, K.L. 1992. Effect of metal shielding on microwave heating uniformity of a cylindrical food model. J. Food Processing and Preservation. *16*, 337–359.

LORENSON, C. 1990. The why's and how's of mathematical modeling for the microwave heating. Microwave World. *11*(1) 14–23.

MILTZ, J., ZUCKERMAN, H. 1992. Effect of metallization in plastic susceptors on browning. Food Sci. & Technol. 467–463.

NYKVIST, W. and DECAREAU, R.V. 1976. Microwave meat roasting. J. of Microwave Power. *11*(1), 4–24.

TURPIN, C. 1989. Browning and crisping. The functions, design, and operation of susceptors. Microwave World. *10*(6), 8–12.

ZUCKERMAN, H. and MILTZ, J. 1992. Characterization of thin layer susceptors for the microwave oven. J. Food Processing Preservation *16*(3), 193–204.

# EFFECTS OF SEMPERFRESH AND JONFRESH FRUIT COATINGS ON POSTSTORAGE QUALITY OF "SATSUMA" MANDARINS

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## ABSTRACT

*Mandarins were coated with Semperfresh™ and Jonfresh™ edible coatings. The weight gain of mandarins after application of Jonfresh and Semperfresh coatings was 0.8% and 0.6% respectively. Weight loss, respiration rate, ascorbic acid, soluble solids (brix) and acidity changes of coated mandarins were compared with uncoated mandarins during storage at 20C and 40% RH for 4 weeks. Semperfresh™ and Jonfresh™ coatings delayed the ripening of mandarins. Both of the coatings were effective to reduce the change of ascorbic acid, soluble solids, titratable acidity and respiration rate. But Jonfresh™ was determined to be most efficient coating for reduction of weight loss.*

## INTRODUCTION

About 4% of world production of mandarins is produced in Turkey (FAO 1992). 80% of these mandarins are Satsuma variety. Since controlled atmosphere storage and cold storage of mandarins are not common in Turkey these fruits are stored in visual marketing conditions at ordinary temperature and low relative humidity. This leads great postharvest losses. Coating of mandarins to prolong shelf-life may be an efficient way to reduce postharvest losses.

Coatings provide a modified atmosphere within fruit which results a decrease in respiration rate and a delay in the ripening of fruits. Other reasons for coating of fruits are to reduce shrinkage, improve appearance and provide a carrier for fungicides and growth regulators (Kaplan 1986).

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In recent years, edible coatings have been tried on various fruits such as citrus fruits (Cohen *et al.* 1990, Hagenmaier and Baker 1993, Motlagh and Quantick 1988), apples (Chai *et al.* 1990, Drake *et al.* 1987 and Santerre *et al.* 1989), pears (Drake *et al.* 1991, Sümnü and Bayindirli 1994), bananas (Alzaemey *et al.* 1989), mango (Motlagh and Quantick 1988), cherry (Drake *et al.* 1988) and apricots (Sümnü and Bayindirli 1995) and found to be effective for reducing the ripening rate of these fruits.

It is common to coat citrus fruits with waxes that reduce the gas exchange between fruit and atmosphere, respiration rate and weight loss. Most common waxes for coating of citrus fruits are carnauba wax, polyethylene wax, beeswax, rice bran wax and shellac (Kaplan 1986).

In Turkey, the use of fruit coatings is recently improving. Semperfresh™ (Surface System Ltd., England) and Jonfresh™ (SC Johnson, Istanbul) are the available coatings for citrus fruits. Jonfresh™ is composed of carnauba wax and shellac. Carnauba wax is used for reduction of the oxygen transfer into the fruit and water vapor out of the fruit, while shellac is used to give a shiny appearance to the fruit. Semperfresh™ is a mixture of sucrose esters of fatty acids, sodium carboxymethyl cellulose and mono-di glycerides of fatty acids. Sucrose esters of fatty acids are used to reduce the oxygen transfer into the fruit and water vapor out of the fruit. Sodium carboxymethyl cellulose enable a coherent film to be formed and cling to the surface of the fruit. Mono-diglycerides of fatty acids act as emulsifiers.

The objectives of this study were to increase shelf-life of mandarins by means of Jonfresh and Semperfresh coatings which are very common in Turkey and to determine the effects of these coatings on quality criteria of mandarins.

## MATERIAL AND METHODS

### Mandarin Treatments

Mandarins (Satsuma variety) were coated with 1.5% (w/v) concentration of Semperfresh (composition: sucrose esters of fatty acids (60%), sodium carboxymethyl cellulose (26%), mono-diglycerides of fatty acids (14%)) and Jonfresh (composition: carnauba wax (11%), shellac (1%) and water (88%)). Jonfresh was used as it was supplied from the manufacturer without any dilution. Prepared Semperfresh solution and Jonfresh are both lipid in water emulsions.

Mandarins were dipped into the solutions for 5 s. The weight gain of mandarins due to coatings was 0.8% and 0.6% for Jonfresh and Semperfresh, respectively. Control mandarins were dipped only into water. After being coated, mandarins were stored at 20C and at 40% RH for 4 weeks. Mandarins were analyzed for titratable acidity, ascorbic acid, respiration rate and soluble solids once a week. Weight loss data were obtained after each 6 days during storage period.

## Quality Evaluation

Oxygen used by the mandarins was measured by Oxygen Gas Analyzer (Oxycheck Criticon). Three mandarins per treatment were stored in each sealed jar for 6 h using three replicates per treatment. Then oxygen which was left in the jars after being used by mandarins was withdrawn by the syringe of the gas analyzer immediately after piercing the jar lids with a syringe. Respiration rate was then calculated by using the formula below:

$$R = \frac{(V_s - V_m)(K_2 - K_1)10}{tG}$$

where; R is the respiration rate (ml $O_2$/kg.h), $V_s$ is the volume of the jar (ml), $V_m$ is the volume of the fruit (ml), $K_2$ is the percentage of oxygen in the jar before the jar is closed, $K_1$ is the percentage of oxygen in the closed jar, t is the time which is usually 6 h and G is the weight of fruit in the jar (kg).

For titratable acidity, ascorbic acid and soluble solids 10 mandarins were pressed by a simple juice presser (Arcelik Robopress ARK71 RF). Then the pressed juice was filtered through filter paper. In analyzing titratable acidity, 100 ml distilled water was added to 10 ml juice and it was titrated with 0.1 N NaOH to a pH of 8.1. Results were expressed as percent citric acid. Soluble solid was measured by a hand refractometer (Carl Zeiss Jena DDR 818408). Ascorbic acid was determined by 2,6 dichloroindophenol method (AOAC 1975). Weight loss was determined by weighing individually the randomly chosen same 10 mandarins for each treatment immediately after coating and then after each 6 days by a laboratory balance (Sartorious 2432). The results were expressed as percent weight loss.

Analysis of variance was used to determine statistical relationships among treatments. Significance was determined at $p=0.05$ level for analysis. Treatment means were compared by Duncan's New Multiple Comparison Method.

## RESULTS AND DISCUSSION

The main problem during storage of mandarins is weight loss leading to shriveling which reduces salability. Coatings were effective for reduction of weight loss of mandarins (Fig. 1). As can be seen from figure, Jonfresh was the most efficient coating for reducing weight loss. Semperfresh was not as effective as Jonfresh due to the difference in composition of the two coatings. This may be due to the high water permeability of sucrose polyesters compared to other commercial waxes (Hagenmaier and Show 1992). This result is similar to results obtained by, Sümnü and Bayindirli (1994) since Jonfresh was found to be more effective than Semperfresh for reduction of weight loss of pears.

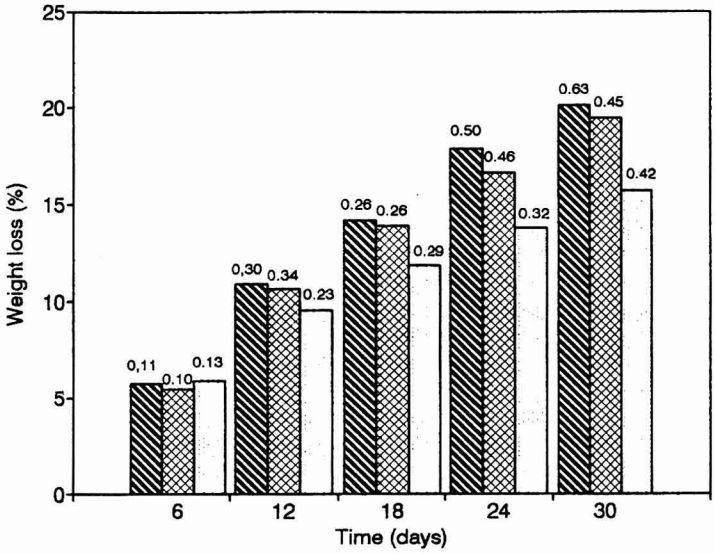


FIG. 1. VARIATION OF WEIGHT LOSS OF MANDARINS WITH DIFFERENT COATINGS

( ▨ ): Control[a], ( ▩ ):Semperfresh[a], ( □ ): Jonfresh[b]

Bars with different letters (i.e., ab) are significantly different at the p=0.05 level
The numbers on each bar show standard error.

Both of the coatings were effective for reduction of respiration rate (Fig. 2). The reduction of respiration rate is related to the reduction of oxygen transfer into the fruit. The effect of coating can be seen by the sudden decrease in respiration rate after the first week for coated mandarins which stays almost constant through out the storage period. Coatings reduced respiration rate almost 50%. There was no significant difference between the two coatings at p=0.05 for reduction of respiration rate.

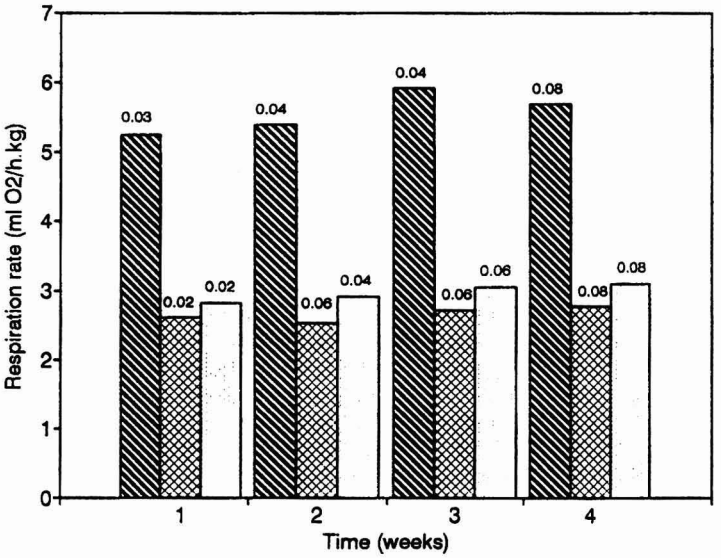


FIG. 2. VARIATION OF RESPIRATION RATE OF MANDARINS WITH DIFFERENT COATINGS

( ▨ ): Control[a], ( ▩ ):Semperfresh[b], ( ▤ ): Jonfresh[b]

Bars with different letters (i.e, a,b) are significantly different at the p=0.05 level. The numbers on each bar show standard error.

Coatings delayed the loss of ascorbic acid (Fig. 3). The decrease in ascorbic acid loss by means coatings is due to the low oxygen permeability of coatings that reduces ascorbic acid oxidation. Since both of the coatings reduced respiration rate effectively this reduction may be reflected to the decrease in the rate of ascorbic acid loss. No significant difference was detected between the two coatings for reducing the change of ascorbic acid. Retention of ascorbic acid by means of sucrose polyester coatings is shown on mango (Dhalla and Hanson 1988) and on apricots (Sümnü and Bayindirli 1995).

Variation of titratable acidity of mandarins can be seen in Fig. 4. Titratable acidity of mandarins were 1.5% just after harvest and showed a significant reduction for control mandarins during storage. For coated mandarins this reduction is very little. This may be due to the sudden decrease in respiration rate of mandarins by using coatings. Since oxygen transfer is reduced the use of acids as substrates in respiration is minimized.

Soluble solids increased during storage of mandarins (Fig. 5). The increase in soluble solids is due to the water loss and drying of mandarins. That's why

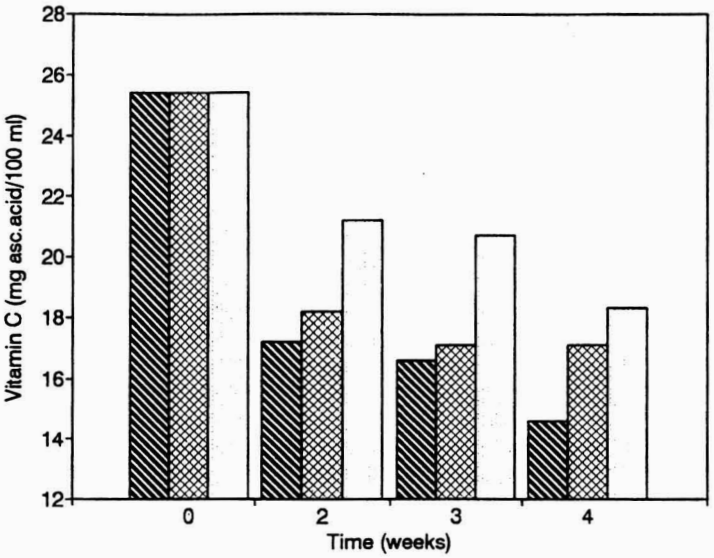


FIG. 3. VARIATION OF ASCORBIC ACID OF MANDARINS WITH DIFFERENT COATINGS
( ▨ ): Control[a], ( ▩ ):Semperfresh[ab], ( □ ): Jonfresh[b]
Bars with different letters (i.e, a,b) are significantly different at the p=0.05 level.

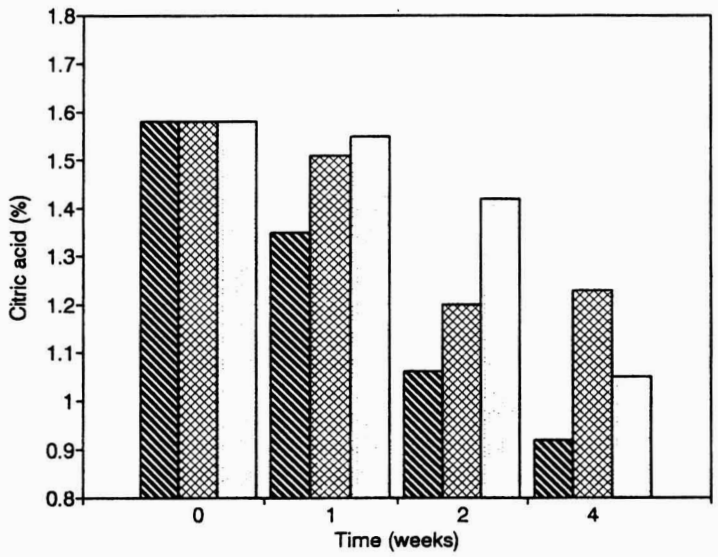


FIG. 4. VARIATION OF ACIDITY OF MANDARINS WITH DIFFERENT COATINGS
( ▨ ): Control[a], ( ▩ ):Semperfresh[ab], ( □ ): Jonfresh[b]
Bars with different letters (i.e , a,b) are significantly different at the p=0.05 level

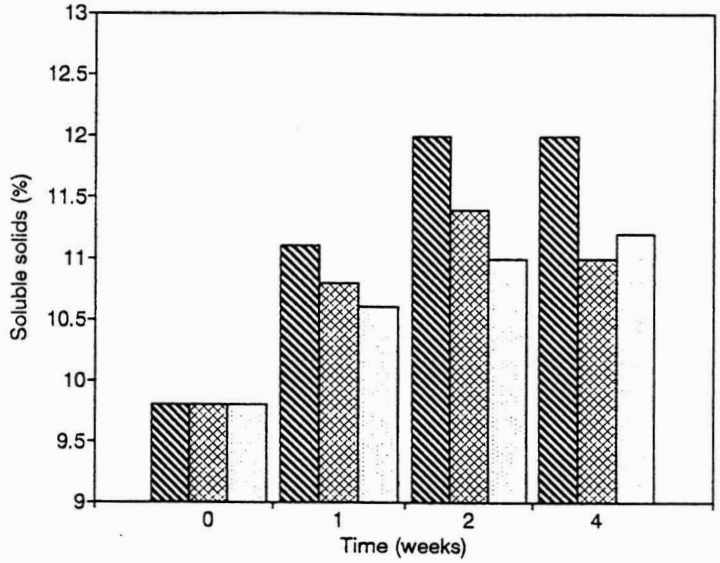


FIG. 5. VARIATION OF SOLUBLE SOLIDS OF MANDARINS WITH DIFFERENT COATINGS

( ▨ ): Control[a], ( ▩ ):Semperfresh[ab], ( ▭ ): Jonfresh[b]

Bars with different letters (i.e, a,b) are significantly different at the p=0.05 level

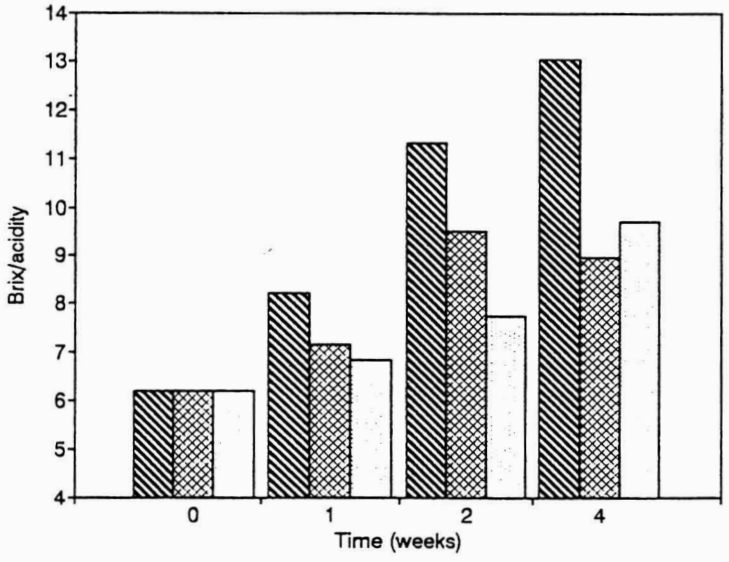


FIG. 6. VARIATION OF BRIX ACID RATIO OF MANDARIN WITH DIFFERENT COATINGS

( ▨ ): Control[a], ( ▩ ):Semperfresh[ab], ( ▭ ): Jonfresh[b]

Bars with different letters (i.e, a,b) are significantly different at the p=0.05 level

coatings that are effective for reduction of weight loss are also effective for retention of soluble solids. Brix acid ratio is an important maturity index for citrus fruits. As storage time increases this ratio also increases. The decrease in acidity during ripening and the increase in brix during storage causes such an increase. Figure 6 shows the effects of coatings on brix acid ratio. Since coatings reduced both the rate of ripening and water loss, the rate of the change of this ratio was also reduced.

Both of the coatings increased the shelf-life of mandarins which was detected by observing appearance and shriveling and using weight loss data. The shelf-life of mandarins coated by Semperfresh was increased 10% while the shelf-life of mandarins coated by Jonfresh was increased 50% compared to uncoated ones. This was an expected result since Jonfresh was more efficient to reduce weight loss and to delay shriveling.

## CONCLUSION

Quality of "Satsuma" mandarins was affected by coating with Semperfresh and Jonfresh. Jonfresh and Semperfresh fruit coatings were effective for retention of soluble solids, titratable acidity, ascorbic acid, and reduction of respiration rate. As long as weight loss and shelf-life extension is considered Jonfresh may be selected as the best coating for mandarins since it reduced weight loss and increased shelf-life in significant amounts compared to Semperfresh.

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## REFERENCES

ALZAEMEY, A.B.S., FALLANA, I.B. and THOMSON, A.K. 1989. Effect of permeable fruit coatings on the storage life of plantain and bananas. Aspects of Applied Biology *20*, 73-80.

AOAC. 1975. Official Methods of Analysis, 12th Ed., Assoc. of Official Analytical Chemists, Washington, DC.

CHAI, Y.L., OTT, D.B. and CASH, J.N. 1991. Shelf-life extension of Michigan apples using sucrose polyesters. J. Food Processing Preservation *15*, 197-214.

COHEN, E., SHALOM, Y. and ROSENBERGER, I. 1990. Post harvest ethanol build up and off-flavor in "Murcott" tangerine fruits. J. Amer. Soc. Hort. Sci. *115*, 775-778.

DHALLA, R. and HANSON, S.W. 1988. Effect of permeable coatings on the storage life of fruits. II. Prolong treatment of mangoes *(Mangifera indica L.cv. Julie)*. Int. J. Food. Sci. Technol. *23*, 107-112.

DRAKE, S.R., CAVALIERI, R. and KUPFERMAN, E.M. 1991. Quality attributes of d'anjou pears after different wax dying temperatures and refrigerated storage. J. Food Quality *14*, 455-465.

DRAKE, S.R., FELLMAN, S.K. and NELSON, J.W. 1987. Postharvest use of sucrose polyesters for extending the shelf-life of stored "Golden Delicious" apples. J. Food Sci. *52*, 1283-1285.

DRAKE, S.R., KUPFERMAN, E.M. and FELLMAN, J.K. 1988. 'Bing' sweet cherry (Prunus avium L.) quality as influenced by wax coatings and storage temperature. J. Food Sci. *53*, 124-126.

FAO. 1992. Production Year Book, Vol. 46, Food and Agricultural organization, Rome.

HAGENMAIER, R.D. and BAKER, R.A. 1993. Reduction in gas exchange of citrus fruit by wax coatings. J. Agric. Food Chem. *41*, 283-287.

HAGENMAIER, R.D, and SHOW, 1992. Gas permeability of fruit coating waxes. J. Amer. Soc. Hort. Sci. *117*, 105-109.

KAPLAN, H.J. 1986. Washing, waxing and colour adding, In Fresh Citrus Fruits (W.F. Wardowski, S. Nagy and W. Grierson, eds.) pp. 379-395, Van Nostrand Reinhold/Avi, New York.

MOTLAGH, F.H. and QUANTICK, P.C. 1988. Effect of permeable coatings on the storage life of fruits. 1. Prolong treatment of Limes (*Citrus aurantifolia* cv. Persian). Int. J. Food. Sci. Technol. *23*, 99-105.

SANTERRE, C.R., LEACH, T.F. and CASH, J.N. 1989. The influence of the sucrose polyester, Semperfresh, on the storage of "McIntosh" and "Golden Delicious" apples. J. Food Processing Preservation *13*, 293-305.

SÜMNÜ, G. and BAYINDIRLI, L. 1994. Effects of Semperfresh and Jonfresh fruit coatings on post storage quality of "Ankara" pears. J. Food Processing Preservation. *18*, 189-199.

SÜMNÜ G. and BAYINDIRLI, L. 1995. Effects of sucrose polyester coatings on fruit quality of apricots. J. Sci. Food Agric. *67*, 537-540.

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MICHAELS, S.L. 1989. Crossflow microfilters ins and outs. Chem. Eng. *96*, 84–91.

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