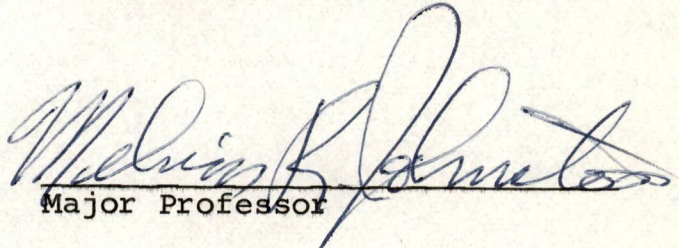


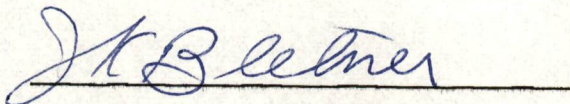
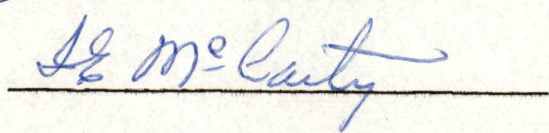
July 24, 1967

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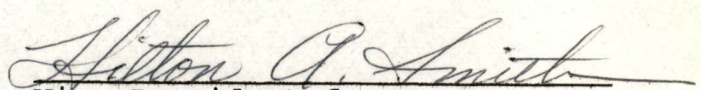
I am submitting herewith a thesis written by Ashvin N. Patel entitled "De-oiling of Peanuts to Yield Two Potentially Useful Foods." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology.


Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:


Vice President for
Graduate Studies and Research

DE-OILING OF PEANUTS TO YIELD TWO POTENTIALLY
USEFUL FOODS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Ashvin N. Patel

August 1967

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CHAPTER I

INTRODUCTION

Many people are enthusiastic about the future of peanuts. There are two important reasons for predicting a substantial growth in the peanut industry. They are:

1. The demanding food needs of the rapidly growing nations of the world. Population explosion throughout the developing countries is creating alarming food problems, particularly the need for protein.

2. Rapid conversion of food habits in the United States and in some foreign countries to the acceptance of convenience foods, instant food preparation, diet foods, prepared nutritious confections, and snack foods.

Peanuts, also known as groundnuts, are a basic cash crop of economic importance to farmers in the Virginia-Carolina area, Southeastern area, and Southwestern areas of the United States.

Although, in nearly all foreign countries, peanuts are crushed for their oil, in the United States most of the peanuts are eaten as such. The peanuts produced domestically are consumed mostly in the form of roasted nuts, peanut

butter, and candy (21).^{*} The market for edible peanuts might be expanded somewhat and at the same time a new, useful food item might be obtained if all or part of the oil could be removed from the raw peanuts.

Defatted peanuts were first investigated by Willich and Feuge (38). This early work established the general conditions of extraction which were later used in pilot plant investigation at the Southern Regional Research Laboratory (26).

Other factors which helped initiate these investigations were that the shelf-life of this new peanut product was expected to be appreciably extended by minimizing oil rancidity, use of defatted peanuts by haemophiliacs to control bleeding (7), and that the development of a new product would increase utilization of peanuts (3).

The objectives of this study were (1) to compare two processes of defatting peanuts, solvent extraction, and hydraulic pressing, and (2) to investigate the possible development of a new peanut product with a high protein and low fat (low calorie) content.

^{*}Numbers in parentheses refer to similarly numbered items in the Bibliography.

CHAPTER II

REVIEW OF THE LITERATURE

I. INTRODUCTION

The peanut, Arachis hypogaea, is thought to be a native plant of Peru and perhaps Brazil, South America. The peanut is now cultivated in all tropical and subtropical countries of the world (27). The total annual world production is about 15 million tons (25).

The U. S. peanut industry is likely to be one of the agricultural industries that will grow appreciably in the years ahead. In 1965, the U. S. peanut crop exceeded 1,245,000 tons of farmer stock peanuts. This commodity is used principally in foods and confections, and lesser amounts are extracted for oil. It is estimated that about 60 percent of this peanuts will find their way into edible markets, 20 percent crushed, 8 to 10 percent exported, 10 percent for planting seed and other uses. Nearly one billion pounds of shelled peanuts will be used directly in foods; 54 percent peanut butter; 19 percent candy; 23 percent salted peanuts;

2 percent peanut-butter sandwiches; and 2 percent in other products (32, 35).

Millions of people in the United States eat peanuts. The peanut flavor ranks in the top group of best-liked flavors. In addition to their excellent flavors, peanuts have a highly acceptable texture. In addition to these highly desirable properties, peanuts also possess a most valuable composition in light of current food requirement (36).

II. VARIETIES AND AREAS OF PEANUT PRODUCTION

There are five distinct varieties of peanuts grown in the United States. They are: the Virginia, Runner, Spanish, Valencia (or Tennessee Red), and African (or North Carolina). In Virginia and North Carolina, the Virginia type peanut is produced almost exclusively. In Alabama, Georgia, and Florida, the small Spanish type peanut constitutes the major volume of the crop, although some of the Virginia type and a small seeded runner of the African type also is grown in the area. Texas and Oklahoma cultivate almost exclusively the Spanish type peanut. The Valencia is grown principally in New Mexico. The Spanish variety is the

only variety recommended for peanut oil. The Spanish peanut is adapted to a wide range of soil and climatic conditions, and it contains a higher oil content than any other variety (31, 8).

In 1962, the United States produced 1.8 billion pounds of peanuts, valued in excess of \$200 million, on slightly more than 1.4 million acres. Peanuts rank either third or fourth in the economy of Virginia, North Carolina, Georgia, Alabama, and Oklahoma, sixth in Florida, and seventh in Texas (34). In 1966, the peanut crop was estimated at 2.4 billion pounds from 1,427,800 acres (19). In India, in 1965-66, the peanut crop was estimated at 4,022,000 tons from 1,771,870 acres.

III. DEVELOPMENT OF THE PEANUT INDUSTRY

The commercial development of the peanut industry began with the erection of a peanut cleaning plant in New York City in 1876. Peanut cleaners soon found, however, that eastern Virginia was the most logical location for the industry, therefore, they concentrated in the Virginia-North Carolina growing area.

At the beginning of the 20th century, peanut

production began to move into the Southeast and Southwest, following the advance of the boll weevil across the Cotton Belt. The first modern shelling plant in the Southwest was built in 1907 in Texas, and by 1917 the peanut shelling industry was firmly established in both the Southeast and Southwest producing area (9).

In 1939, 121 peanut shelling plants were reported in operation, 65 in the Southeast, 22 in the Southwest, and 34 in the Virginia-North Carolina area (8). Fewer than 90 shelling plants were active in all areas (5).

When the United States entered World War II, the emphasis of Government programs shifted from an attempt to restrict the supply of peanuts to an effort to expand peanut production to help alleviate the shortage of vegetable oils. Acreage goals were expanded to 5 million acres in 1942 and in 1943, all marketing quotas and acreage allotments were terminated.

In the years immediately following World War II, there was an acute worldwide shortage of vegetable oils. During this period from 1946 to 1948, the government continued to encourage peanut production (9).

In the early development of the peanut industry,

large quantities of peanuts, particularly in the Southeast, were hogged-off. Most of the rest reached the consumer in the roasted-in-shell form. By 1960, over 10 times as many peanuts reached the consumer shelled than in-shell (9).

IV. CHANGES IN FARM STORED PEANUT STOCKS

During storage, farm stored peanut stocks undergo changes which reduce their value, such as loss of quality and weight, damage to kernels, changes in moisture content, and losses due to insects and rodents.

Report of a 5 year study conducted by the U. S. Department of Agriculture (16) showed that the quantity of sound mature kernels tend to decrease and the amount of damaged kernels tend to increase with length of storage. especially after the first 6 months. Moisture content of peanut kernel was the most important factor affecting storability and changes in quality. The report also shows that in commercial warehouses peanuts with more than 10 percent initial moisture often heat and become moldy.

Myklestad (25) found that the major requirements for preservation of peanuts during prolonged storage was proper drying (moisture content to 9-10 percent), controlled

temperature, and the air humidity should be maintained at a value not exceeding 75 percent R. H.

Schenk (28) reported that peanuts exchange gases at rates inversely related to the temperature at which they were cured. The retarded gas exchange was due to the presence of a semipermeable layer at or near the surface of the peanut cotyledons. He also found that roasting had little or no effect on the permeability of this layer to gases.

Physical aspects. Wet peanuts pack more densely, collect dirt and debris more readily, and consequently offer greater resistance to air flow, which would require more efficient drying, actually get less aeration than dry peanuts. High temperature causes off-flavors and affects viability, and is not recommended for peanuts intended for eating (25).

Biological aspects. Observation of peanuts stored in bins as well as those used in laboratory test in Tifton, Georgia, indicated that insect infestation and damage to the kernels were closely associated with condition of the peanut shells at time of storage (16). During prolonged periods of high humidity, mold was frequently observed in stored peanuts.

Chemical aspects. Stanbury and Guthrie (30) experimented with storage of unshelled peanuts maintained at various temperatures in closed containers and carried out analysis for total nitrogen, sugars, oil content, iodine number, and free fatty acid concentration of the oil, and protein solubility. At the end of the 2 years of storage at temperatures below 1° C. no change in these constituents was found. At room temperature (25°-28° C.) a slight increase in free fatty acid concentration was observed.

V. UTILIZATION OF PEANUT

Although in nearly all foreign countries peanuts are crushed for their oil, in the United States most of the peanuts are eaten as such. Primary products from peanuts include edible confections such as peanut butter, salted peanuts, peanut candy, peanut butter sandwiches, and other products. Secondary products are peanut oil, cake or meal, and flour.

In India, most of the peanuts are crushed for their oil and residues are utilized for making peanut cake. The

greater amount of the peanut cakes are used as fertilizer and the rest of them are used as cattle feeds.

The edible consumption rate for 1966-67 is estimated at about 8 pounds per person--up slightly from the 7.7 pounds of the previous year. With an increased population, this probably indicates that total consumption will go even higher in the future. In 1965-66, about 56 percent of the total edible peanuts went into the manufacture of peanut butter, 23 percent were salted, and 19 percent were used in candy (18).

The greatest increase in the utilization of peanuts has been in the manufacture of peanut butter. Utilization has increased from 460 million pounds (farmers stock basis) in 1955 to an estimated 675 million in 1964. Data on the production and consumption of peanut butter are not available (20).

Salting is the second largest outlet for shelled peanuts. Use of peanuts for salting in 1955 to 285 million pounds estimated for 1964 (20).

Candy manufacturers have increased their use of peanuts from 168 million pounds in 1955 to 225 million pounds estimated for 1964 (20).

Use of cleaned, roasting stock peanuts has remained relatively stable in recent years at about 75-88 million pounds annually (20).

The U. S. D. A. has recently developed a process to make low-calorie peanuts. The process removes about 80 percent of the oil and 66 percent of the calories--leaving intact the original peanut flavor and high protein content. This method has been successfully commercialized by at least two U. S. processors. One company is now distributing partially defatted peanuts under the name "Cris-P-Nuts," and the other company is distributing the product under the name "Light Bite" (24).

Increased utilization of peanuts and their products can only be obtained through knowledge of their fundamental chemical and physical properties as well as of the chemical reactions they undergo in processing. Thus, the following new or intensified research recommendations are considered critical (33):

1. Definition of quality of peanuts in objective terms including chemical, physical and microbial.
2. Instrumentation for the measurement of quality characteristics.

3. Relation of carbohydrate and protein components to aroma and flavor.
4. Molds as they affect the utilization of peanuts.
5. Interrelation of cultural, harvesting, and curing practices and processing on the flavor, aroma, color, texture, and nutritive qualities.

VI. DEVELOPMENT POTENTIAL OF PARTIALLY

DEFATTED PEANUTS

Processing

Solvent extraction. Willich and Feuge (38) showed that whole, blanched peanuts were freed of oil by soaking them at ambient temperatures in a suitable solvent, like isopentane or hexane. Rate at which oil is removed depends upon operating conditions. They found that under the experimental conditions employed, at least sixty hours were required to remove about 75 percent of the oil. As the moisture content of the peanuts increased, the time required to extract a given proportion of the oil increased.

The authors also (38) observed that removal of the solvent from the extracted peanuts was dependent upon the

pressures and temperature used. They reported that from 4 to 16 hours of striping with air were required to remove the solvent from the extracted peanuts.

The authors summarized that partially de-oiled peanuts resemble to some degree the ordinary products in appearance and flavor, though the flavor is relatively mild.

Pominski, Pattin, and Spadaro (26) found in a study of desolventization of defatted peanuts that there is little difference in rate of direct drying at 212° F. for the forced draft and vacuum ovens. In both cases, though a low level of 2 percent volatiles was reached in 4-5 hours, a total of 9 hours of drying was required to eliminate taste traces of hexane. Excess drying time at 212° F., after solvent has been eliminated, degraded the taste and appearance of the peanuts.

Hydraulic pressing. The process developed by U. S. D. A. removes about 80 percent of the oil and about 66 percent of the calories but no protein.

The process consists essentially of three rather simple effective mechanical operations. They are: (1) pressing, (2) reconstitution or expansion, (3) drying and roasting.

Vix, Spadaro, Pominski, and Pearce, Jr. (37) reported that hydraulically pressing peanuts at 2000 psi for 60 minutes removes about 80 percent of the oil. They also observed that 6 percent moisture content of fresh peanuts minimizing breakage during pressing.

Distorted and mis-shapen peanuts are expanded to essentially their original shape by immersing them in boiling water for 5-8 minutes, either atmospherically or under pressure. The moisture content of the expanded peanuts ranged from 35 to 45 percent. The expanded peanuts are dried and roasted, either by infra-red heat, hot air fluidized bed or cooking in hot oil (37).

Nutritional Aspects

Calorie intake plays an important part in good nutritional habits. The effects are generally correlated with age, health, occupation, and daily habits of each individual. Women usually require enough food to produce an energy value equal to 1500 to 2800 calories per day, whereas men require from 2000 to 3500 calories. Kirk and Othmer (17) reported that peanuts are very nutritious, packing 2645 calories to the pound.

Vix, Pominski, Pearce, Jr., and Spadaro (36) reported that the protein content corresponding to 100 calories intake of food energy from partially defatted peanuts is about 137 percent more than that from roasted full-fat peanuts. This is equal to about 10.5 grams of protein of the 24 grams of partially defatted peanuts that are required to equal 100 calories. On the other hand, 17 grams of full-fat peanuts, also supplying 100 calories, will furnish only 4.42 grams of protein.

Hoffpauir (12) reported that peanuts contain an average of 50 percent fat, 30 percent protein, 2.9 percent crude fiber, 14.0 percent nitrogen-free extract, 3.0 percent ash, 0.2 percent reducing sugars, 4.7 percent disaccharides, 4.2 percent starch, and 2.6 percent pentosans (moisture free basis). He concluded that the peanut oil consists of the glycerides of long-chain fatty acids and contains tocopherols which serve as antioxidants which contribute to its excellent stability. The protein has a high digestibility coefficient and contains appreciable amounts of the 10 nutritionally essential amino acids. Carbohydrates present in the kernel include starch, sucrose, pectic materials and cellulose.

Booher (6) reported that the peanut is an especially rich source of vitamins A, B₁, C, and Niacin, a 2- ounce portion of peanuts supplies 1/8 of the total daily needs of riboflavin. He also noted that modern commercial methods of roasting of processing peanuts in hot oils cause a destruction of about 70-80 percent of the thiamine value.

Holley (13) reported, after 25 years of research on the chemistry of Spanish, Valencia, and Virginia type peanuts, that as a peanut seed matures the oil-protein ratio gradually changes from 1:4 to 2:1. For top quality peanuts, the percentage oil should be nearly twice the percentage of protein. He reported that top quality peanuts usually show no more than 0.05 percent free fatty acids. This may be due to either immaturity or to growth of molds or other micro-organisms.

Johns and Jones (14, 15) isolated two globulins, arachin and conarachin from peanuts. Arachin contains 0.4, and conarachin 1.09 percent of sulfur. They also found that arachin gave 4.96 and conarachin 6.55 percent of basic nitrogen. In further study, they analyzed the globulin of peanuts and their results showed them to contain the basic amino-acids, arginine, histidine, lysine, and cystine.

Gladys, Elsie, Eleanor, and Reynolds (11) found musty off-flavors in unroasted, and roasted and salted peanuts grown in soil in which technical benzene hexachloride at a dosage rate to give 1 pound gamma isomere per acre or on which lindane, 1 pound per acre, applied with the fertilizer were used as insecticides. Slightly stronger off-flavors were noted in samples where benzene hexachloride was used than in those with lindane was used, however, in both cases, the eating quality of the peanuts was impaired seriously.

Abbott (2) reported that higher demand for oil seed proteins in the high income countries, where animal proteins were plentiful, was likely to stem mainly from reasons of variety, price, flavor, texture, health, and properties favorable for use in prepared and prepackaged foods. In low income countries, in contrast, the human need for protein was greater but the masses of the population lack the means to pay for it. Under such conditions, proteins were consumed mainly as natural ingredient of the chief hunger satisfier: cereals and pulses or legumes.

Milner (22) described the use of peanut and other oil seeds as protein sources for human food, and particularly as

food for children. The defatted residues of this product could have considerable potential in some undernourished areas where they may have heretofore been utilized at best for animal feeding and often to an even greater extent as fertilizers.

Partially defatted peanuts offer the possibility of adding to peanuts many other ingredients, flavors, spices, and coloring. Included are ingredients such as amino acids, fatty acids, vitamins, minerals, salt, monosodium-glutamate, sugar, honey, and flavorings such as chocolate, barbecue, cheese, onion, mint, maple, paprika, cinnamon, curry, lemon, raspberry, and cherry. Spices include cloves, mace, and ginger.

CHAPTER III

MATERIALS AND METHODS

I. MATERIALS

The two varieties of peanuts utilized in this study were dry shelled Virginia and Spanish. The shelled Virginia peanuts were purchased as U. S. No. 1 grade from one company and the Spanish type unshelled peanuts were purchased from another company. The Spanish type peanuts were shelled manually.

The petroleum ether employed was a commercially available product which had a boiling range of 35°-59° C. The hexane was of the commercial grade that is used for oil extraction. It had a boiling range of 63°-69° C. Commercial grade hexane was used because of its general acceptance for processing foods, its availability, and low cost.

The laboratory model Carver hydraulic press was used to expel the oil from the peanuts.

II. TREATMENTS FOR EXTRACTING OIL

Five different treatments were studied to determine a satisfactory method to remove the oil from each of the two varieties of peanuts.

Treatment I--Solvent Extraction

The shelled peanuts were roasted at 180° C. in a drying oven for 1 hour, cooled for 24 hours, and then the skins were removed manually.

In the removal of the oil, each of the varieties was soaked in the hexane solvent at room temperature for 9 days. Exactly 240 g. of peanuts was employed and the solvent was added in a solvent:peanut ratio of 1:2 by weight.

The solvent from the solvent-laden peanuts of both varieties was removed by placing them in a small vacuum oven for 8-1/2 hours. The pressure in the vacuum oven was maintained at 25 mm. of mercury. The temperature was maintained at 100° C.

Treatment II--Hydraulic Pressure

Both varieties of peanuts were pressed by laboratory model Carver hydraulic press to extract the oil. A volume

of 240 g. of each variety of peanuts was measured in a 500 ml. cylinder before pressing. The sample was then divided into three batches of 80 g. each for extraction of oil by pressing. In each batch, the amount of peanuts, pressure, and time was maintained at 80 g., 1000 psi, and 30 minutes respectively.

The skin of both varieties was removed from the pressed, mis-shapen peanuts. Afterwards they were expanded or reconstituted in boiling water at atmospheric pressure for 10 minutes, drained, and dried in a vacuum oven for 3-1/2 hours at 25 mm. of mercury and a temperature of 100° C.

Treatment III--Hydraulic Pressure--Solvent Extraction

In this treatment, 240 g. of dry raw shelled peanuts were hydraulically pressed at a constant pressure of 1000 psi for 30 minutes. They were put into a 1000 ml. flask containing hexane. The solvent was used in a solvent:peanut ratio of 1:2 by weight. The peanuts were removed after 72 hours and put in the drying oven for 30 minutes at 100° C. to remove the solvent. The procedures employed in treatment II for removal of the skin and reconstitution of the peanuts were used.

Treatment IV--Solvent Extraction--Hydraulic Pressure

A 240 g. of dry raw shelled peanuts were put in a 1000 ml. flask, and hexane added in the ratio of 1:2 by weight. After 72 hours of soaking, the peanuts were removed from the solvent and hydraulically pressed at 1000 psi for 30 minutes. The skin removal and reconstitution was the same as in treatment II.

Treatment V--Hydraulic Pressure--Solvent Extraction--Hydraulic Pressure

The hydraulically pressed peanuts were put in the solvent for 72 hours as in treatment III. After 72 hours soaking, the peanuts were removed from the solvent. They were again hydraulically pressed as in treatment II. The skin and reconstitution was the same as treatment II.

All treatments were carried out in triplicate.

III. METHODS OF ANALYSIS

The samples of peanuts from both varieties and from the five treatments were analyzed for the following factors.

Percent Nitrogen and Crude Protein

Nitrogen was determined by the Kjeldahl Method (1).

Exactly 0.5 g. of sample was weighed and placed in a Kjeldahl flask. Basically, the method converts nitrogen into ammonium sulfate during the digestion process with concentrated sulfuric acid. The ammonium sulfate was treated with strong base (40 percent NaOH sol.) and heated to distill ammonia which was collected in 25 ml. of a saturated boric acid solution. The boric acid solution with ammonia was treated with standard acid and the percent nitrogen was calculated from the titration data. The percent nitrogen was related to the percent protein by a conversion factor of 6.25.

Fat (Oil)

Fat was determined by weighing a 2-3 g. sample of dry ground peanuts into a thimble. The sample with petroleum ether was then placed in a Soxhlet-type extractor for 12 hours. The sample was placed in the drying oven to evaporate the petroleum ether at 95°-100° C. for 1-1/2 hours. The sample was transferred to a desiccator, cooled, and weighed. The loss in weight was calculated and expressed as percent fat (1).

Moisture

Moisture was determined on each sample. Approximately 3-4 g. of ground sample was placed in an aluminum dish, and weighed on an analytical balance. The dishes, with sample, were placed in a drying oven at 130° C. for 4 hours. After removal from the oven, the dishes and their contents were cooled in a desiccator, and weighed. Moisture content was expressed as the loss of weight of original samples and expressed as percent (4).

Volume and Weight

The dry expanded peanuts of both varieties were put in a 500 ml. graduated cylinder to measure the volume and also were weighed.

Shear-Press Value

Shear-press value in # force was measured on each sample (10 g.) of the dry expanded peanuts by Shear-Press.

Statistical Analysis

Each factor was measured and statistically analyzed by the split plot design (two varieties, three replications and five treatments). The effect of all factors studied was

tested for significance by analysis of variance. Significance among means was determined by use of Duncan's Multiple Range Test.

Taste Panel Studies

The Virginia type peanuts and treatment II (hydraulic pressing) were chosen for preparing samples for sensory evaluation. The hydraulic pressure was increased to 2000 psi for 30 minutes to insure the removal of approximately 72 percent oil from the peanuts. The pressed peanuts were reconstituted in the four following flavors and concentrations: (1) salt solutions of 2, 3, and 4 percent; (2) sugar solutions of 10, 20, and 30 percent; (3) beef broth solutions of 25, 50, and 100 percent with 1 percent salt; and (4) monosodium-glutamate (MSG) solutions of 1, 2, and 3 percent with 1 percent salt. The pressed and reconstituted peanuts were roasted in hot air in an electric oven at 300° F. for 1 hour.

Ranking Test was used for sensory evaluation of the roasted peanuts. The taste panel was asked to evaluate the samples for the most acceptable concentration of the three concentrations used of each flavor. Four flavors were

served to each taste panel member. The taste panel was instructed to rank the samples in order of preference, one being the most preferred and three being the least preferred. Point values for ranked positions were: three for one; two for two; and one for three. Significance of the differences between treatment means were determined by referring to the table of probabilities (23). Based on the results obtained from the above test, samples (10-15 g.) of the most acceptable concentrations from each of the four flavors were again served to the taste panel to determine the most acceptable flavor and texture. Again the taste panel was instructed to rank the samples in order of preference, one being the most preferred and four being the least preferred. Significance of the differences between treatment means were determined by referring to the table of probabilities (23).



CHAPTER IV

EXPERIMENTAL RESULTS

In discussing the results in this experiment the methods of oil extraction will be referred to as treatments:

(1) solvent extraction, (2) simply pressing of peanuts, (3) pressing followed by solvent extraction, (4) solvent extraction followed by pressing, and (5) pressing plus solvent extraction plus pressing.

I. MOISTURE

The analysis of variance (Table I) shows a significant difference in percent moisture of the pressed and expanded peanuts between treatment and replications. It shows no significant difference between varieties. The results of Duncan's Multiple Range Test (Table II) shows no significant difference between treatments IV, II, and V. The lowest and highest moisture values for the Spanish variety were 0.54 percent in treatment I and 3.35 percent in treatment III. In the Virginia variety, treatment I was low with 0.44 percent and treatment III was highest with 3.84 percent

TABLE I

RELATIONSHIP OF THE CHEMICAL ANALYSIS OF DRY PRESSED AND RECONSTITUTED PEANUTS TO VARIETY AND TREATMENTS

Sources of Variance	Mean squares					Volume in ml.
	d.f.	% Moisture	% Fat (oil)	% Protein	Weight in gms.	
Among Treatments	4	588.880**	2928.692**	736.692**	21.398**	0.0001
Among Variety	1	0.013	92.189**	1398.960**	1.476	0.0001
Between T x V	4	14.198**	125.755**	4.797**	0.957	0.0001
Among Replications	2	24.193**	7.437**	43.272**	1.164	0.0001
Between T x R	8	69.343**	42.916**	8.524**	0.944	0.0001
Between V x R	2	5.892**	35.829**	9.654**	1.325	0.0001
Between T x V x R	8	6.636**	46.021**	4.912**	1.026	0.0001
Error	60	0.0418	0.3024	0.4501	2090.9162	0.0000

***Means significant at 0.01 level of probability.

*Means significant at 0.05 level of probability.

TABLE II
RESULTS OF DUNCAN'S MULTIPLE RANGE TEST (TREATMENTS)

	Treatments				
	I	II	III	IV	V
% Moisture	0.49 ^a	2.78 ^b	3.59 ^c	2.60 ^b	3.59 ^b
% Fat (oil)	36.59 ^a	31.97 ^b	21.89 ^c	32.36 ^b	20.69 ^d
% Protein	33.05 ^a	34.91 ^b	41.74 ^c	35.08 ^b	42.33 ^c
Weight in gms.	206.26 ^a	135.62 ^{ab}	115.91 ^b	126.68 ^b	107.58 ^b
Volume in ml.	363 ^a	305 ^a	225 ^a	301 ^a	243 ^a

Note: Means of each analytical factor followed by the same letter are not significantly different at 0.05 level of probability.

moisture. The interactions show a significant difference between $T \times V$, $T \times R$, and $T \times V \times R$.

II. FAT (OIL)

The analysis of variance (Table I) indicates a significant difference in percent fat content of the solvent extracted and the dry pressed and expanded peanuts between varieties, between treatments, and between replications. Duncan's Multiple Range Test (Table II) shows no significant difference between treatments II and IV. The lowest and highest fat values for the Spanish variety were 19.93 percent in treatment III and 37.63 percent in treatment I. In the Virginia variety, treatment V was low with 19.98 percent and treatment I was highest with 35.55 percent fat content. The interactions show a significant difference between $T \times V$, $T \times R$, and $T \times V \times R$.

III. CRUDE PROTEIN

The analysis of variance (Table I) shows a significant difference in percent protein content of the solvent extracted and the dry pressed and expanded peanuts between treatments, between varieties, and between replications.

The results of Duncan's Multiple Range Test (Table II, page 29) shows no significant difference between treatments II, and IV; III and V. The lowest and highest protein values for the Spanish variety were 30.21 percent in treatment I and 39.21 percent in treatment III. In the Virginia variety, treatment I was low with 35.90 percent and treatment 5 was highest with 45.48 percent protein. The interactions show a significant difference between T x V, T x R, and T x V x R.

IV. WEIGHT

The analysis of variance (Table I, page 28) indicates a significant difference in weight in grams of the solvent extracted and dry pressed expanded peanuts between treatments. It shows no significant difference between varieties and between replications. Duncan's Multiple Range Test (Table II, page 29) shows no significant difference between treatments II through V. The lowest and highest weight of dry oil extracted peanuts for the Spanish variety were 107.67 g. in treatment V and 206.66 g. in treatment I. In the Virginia variety, treatment V was low with 107.50 g. and treatment I was highest with 205.87 g. peanuts. The

interactions show no significant difference between $T \times V$, $T \times R$, and $T \times V \times R$.

V. VOLUME

The analysis of variance (Table I, page 28) shows no significant difference in volume of solvent extracted and pressed expanded peanuts between treatments, between varieties, and between replications. The lowest and highest volume of dry extracted peanuts for the Spanish variety were 222.0 ml. in treatment III and 358.0 ml. in treatment I. In the Virginia variety, treatment III was with 228.0 ml. and treatment I was highest with 368.0 ml. peanuts. The result shows no significant difference in interactions between $T \times V$, $T \times R$, and $T \times V \times R$.

VI. SHEAR-PRESS VALUE

In Spanish variety, the results showed (Table III) 248, 508, 773, 509, and 734 shear-press values in # force in treatments I, II, III, IV, and V, respectively. The lowest and highest shear-press values for the Spanish variety were 248 # force in treatment I and 773 # force in treatment III. In

TABLE III

SHEAR-PRESS VALUE (# FORCE) OF THE DRY EXPANDED PEANUTS

Treatments	Shear-press value in # force	
	Spanish variety means of reps.	Virginia variety means of reps.
I. Solvent Extraction	248	267
II. Hydraulic Pressure	508	607
III. Hydraulic Pressure followed by Solvent Extraction	773	704
IV. Solvent Extraction followed by Hydraulic Pressure	509	573
V. Hydraulic Pressure plus Solvent Extraction plus Hydraulic Pressure	734	893

the Virginia variety, treatment I was low with 267 # force and treatment V was highest with 893 # force.

VII. CORRELATION COEFFICIENTS

Significant correlation coefficients were found for several of the variables studied (Table IV).

Moisture and protein showed a positive correlation coefficient of 0.5092. No significant correlation coefficient was shown between shear-press values and moisture. It showed a negative correlation coefficients of -0.5631, and -0.7427 between fat, weight, and volume respectively.

Fat showed a positive correlation coefficient of 0.5296 and 0.8876 for weight and volume respectively and a negative correlation coefficient of -0.8087 and -0.9410 between protein and shear-press values respectively.

Protein showed a negative correlation coefficient of -0.4457 and -0.7231 for weight and volume respectively.

Weight and volume gave a positive correlation coefficient of 0.6036.

VIII. ORGANOLEPTIC EVALUATION

Organoleptic evaluation (Table VIII, Appendix) showed

TABLE IV

CORRELATION COEFFICIENTS FOR DIFFERENT VARIABLES STUDIED

	% Moisture	% Fat (oil)	% Protein	Weight in gms.	Volume in ml.	Shear-press values
% Moisture	- - -	** -0.5990	** 0.5092	** -0.5631	** -0.7427	0.8160 N.S.
% Fat (oil)	- - -	- - -	** -0.8087	** 0.5296	** 0.8876	** -0.9410
% Protein	- - -	- - -	- - -	** -0.4457	** -0.7231	- - -
Weight in gms.	- - -	- - -	- - -	- - -	** 0.6036	- - -

**Significant at 0.01 level of probability.

no significant difference in flavor of the roasted and reconstituted peanuts made from three concentrations of salt (2, 3, and 4 percent), sugar (10, 20, and 30 percent), and beef broth (25, 50, and 100 percent with 1 percent salt). Significant differences in flavor of the roasted, pressed, and reconstituted peanuts were found between concentrations of MSG (1, 2, and 3 percent with 1 percent salt), with the 2 percent being most preferred.

Organoleptic evaluation (Table IX, Appendix) showed significant differences among flavors of the roasted, pressed, and reconstituted peanuts made from 2 percent MSG, 3 percent salt, 20 percent sugar, and 50 percent beef broth with 3 percent salt being most preferred. No significant difference in the texture was found between the peanuts made from 3 percent salt, 2 percent MSG, and 20 percent sugar. It did show significant of lower preference for the texture of the peanuts made from 50 percent beef broth.

CHAPTER V

DISCUSSION

The raw Spanish and Virginia type peanuts contained 51.14 and 49.54 percent oil, respectively. The pressing of raw peanuts at 1000 psi for 30 minutes (treatment II) showed the highest percentage 36.56 percent on original oil basis) oil removal. The amount of oil removed was found to be related to the time and pressure applied.

It was found that 29.82 percent of oil was removed from the roasted peanuts by solvent extraction (treatment I) in 9 days. Studies by Pominiski, Patton, and Spadaro (26) indicated that the fully roasted peanuts with 81.30 percent oil removed have a better appearance than peanuts with lesser amounts of oil removed, also they do not have a mottled appearance due to unextracted spots of oil near and on the surface. In this study, the roasted peanuts with 29.82 percent oil removed by solvent extraction, had a mottled appearance but the surface was smooth and the color was lighter.

The flavor of peanuts can be enhanced by roasting. Because of the mildness of flavor, solvents used in de-oiling

must be relatively free of high boiling contaminants which may remain behind and impair the flavor. The strength of the characteristic flavor increases in the de-oiled product as the amount of oil left in the product increases (26).

In the amount of oil removed, combinations of pressing and solvent extraction methods showed the following results. (1) The pressing of peanuts (1000 psi, 30 minutes) followed by solvent extraction for 72 hours (treatment III), showed 39.00 and 20.22 percent oil removed by pressing of solvent respectively. (2) The solvent extraction followed by pressing (treatment IV) gave 1.00 and 36.46 percent oil removed by solvent extraction and by pressing, respectively. (3) The pressing plus solvent extraction plus again pressing (treatment V) showed 39.02, 20.22, and 0.00 percent oil removed by each method, respectively.

In cases of pressing followed by solvent extraction (treatment III) and pressing plus solvent extraction plus pressing (treatment V), total oil removed was highest (59.22 and 59.24 percent, respectively). This may be due to the breaking of the structure of the peanuts by pressure. While in case of solvent extraction followed by pressing (treatment IV), only 1.00 percent of the oil was removed after 72

hours soaking and 36.46 by pressing. Fan, Morris, and Wakeham (10) working with dried peanuts, found that although the extraction of oil with pentane and hexane left most of the tissue cells undamaged, they also found that the first layer of the kernel cells, just under the skin of the peanut, greatly retarded oil extraction by petroleum solvents.

Results obtained from above tests, considering the economic point of view and the amount of oil removed, the removal of oil from raw peanuts by simply pressing (treatment II) was the best method used in this experiment. Other treatments were laborious and time consuming.

Varietal differences did not appear to be a factor in the removal of oil from the peanuts either by solvent extraction or by pressing.

The raw peanuts contained an average of 5.50 percent moisture before they were pressed. It was reduced to 2.79, 3.44, 2.60, and 3.14 percent in treatment II, III, IV, and V, respectively during drying process after reconstitution. Roasted peanuts (treatment I) contained 1.50 percent moisture before they were extracted. The moisture was reduced to 0.49 percent during the desolventization process.

The percentage of protein remained the same in all peanuts (on a dry weight basis), although treatments showed various percentage of protein. This may be due to the different amounts of oil extracted from the peanuts.

It was found that the weight of the extracted peanuts was related to the amount of oil removed.

The volume of 240 g. of raw Spanish and Virginia type peanuts was 365 and 380 ml. respectively. There was considerable reduction in volume of the peanuts extracted by solvents (treatment I) as compared to pressing which was approximately 2.76 percent. The pressed and reconstituted peanuts showed 16.66, 39.00, 18.50, and 34.20 percent reduction of volume in treatments II, III, IV, and V, respectively. Decrease in volume might be due to the shrinkage as well as breaking of the structure of the peanut by pressing.

In the Spanish variety, the results showed 248, 508, 773, 509, and 734 shear-press values in # force in treatments I, II, III, IV, and V, respectively. In the Virginia variety, the results indicated 267, 607, 704, 573, and 893 shear-press values in # force respectively. Treatment I (solvent extraction) with 29.82 percent oil removed showed an average of 816 shear-press values. It indicated that the

shear-press values increase with increased removal of oil. An important factor to be noted is the negative correlation coefficient of -0.941 between the texture (shear-press values) of the pressed and reconstituted and percent fat removed.

The Virginia type peanut was selected for taste panel evaluation because it contains approximately 2 percent less oil and 5 percent greater protein than the Spanish variety. Secondly, it is larger in size, better in appearance and skin removal than the Spanish type.

The process for removing oil from raw peanuts by pressing (treatment II) was preferred over other methods used in this experiment; because with simply pressing, the problems and extra processing steps associated with subsequent removal of solvents from the products were overcome.

The pressed and reconstituted peanuts which were made from different concentrations of salt (2, 3, 4 percent), beef broth (25, 50, 100 percent), and MSG (1, 2, 3 percent) showed an average increase in volume of 1.88 percent and an average increase in weight of 2.33 percent with increased concentration of solutions. Data in Table VI (Appendix)

show that there was a 7.14, 14.75, and 18.75 percent increase in volume and a 3.00, 10.82, and 13.45 percent increase in weight of the pressed and reconstituted peanuts made from 10, 20, and 30 percent sugar solutions respectively.

There was no significant difference in concentration of the flavors used except in the case of MSG (2 percent). The salty flavor was significantly preferred over other flavors. Beef broth flavor was significantly poorer than sugar, MSG, and salty flavors.

Texture wise, the salt reconstituted peanuts were preferred over all others. Beef broth reconstituted peanuts were judged to be the poorest. The pressed and reconstituted peanuts were found to be harder in texture and lighter in weight than regular oil roasted peanuts.

Commercially, defatted peanuts would probably be salted by spraying with water before being sprinkled with salt. Salting by spraying peanuts with saturated salt solution also may have possibilities.

The utilization of partially defatted peanuts could probably be increased by adding to peanuts many other ingredients, flavors, spices, and coloring.

CHAPTER VI

SUMMARY

A study was made to compare two processes of defatting peanuts, solvent extraction and hydraulic pressing and to investigate the possible development of a new peanut product with a high protein and low fat content.

Under conditions of this experiment the following findings were made:

1. Considering the amount of oil removed, pressing (treatment II) was the best method used in this experiment. Other treatments were laborious and time consuming.

2. Simply pressing of peanuts was preferred over other methods, because the problems and extra processing steps associated with the subsequent removal of solvents from the product were overcome.

3. Varietal differences would not appear to be a factor in the removal of oil from the peanuts either by solvent extraction or by pressing.

4. There were significant differences between treatments, between varieties, between replications, and

between interactions for moisture, fat, and protein of defatted peanuts.

5. Fat showed a negative correlation coefficient of -0.8067 and -0.9410 between protein and shear-press values (texture) respectively.

6. There was a 7.14, 14.75, and 18.75 percent increase in volume and a 3.00, 10.82, and 13.45 percent increase in weight of the pressed and reconstituted peanuts made from 10, 20, and 30 percent sugar solutions.

7. The salty flavor was significantly preferred over other flavors used and beef broth flavor was significantly poorer than sugar, MSG, and salty flavors.

8. The pressed and reconstituted peanuts were found to be harder in texture and lighter in weight than regular oil roasted peanuts.

9. The raw Spanish and Virginia type peanuts contained 51.14 and 49.54 percent oil, respectively.

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APPENDIX

TABLE V

CHEMICAL ANALYSIS OF PRESSED AND RECONSTITUTED
PEANUTS OF SPANISH VARIETY

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press values # force
Spanish	I. Solvent Extraction	1	0.53	37.37	28.50	208.40	355.00	357
			0.50	38.32	31.13			
			0.46	37.98	30.50			
		2	0.27	37.16	31.30	205.20	360.00	252
			0.31	37.62	30.50			
			0.32	36.61	28.50			
		3	0.79	37.62	31.20	206.40	360.00	234
			0.75	38.80	30.44			
			0.88	37.21	30.06			
II. Hydrau- lic Pressure	1		3.38	32.87	31.87	139.50	310.00	422
			3.40	32.83	31.62			
			3.55	33.11	31.62			
	2		2.75	33.27	31.75	134.25	305.00	594
			2.72	33.59	31.50			
			3.19	34.32	31.19			
	3		2.69	34.55	34.94	134.00	300.00	708
			2.58	33.30	34.81			
			3.00	34.60	34.38			

TABLE V (continued)

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press values # force
Spanish	III. Hy- draulic Pressure + Solvent Extraction	1	2.39	21.68	40.56	117.60	210.00	560
			2.35	20.76	83.87			
			2.28	20.84	38.44			
	Extraction	2	4.08	19.55	37.88	116.50	220.00	840
			3.73	19.52	40.56			
			3.99	18.86	38.94			
		3	3.74	18.76	39.69	115.00	235.00	910
			3.47	19.53	39.31			
			4.11	19.92	38.63			
	IV. Solvent Extraction + Hydraulic Pressure	1	3.43	33.59	31.50	132.00	305.00	469
			3.62	34.66	32.06			
			3.63	33.98	31.62			
		2	1.88	34.34	31.62	126.60	305.00	573
			2.00	34.28	33.31			
			2.24	34.34	32.56			
		3	2.40	32.28	33.19	133.25	315.00	486
			2.17	32.67	33.81			
			2.21	33.30	34.31			

TABLE V (continued)

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press value # force
Spanish	V. Hydraulic	1	1.94	22.89	38.06	97.50	220.00	697
	Pressure +		2.06	22.98	37.87			
	Solvent		2.34	21.46	38.06			
	Extraction							
	+ Hydraulic	2	3.46	20.37	41.00	106.00	230.00	862
	Pressure		3.54	20.87	40.25			
			4.19	19.53	40.25			
		3	2.52	21.54	38.75	119.50	260.00	639
			2.46	21.23	39.31			
			2.48	21.76	39.25			

TABLE VI

CHEMICAL ANALYSIS OF PRESSED AND RECONSTITUTED
PEANUTS OF VIRGINIA VARIETY

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press values # force
Virginia	I. Solvent Extraction	1	0.33	35.85	35.75	208.80	365.00	251
			0.29	36.56	36.00			
			0.34	36.30	35.44			
		2	0.26	35.88	34.94	206.00	370.00	268
			0.26	36.39	33.81			
			0.29	36.46	35.44			
		3	0.79	34.37	37.62	202.80	370.00	283
			0.70	34.17	37.19			
			0.69	33.95	36.94			
II. Hydraul- ic Pressure	1		2.86	30.16	36.56	135.00	310.00	570
			2.56	30.34	35.94			
			2.65	29.19	36.31			
	2		2.68	28.24	37.31	131.50	300.00	698
			2.59	29.72	36.00			
			2.36	29.35	36.44			
	3		2.42	34.60	38.50	139.50	305.00	553
			2.43	34.29	38.63			
			2.24	34.10	39.00			

TABLE VI (continued)

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press values # force
Virginia	III. Hy- draulic Pressure + Solvnet	1	2.52	23.63	42.75	114.25	215.00	625
			2.53	23.10	44.75			
			2.55	22.72	43.37			
	Extraction	2	5.01	29.72	42.12	118.00	240.00	803
			4.50	28.14	43.56			
			4.63	29.35	42.44			
		3	4.53	19.24	46.56	113.25	230.00	683
			4.22	19.15	46.81			
			4.11	19.60	46.19			
	IV. Solvent Extraction + Hydraulic Pressure	1	2.75	38.41	37.75	126.00	295.00	658
			2.73	28.83	37.44			
			2.61	29.11	38.19			
		2	2.49	30.79	35.87	129.00	315.00	542
			2.21	30.32	35.56			
			2.09	29.10	36.12			
		3	2.27	31.96	38.94	113.25	275.00	518
			2.78	31.67	38.50			
			3.30	31.95	39.25			

TABLE VI (continued)

Variety	Treatment	Repli- cation	% Moisture	% Fat	% Protein	Weight in gms.	Volume in ml.	Shear- press values # force
Virginia	V. Hydraulic	1	3.08	18.46	45.75	100.50	230.00	920
	Pressure +		2.65	19.28	45.37			
	Solvent		2.49	19.42	46.19			
	Extraction							
	+ Hydraulic	2	4.25	21.55	46.37	108.00	256.00	851
	Pressure		3.91	20.80	45.38			
			3.54	20.46	45.75			
		3	2.16	20.83	44.19	114.00	275.00	915
			2.14	19.07	44.87			
			2.17	19.98	45.50			

TABLE VII

VOLUME AND WEIGHT OF PRESSED (ROASTED) AND RECONSTITUTED PEANUTS OF
VIRGINIA VARIETY MADE FROM DIFFERENT CONCENTRATIONS
AND FLAVORS

	Salt			Beef broth				Sugar			M S G		
	2%	3%	4%	25%	50%	100%		10%	20%	30%	1%	2%	3%
Weight in gms.	130	131	133	132	131	134		135	147	156	131	133	134
Volume in ml.	260	260	265	260	260	265		280	305	320	260	262	265

TABLE VIII

PERFORMANCE OF PANELISTS FOR CONCENTRATION OF FLAVORS OF
 DRY ROASTED AND RECONSTITUTED PEANUTS

Treatments	Concentration of flavor	Points for Preference		
		Americans	Indians	Total
Sugar solution	10%	22	10	82
	20%	22	13	35
	30%	16	13	29
Salt solution	2%	20	11	31
	3%	20	15	35
	4%	20	10	30
Beef Broth with 1% salt	25%	21	11	32
	50%	18	14	32
	100%	21	11	32
M S G with 1% salt	1%	16	10	26
	2%	23	16	39
	3%	21	10	31

Note: Panel composition: 6 Indians and 10 Americans. Highest score indicates most preferred sample.

TABLE IX

PERFORMANCE OF PANELISTS FOR FLAVORS AND TEXTURE OF THE
 DRY ROASTED AND RECONSTITUTED PEANUTS

Treatments	Flavor score			Texture score		
	Americans	Indians	Total	Americans	Indians	Total
Sugar (20%)	11	9	20	15	9	24
Salt (3%)	29	9	38	25	6	31
Beef Broth (50%)	11	6	17	5	9	14
M S G (2%)	19	6	25	23	8	31

Note: Panel composition--7 Americans and 3 Indians. Highest score indicates most preferred sample.

VITA

The author was born on November 20, 1939, in Kuched, India. He received his B. S., with a major in Agriculture, from B. A. College, Sardar Vallabhbhai Vidyapeeth, Anand, in 1963. He worked in Department of Soil Conservation, Gujarat State Government, India, for one year. In 1964 he came to the University of Tennessee, Knoxville, Tennessee, and worked for his M. S. in Food Technology.

He was married to Miss Taru D. Patel, B. S. (Chemistry), on April 20, 1964.