

Peanut Milk and Peanut Milk Based Products Production: A Review

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*Since the early 1950s, numerous reports have been published suggesting that peanut milk and peanut milk based products can be prepared in a wide variety of ways. Emphasis has shifted from preparing inexpensive milk like beverages, very nutritious but somewhat lacking consumers appeal, to using the peanut milk or peanut protein isolates as an animal milk extender without changing flavor, to develop more attractive fermented products, and to precipitate proteins from the milk in order to get a curd called “tofu,” and to produce cheese analogs. Great attention has been paid to the improvement of the stability, sensory properties, and shelf-life of the milk, using physical and chemical treatments. Many efforts have been deployed for supplementing the products. Thanks to recent advances, the removal of aflatoxin from peanut milk can be achieved using *Flavobacterium aurantiacum* as a biodegrader. It has also found application as liquid coffee whitener. However, despite all these developments and publications, there is still a need for much more diversified studies in order to definitely overcome the stability, the nutty flavor, and sensory problems always encountered when producing peanut milk and some peanut milk based products.*

Keywords fermented, free flow flour, grinding, miltone, partially defatted, soaking

INTRODUCTION

Over the last 50 years, many ways of producing peanut milk have been developed. Its composition depends on the desire of the producer, but, in all cases, this low cost milk has a high protein content. One of the earliest scientists to suggest the preparation of peanut milk is perhaps the African-American, George Washington Carver.

Soaking and grinding full-fat raw peanuts with water to get slurry, subject to filtration produce usually peanut milk (aqueous extract of peanut kernels, *Arachis hypogea* L.) (Chandrasekhara et al., 1971; Beuchat et al., 1978; Bucker et al., 1979; Rubico et al., 1987, 1988; Chan et al., 1991, 1992; Shurpalekar et al., 1964; Chandrasekhara et al., 1964; Schaffner and Beuchat 1986; Schaffner et al., 1985) and also by grinding unsoaked roasted peanuts, raw full-fat, or partially defatted peanuts to form free-flow flour to which water may later be added to make an emulsion. Another way is to use the peanut milk or peanut protein isolates to extend animal milk (toned milk). In all cases, the peanut or peanut flour to water ratio change greatly from one producer to another. The milk-like product produced is then homogenized, sterilized in much the same way as fresh milk, and also

supplemented with vitamins and minerals and is sometimes flavored. Details of these methods are given in the works of Barley (1951), (Jasper, 1973), Mitchell (1950), Chandrasekhara et al. (1971), Schmidt et al. Mendelsohn (1980), Rubico et al. (1987, 1988), and Chan Lee and Larry R. Beuchat (1992), (Priepke et al., 1980). According to Rao et al. (1964), peanut milk combined with other milks can be spray dried, and the powder has longer shelf-life and can be readily reconstituted in water.

Over the years, peanut milk has been successfully converted into low cost edible products with high nutritional value. In this area, researchers have focused on products resulting from fermentation, such as yogurt, buttermilk, ripened cheese analogs, and some on fermented products, in particular, the curd or “tofu.” The works of Ramamurti et al. (1964), (Jasper, 1973), Patel (1968), (Van, 1992), Beuchat and Nail (1978), Bucker Jr. et al. (1979), Schaffner et al. (1985), Schaffner and Beuchat (1986), Chan Lee and Beuchat (1991), Show-Ling Chen et al. (1979), and K. Mochizuki et al. (1979), (Maltz, 1981) are an illustration. These products have better sensory properties than the original milk. In this regard, recent advances in fermented products manufacturing have revealed, through the work of Lee and Beuchat (1991), (Hao and Brackett, 1988) that hexanal, which is one of the compounds responsible for unwanted beany flavor in peanut milk, completely disappeared as a result of fermentation. Cooking may also reduce the hexanal content of

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peanut milk (Chan Lee and Beuchat, 1992). Thanks to some kind of fermentation, aflatoxin has been successfully removed from peanut milk.

For ages it has been well known that peanut milk and peanut milk products have nutritional benefits for young and old alike because of their extreme richness in protein, minerals, and essential fatty acids, such as linoleic and oleic, which are acids considered to be highly valuable in human nutrition. Thus, Dora Armstrong, Jasper (1973) a missionary in the Belgian Congo, used peanut milk as a substitute for cow's milk to save the lives of many undernourished babies (Jester, 1942). It is extensively used in India and most developing countries by low income starch diets, underweight people, vegetarians, and more recently, by children allergic to cow's milk proteins. The current interest in peanut milk and peanut milk products is motivated by the fact that dairy and dairy products are always priced too high for the low income people. Another factor, no less important, is the growing awareness of the nutritional benefits of vegetable proteins in low fat and low cholesterol diets by health conscious people.

The purpose of this article is to define the different ways of producing peanut milk and peanut milk products and the effects of processing conditions on peanut milk and the developments that have occurred in the peanut milk manufacturing during the last half-century. In addition, this article will also point out that increases in production and the use of peanut milk is the best prospect for meeting the nutritional needs of huge segments of the populations in developing countries, where malnutrition is endemic. Moreover, this article offers a concise panorama of knowledge for those who want to undertake studies related to peanut milk and peanut milk products.

In this article the production of peanut milk is covered first. Thereafter, the effects of processing conditions on peanut milk and the manufacture of peanut based products are discussed.

PEANUT MILK PRODUCTION

One of the earliest methods for preparing peanut milk is to mix the finely ground peanut flour with water. It was a finding of Mitchell (Jasper, 1973). In 1950, he patented a process for making delicious, stable, and highly nutritious aqueous nut emulsions by converting practically the whole-shelled peanut into a free-flowing nut product, prior to mixing with water. The emulsion is prepared by adding one part of the free-flowing nut product to ten parts water and intensively agitating the mixture until an aqueous emulsion is formed. The stability of the product is greatly improved by heating at temperatures of 66° to 87°C for about 15 to 20 min and homogenizing. The settling of the minute suspended solid particles may be substantially inhibited by the addition of a suitable alkalinizing agent, such as disodium phosphate or sodium bicarbonate. The pH of the nut emulsion without additives is between 6.0 and 6.2, and a sufficient alkalinizing agent should be added to raise the pH value to 6.0 or 6.8. Increased stability is due to the increased solubility of the proteins.

The addition of about 1.0 to 1.2 disodium phosphate by weight is sufficient to achieve the desired stability. To achieve the desired degree of stability for freezing, shipment or storage of the emulsion, up to 1% by weight of "edible emulsifying agents," such as alginates, gelatin, or vegetable gums, are added. Edible sweetening and flavoring material are added to the drinks. Supplementing the emulsion with added vitamins, amino acids, minerals, or other supplements may achieve desired nutritive balance.

One of the most popular ways for producing peanut milk is to soak the peanuts in water prior to grinding. This was done by Barley (1951). According to Barley, peanut milk is made from sludge produced by grinding one volume of raw peanuts with 6 volumes of water for 30 min. The pH is adjusted to 9.0, and using a cream separator, the fat is removed from the starch and fiber. This process provides a yellow liquid nearly fat free and constitutes high proteins milk. Dora Armstrong (Jasper, 1973) produced milk from peanut in much the same way, but subsequent deodorizing was done by bubbling steam through it.

Another way for producing the beverage, unlike the previous ones, uses neutralized and spray-dried peanut protein isolates contain 92% protein to extend animal milk. The drawback of this process is its uneconomical aspect. Consequently, the process for making Miltone was modified to use wet protein isolate produced *in situ*. This method gained popularity in India in the 1970s and some developing countries. Buffalo's milk is known for being unnecessarily high in fat content for beverage milk (8%) and is scarce and expensive for most of the population. Thus, in India and some developing countries, the production of toned peanut milk, called "Miltone" or "vegetable toned milk," which is buffalo milk extended or toned with peanut proteins isolates, has become reality. (Enwokolo and Smart, 1996; Hudson, 1987, 1994; Jasper, 1973; Priepke et al., 1980; Hao and Brackett, 1988; Salunkhe and Kadam, 1989; Van, 1992; Maltz, 1981; Chandrasekhara et al., 1971).

The solvent extracted peanut flour is dispersed in alkaline water in 200-L stainless steel tanks provided with stirrers, and the protein liquor is separated in a horizontal-bowl peeling centrifuge. The liquor is further clarified in a Wesphalia disc-type separator and detoxified with hydrogen peroxide at 75°C and pH 9.5 Chandrasekhara et al., 1971. The hydrogen peroxide is removed by catalase obtained from fungal fermentation (Srekanthia et al., 1968). The detoxified liquor is then pumped into a tank in which the protein is precipitated by the addition of 5N H₂SO₄. The protein precipitate is separated from the liquor in a non-perforate basket-type centrifuge. The protein is redispersed in water at pH 6.8–7.0 and is homogenized in a colloid mill. Buffer salts (phosphates and citrates) are added, and the peanut flavor is removed by sparging with steam.

The deodorized liquor is pumped into a pasteurizing unit and mixed with the required amount of liquid glucose, vitamin premix, and standardized milk (around 2% fat). Thus, the Miltone obtained is homogenized and pasteurized by passing through a plate heat exchanger and is then cooled to 4°C, bottled, and capped. The drink has a protein, carbohydrate, and vitamin content equivalent to that of animal milk. The sterilized product is

stable for up to 6 mo at room temperature. Its acceptability has been found to depend on the color of the product, absence of peanut flavor, taste and likeness to milk, and mouth feel.

Another way, no less popular, enables one to get the milk by soaking the peanuts in a chemical solution prior to grinding. In this aspect, the literature reports that peanut milk is traditionally prepared by soaking the peanuts in 1% sodium carbonate solution for 16 to 18 h, followed by draining the excess water and grinding in an adequate quantity of water. The wet mash is steeped for 4 to 5 h and filtered through a coarse cloth to recover the product (Salunkhe and Kadam, 1989). Many variants of this method are available, and all of them are modifications of the Illinois process for preparing soybean milk.

In Beuchat and Nail (1978), Salunkhe and Kadam (1989), Van (1992), Maltz (1981), Chandrasekhara et al. (1971) prepared peanut milk desirable for fermentation by lactic acid bacteria as follow:

Florunner cv. Peanuts (*Arachis hypogaea* L.) served as test material from which peanut milk was prepared. Peanuts (1 kg, skin attached) were submerged in tap water containing 0.2, 0.6, and 1.0% sodium bicarbonate O acid and soaked for 16–18 h at room temperature (22°C). A control consisted of peanuts soaked in water containing no added chemical. Peanut mixtures were then either brought to boiling or allowed to remain at room temperature. Following soaking or immediately after heating (for some tests), fluid was drained and peanuts were washed with tap water and ground using an Oster Kitchen Center (Oster Milwaukee, WI). The ground peanuts were combined with 5 L of water and steeped at room temperature for 4–5 h before filtering through 8 layers of cheesecloth. The filtrate was referred to as peanut milk.

In Bucke Jr. et al. (1979) utilized blanched, deskinmed, full fat Runner variety peanut kernels stored at 5°C prior to use to produce peanut milk. One volume of peanut kernels was steamed for 30 min in a rice steamer, ground in a kitchen food grinder (Osterizer), and mixed with 9 volumes of distilled water. The resulting slurry was comminuted twice in a 10.3 cm (4 in.) diameter Premier colloid Mill, first at a setting of 0.20 mm (0.008 in.), and then at 0.10 mm (0.004 in.). The peanut milk thus obtained was filtered through three layers of cheesecloth and the residue discarded. Tween 80 (J.T. Baker) was added to the filtrate to give a final concentration of 0.08% (v/v). This mixture was blended in a 4 L (1 gal.) stainless steel Waring Commercial Blendor at low speed for 2 min and then dispersed in 150 mL amounts into 200 mL screw-cap dilution bottles. These bottles of peanut milk were autoclaved at 121°C for 15 min and after sterilization, while still warm, they were vigorously shaken to redistribute an oil-like layer which had separated during sterilization.

The method for preparing non-defatted and partially defatted peanut beverage used by Rubico et al. (1987, 1988), and also a modification of the Illinois Process for preparing soymilk (Nelson et al., 1976; Schmidt et al., 1978) is presented in Table 1 and Figure 1. Chan Lee and Beuchat (1991, 1992) prepared peanut milk according to the following flow diagrams presented in Figures 2 and 3.

Table 1 Preparation of peanut beverage

1. Peanut kernels	Partially defatted or full-fat peanuts (blanched, Florunner)
2. Blanch and hydrate	Blanch in boiling tap water containing 1.0% sodium bicarbonate for 20 minutes (1:5, kernels: solution)
3. Drain	Drain and rinse with tap water
4. Weigh water	Calculate amount of tap water taking in account the water absorbed during blanching
5. Grind	Three passes in colloid mill (Koloid Mills Inc. Muncie, IN)
6. Filter	Muslin Cloth
7. Formulate	Supplementation of 6% refined sucrose by weight of milk
8. Heat and homogenize	Heat to 71°C; two passes through No-Bac Unitherm IV Model 40 (Cherry-Burrell Corp., Cedar Rapids, IA) 2000 psi or 3000 psi
9. High temperature heating	110 or 121°C
10. Cool	Abrupt cooling to 4.4°C
Bottle and store	Store at 1°C

Ojofeitiimi et al. (2001) described a process for manufacturing peanut milk. Two hundred grams of dried shelled groundnut seed (*Arachis Hypogaea* L.) was cleaned and soaked for 20 min for dehulling. The steeping water was decanted and the groundnut seeds washed. It was then milled into a fine paste. About 400 mL of tap water was added to the fine paste. The slurry obtained was slowly sieved to remove the chaff by using locally available double layered cheesecloth. The creamy milk was then put on a stove to boil from 25 to 35 min and granulated sugar was added to taste.

Pominski and Spadaro (1982) (Hudson, 1987) successfully prepared milk like product from peanut. Defatted or partially defatted peanuts that had not been heated above 120°C during blanching or oil removal were used in this process. The steps of the process comprises mixing the finely ground flour with water (1.9 w/w), heating for 1 min at 100°C, then pasteurizing for 10 min at 82°C, cooling, and refrigeration. The milk-like suspension can remain stable for 8 d. A similar procedure can be used with full fat peanuts, but the product is stable for only 2 d.

Abdullah et al. (1993), succeeded to formulate a liquid coffee whitener as a substitute for sodium caseinate and water. The coffee whitener consisted of water, peanut milk, partially hydrogenated coconut oil, corn syrup solids, 0.2% distilled mono- and diglycerides, 0.4% polysorbate 60, and 0.3% dibasic potassium phosphate (K_2HPO_4).

To formulate coffee whitener, corn syrup and polysorbate 60 were combined with peanut milk and water and heated at 40°C. Potassium phosphate dibasic was added to the mixture and the temperature was increased to 80°C. The melted fat and emulsifier were added and the mixture was held at 80°C for 20 min. The hot formulations were homogenized twice at 211 kg/cm², bottled, cooled, and stored at 4°C.

Results of tests to screen for performance of the liquid coffee whitener in coffee indicated that only 3 formulations were

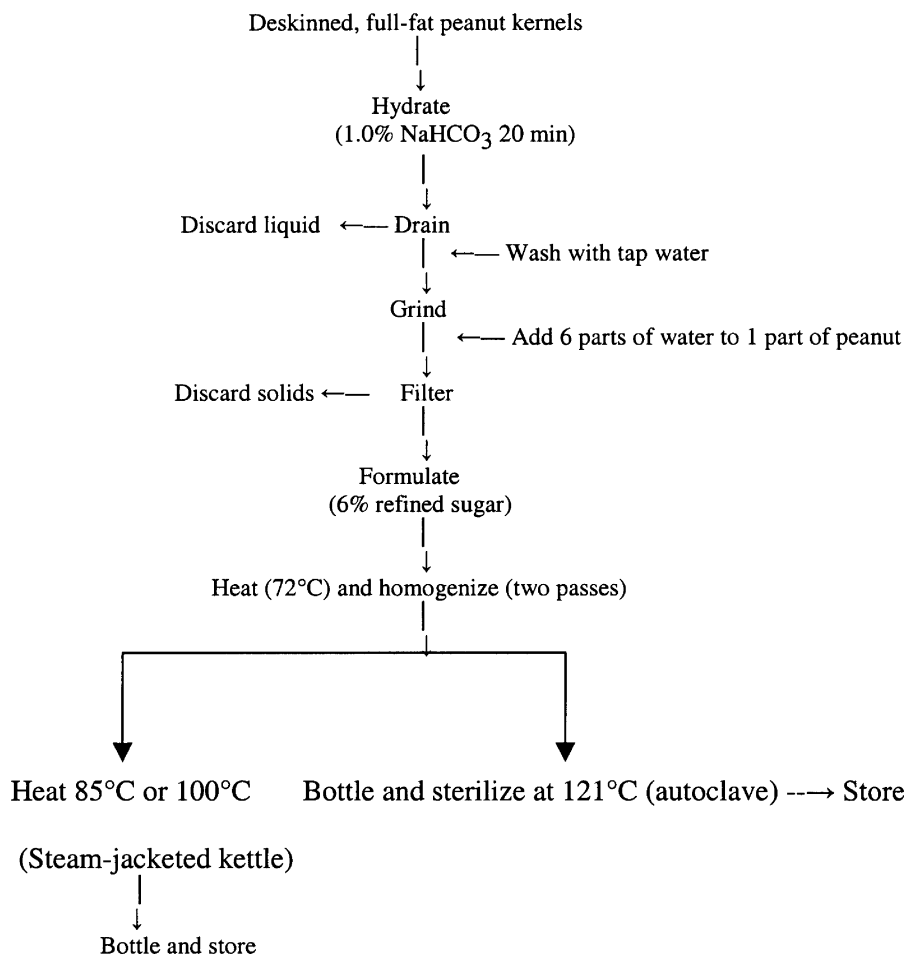


Figure 1 Flow diagram for the preparation of peanut beverage.

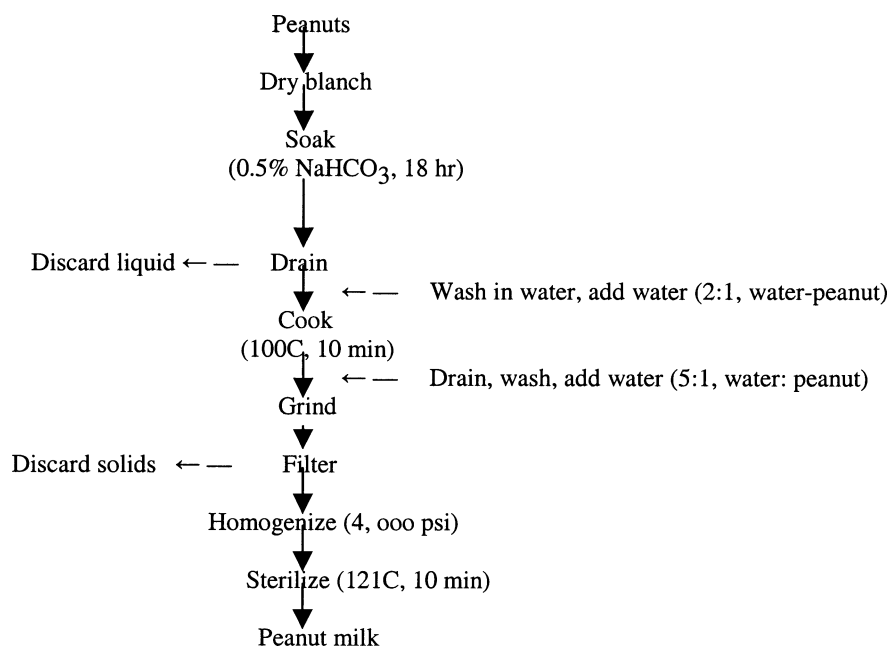


Figure 2 Flow diagram for the preparation of peanut milk.

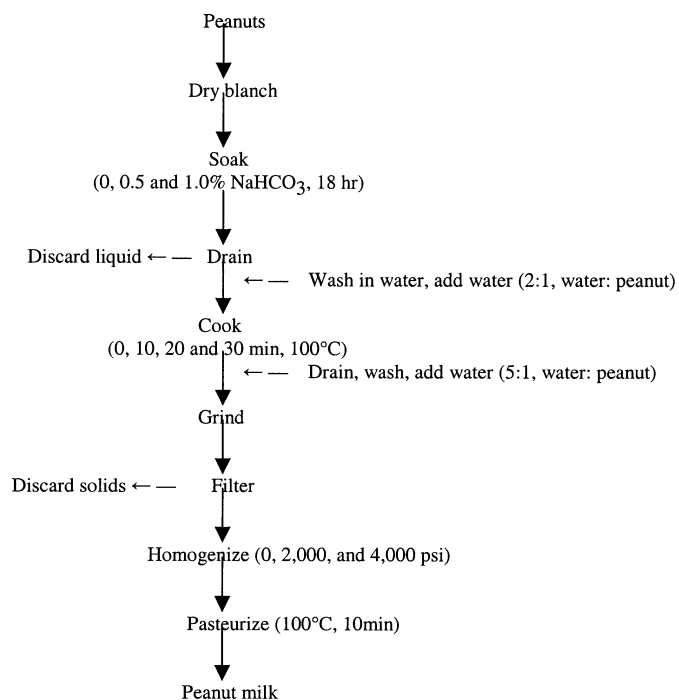


Figure 3 Flow diagram for the preparation of peanut milk.

judged acceptable in terms of appearance, flavor, and overall quality by all 6 panelists (Table 2). These formulations contained combinations of 40% peanut milk, 6% oil, 2% corn syrup solids, 30% peanut milk, 9% oil, 12% corn syrup solids, 20% peanut milk, 6% oil, and 8% corn syrup solids.

Table 2 Performance characteristic^a of coffee whitener prepared from peanut extract in coffee

Formulation ^b	Number of panelists out of 6 who indicated attributes acceptable			Comment
	Appearance	Flavor	Overall	
30-3-4	1	1	2	Oily, bitter, clumpy, precipitate
30-3-12	0	6	0	Heavy precipitate, bitter, flocculation
30-9-4	6	1	1	Bitter, oil layer, taste bland
30-9-12	6	6	6	Good flavor, slight foam,
40-6-2	6	6	6	Good flavor, no precipitate, good appearance
40-6-14	0	0	0	Very heavy precipitate, cream layer on top, off flavor
40-1-8	0	1	0	Heavy precipitate, bitter
40-6-8	6	5	5	Little precipitate
50-3-4	0	0	1	Bitter, oily, clumpy
50-9-12	0	2	2	Heavy precipitate, foamy, bitter
50-9-4	0	6	6	Oily, precipitate
50-3-12	0	0	0	Precipitate, oily after taste, bitter
60-6-8	4	1	3	Slight precipitate, ring on top, bitter
20-6-8	6	6	6	Bland, good color, good taste

^aJudges were asked to rate formulations as acceptable (A) or not acceptable (NA) with respect to appearance, flavor and overall acceptability.

^bPercent peanut milk, oil and corn syrup solids.

All formulations containing at least 50% peanut milk resulted in extensive precipitation, feathering, poor solubility, and bitter taste. They concluded that 40% was the maximum amount of peanut milk for optimum formulation. The maximum fat content increased from 6% to 9% as peanut milk was decreased from 40% to 20%. A concentration of 2–9% corn syrup solids could be used with 20–40% peanut milk.

So far, the physical treatment, which gives peanut milk a better shelf-life, is drying, although this area is discussed the least throughout the literature.

A process for the preparation of spray-dried infant food containing 26.4% protein and 18.2% fat was described by Shurpalekar et al. (1964) (American Peanut Research and Education, Inc, 1973; Clavero et al., 1993; Enwokolo and Smart, 1996; Hudson, 1994; Hao et al., 1987–1989; Hudson, 1987; Jasper, 1973; Pripke et al., 1980; Hao and Brackett, 1988; Salunkhe and Kadam, 1989; Van, 1992; Maltz, 1981; Chandrasekhara et al., 1971; Beuchat and Nail, 1978; Bucker Jr. et al., 1979; Rubico et al., 1987, 1988; Chan and Beuchat, 1991, 1992). The flow diagram of the process is outlined in (Figure 4). The process is briefly described as follows. Peanut protein was peptized in water by the addition of sodium hydroxide. Buffer salt (0.1% each of sodium bicarbonate, sodium citrate, and disodium hydrogen phosphate) was added, and the final pH was adjusted to 6.5. Full-fat soy flour was dispersed 6 times its weight of water, and the pH of the dispersion was adjusted to 8.0. The dispersion was stirred mechanically for 10 min and homogenized in a triple homogenizer at a pressure of 1000 psi. It was then passed through a 60-mesh vibrating sieve to remove coarse particles and fiber. The pH of the dispersion was readjusted to 6.8. This was mixed with the peptized peanut protein dispersion. The mixture contained equal amounts of peanut and soy proteins. Sufficient amount of dextrimaltose and hydrogenated peanut oil were added, so that the fat and protein contents of the final spray dried food were about 18 and 26%, respectively. The dispersion, containing about 25% total solids, was homogenized, pasteurized, and spray-dried. The temperature of the inlet air for spray drying was about 120°C, and that of outlet air was about 80°C.

The infant food was fortified by mixing with D-L methionine (4 g/kg of infant food), calcium and iron salts, and vitamin premix, so that the contents of minerals, vitamins, and methionine in the food were nearly equal to those in full-cream milk powder.

Table 3 (Shurpalekar et al., 1964) shows that the infant food (based on peanut protein isolate and full-fat soy flour) contains about 26% protein and 18% fat compared to 22% protein and 18% fat prescribed for infant milk food by the Indian Standard Institution (1960). The mineral and vitamin contents of the infant food are nearly the same as those of infant milk food. The total plate count (21,000 to 24,000 per gram of food) was less than the maximum specified by the Indian Standards Institution for infant milk food. The product was free of from *Bacillus coli*, *Salmonella*, and pathogenic anaerobes. The infant food reconstituted readily in warm water, giving a milk-like emulsion. Shelf-life studies (Table 4) indicated that the food was organoleptically

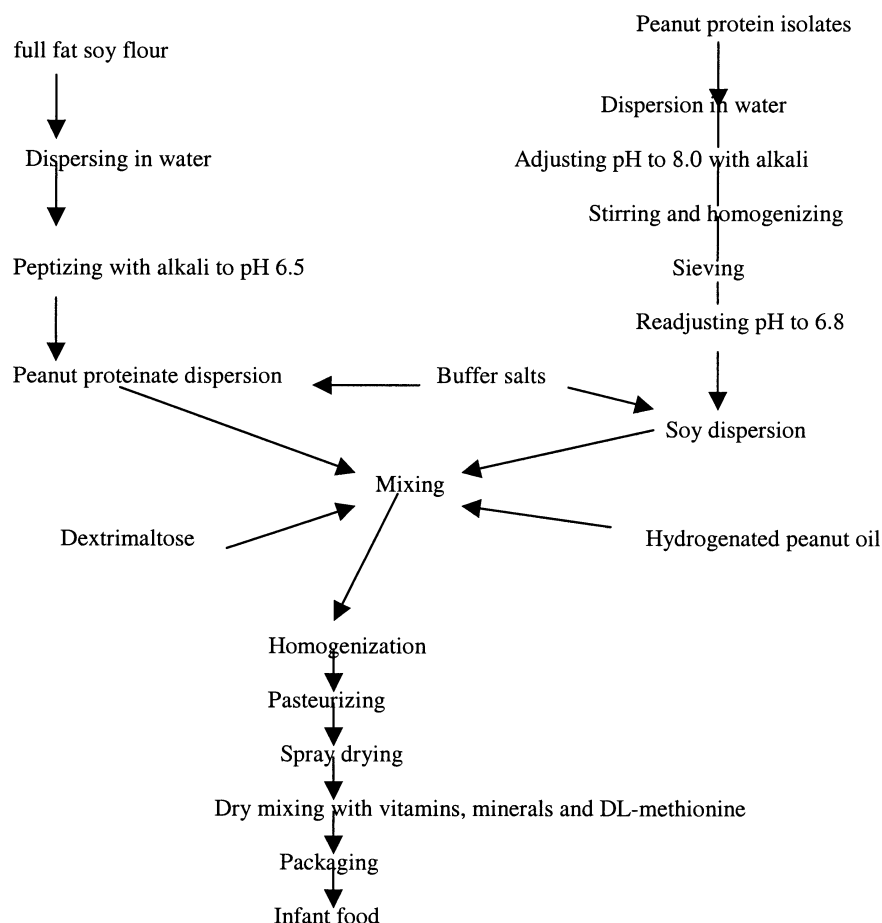


Figure 4 Flow diagram of the process for the preparation of infant-food formulation based on peanut protein isolate and full-fat soy flour.

acceptable after 8 mo at 37°C, the respective losses of vitamin A and C and Thiamine being 24, 32, and 18%.

In 1964, Chandrasekhara et al. (Jasper, 1973; Priepke et al., 1980; Hao and Brackett, 1988; Salunkhe and Kadam, 1989; Van,

1992; Maltz, 1981; Chandrasekhara et al., 1971; Beuchat and Nail, 1978; Bucker Jr., et al., 1979; Rubico et al., 1987, 1988; Chan and Beuchat, 1991, 1992; Shurpalekar et al., 1964) studied another spray dried infant food containing 26% protein and 18% fat and prepared in much the same way as that of Shurpalekar et al., 1964 (American Peanut Research and Education, Inc., 1973; Clavero et al., 1993; Enwokolo and Smart, 1996; Hudson, 1994; Hao et al., 1987–1989; Hudson, 1987; Jasper, 1973; Priepke et al., 1980; Hao and Brackett, 1988; Salunkhe and Kadam, 1989; Van, 1992; Maltz, 1981; Chandrasekhara et al.,

Table 3 Chemical composition^a of infant food formulation based on peanut protein isolate and full fat soy flour (values per 100 g)

Constituent	(g)
Moisture	2.7
Protein	26.4
Fat	18.2
Ash	5.5
Carbohydrates (by diff.)	47.2
Calcium	0.95
Phosphorus	0.75
Iron (mg)	6.0
Vitamins	
Thiamine (mg)	0.9
Riboflavin (mg)	1.5
Niacin (mg)	6.0
Vitamin A (I.U)	1480
Vitamin D (I.U)	390
Vitamin C (mg)	30

^aAlso fortified with 5 mg vitamin E, 4.0 mg calcium panthothenate, 0.6 mg pyridoxine, 0.1 mg folic acid, 150 mg inositol, 130 mg choline, 3.5 µg biotin, and 2.2 µg vitamin B12 per 100 g of the food.

Table 4 Effect of storage on the quality of spray-dried infant-food formulation based on peanut protein isolate and full-fat soy flour

Organoleptic quality	Initial Acceptable	8 months at 26–28°C Acceptable	8 months at 37°C Acceptable
Color of food	Pale	Pale	Pale
Free fatty acids ^a (as % oleic acid)	1.6	4.8	6.0
Peroxide value ^b	0.4	5.8	7.5
Vitamin A (I.U./100 g)	1500	1210	1140
Vitamin C (mg/100 g)	30	24.5	20.5
Thiamine (mg/100 g)	0.90	0.80	0.74

^aExpressed on fat basis.

^bMillimols of oxygen per kg of fat.

Table 5 Tristimulus color values of freeze-dried legume milk powders and CBMP

Substrate	Fermentation treatment	Tristimulus values		
		<i>b</i>	<i>L</i>	<i>a</i>
Cowpea	Unfermented	70.31	0.31	13.87
	<i>L. bulgaricus</i>	74.47	1.61	16.54
	<i>S. thermophilus</i>	73.83	1.51	15.70
Peanut	Unfermented	49.03	3.26	11.05
	<i>L. bulgaricus</i>	52.27	4.33	13.01
	<i>S. thermophilus</i>	50.22	4.52	12.75
Soybean	Unfermented	63.55	2.17	20.50
	<i>L. bulgaricus</i>	64.40	3.27	21.61
	<i>S. thermophilus</i>	65.44	2.30	21.39
CBMP	—	94.72	−2.85	15.14

1971; Beuchat and Nail, 1978; Bucker Jr. et al., 1979; Rubico et al., 1987, 1988; Chan and Beuchat, 1991, 1992). The blend contained coconut skim milk concentrate, peanut protein isolate, and skim milk powder. The composition was adjusted so that the proteins contributed by coconut, peanut, and skim milk were in proportion of 2:2:1, respectively. Dextrins and hydrogenated peanut oil were added, and the powder was fortified by dry blending with minerals, thiamin, niacin, riboflavin, ascorbic acid and calciferol, and other vitamins. The product kept well for 9 mo when packed in tin containers or polyethylene bags.

Holsinger (1978) (Van, 1992) also prepared a spray dried beverage formulation containing 50% sweet whey solids, 20% soybean oil, 24.6% defatted peanut flour, and 5.4% corn syrup. The beverage base contained 20.6% protein, 21.6% fat, 48.3% carbohydrates, 5% ash, 3.5% moisture, and 1% fiber. It can be reconstituted in water. It is bland in taste and can be used in a child feeding program.

In 1986, Schaffner and Beuchat studied the functional properties of freeze-dried powders of both unfermented and fermented aqueous extracts of legumes seeds. They found that the color of unfermented and fermented freeze-dried legume milk pow-

ders was darker than that of CBMP, as can be seen by the relative *L* values listed in Table 5. Fermentation caused an increase in *L* values, indicating that products became lighter in color. The legume powders were also slightly redder, as indicated by their positive *a* values, while the CBMP was slightly greener (with a negative *a* value); fermentation caused an increase in redness. The soybean powder was the most yellow, having the highest *b* value. The cowpea and peanut powders exhibited about the same degree of yellowness, as did CBMP, and fermentation did not significantly influence *b* values for any of the legumes products evaluated. Overall, little difference was noted between color changes induced by *L. bulgaricus* and *S. thermophilus*.

The most important pigments in the coloration of oilseed protein products are the plant phenols (Blouin et al., 1981) and it is likely that these compounds also contribute (Schaffner and Beuchat, 1986), significantly to the coloration of fermented legume milks and freeze-dried powders produced from them.

An interesting observation was made when they compared the *L* values of the liquid fermented legumes milks (Schaffner and Beuchat, 1986) to those of the freeze-dried products. Upon freeze-drying, the *L* values of the soy bean and peanut products decreased dramatically. In contrast, when the cowpea product was freeze-dried, the *L* values actually increased slightly. From the view point of the color acceptability of freeze-dried powders, the cowpea product came the nearest to CBMP.

The oil emulsion capacity of legumes powders exceeded that of CBMP, possibly because of differences in powder composition and particle size (Table 6). Unfermented peanut and soybean powders, as well as powders that had been prepared from respective extracts fermented with *S. thermophilus*, had better emulsion capacities than cowpea powders. This may be due to the higher lipid content in peanut and soybean powders (Schaffner and Beuchat, 1986). The presence of lipids in the dried powder may facilitate the incorporation of added oil into stable emulsion. Differences in metabolic activities of *L. bulgaricus*

Table 6 Emulsion capacities of freeze-dried legume milk powders and CBMP

Treatment	g of powder/25 ml water ^{a,i}	Product type			
		Cowpea	Peanut	Soybean	CBMP ^j
Unfermented	0.5	^a 133.0 ^c	^a 174 ^b	^a 179.3 ^a	118.4 ^d
	1.0	^e 86.6 ^b	^d 99.3 ^a	^c 100.4 ^a	69.3 ^c
	3.0	^h 40.3 ^{ab}	^h 39.3 ^b	^f 42.8 ^a	29.9 ^c
Fermented with <i>L. bulgaricus</i>	0.5	^b 130.1 ^b	^a 172.8 ^a	^b 116.6 ^c	118.4 ^c
	1.0	^f 74.9 ^b	^e 95.0 ^a	^d 72.6 ^b	69.3 ^c
	3.0	ⁱ 30.5 ^b	^h 37.5 ^a	^g 29.8 ^b	29.9 ^b
Fermented with <i>S. thermophilus</i>	0.5	^d 103.8 ^c	^b 150.4 ^a	^b 117.4 ^b	118.4 ^b
	1.0	^g 70.4 ^b	^f 85.1 ^a	^e 70.5 ^b	69.3 ^b
	3.0	ⁱ 29.1 ^b	ⁱ 34.7 ^a	^g 30.3 ^b	29.9 ^b
CBMP ^j	0.5	^c 118.4	^c 118.4	^b 118.4	
	1.0	^g 69.3	^g 69.3	^e 69.3	
	3.0	ⁱ 29.9	ⁱ 29.9	^g 29.9	

^{a,i} Values shown are ml of oil emulsified/g of powder. Numbers in columns are significantly different if not preceded by the same superscript letter; numbers in row are significantly different (0.05) if not followed by same superscript letter.

^j Emulsion capacities for CBMP are included for comparison purpose only. This product was not derived from legume seed or produced by fermentation procedure.

and *S. thermophilus* may also have had an effect on the emulsion capacity of various legume powders.

Most of the freeze-dried powders prepared from the legume milks had both greater foam capacity and stability before fermentation when compared with CBMP. All the freeze-dried legume milk powders exhibited about the same initial increase in volume upon shaking; however, the relative stabilities of the foams were quite different. The most stable foam was that of unfermented freeze-dried cowpea milk, followed by unfermented milks made from peanuts and soybeans, respectively. In every instance, fermentation reduced the foam stability of freeze-dried. One explanation for these results is that acid coagulation of the proteins in the legume milk rendered them denatured and unable to retain structural integrity in foams. As noted by Yasumatu et al. (1972), the presence of fat can have a detrimental effect on foam expansion and stability. Unfermented freeze-dried cowpea milk powder, which has a very low fat content compared to the other legume milk powders, had the greatest foam stability.

Pasteurization and fermentation resulted in changes in disc gel electrophoretic patterns of the freeze-dried legume milk proteins. The pasteurization of peanut and soybean milks resulted in proteins with higher molecular weights, as evidenced by a decreased distance of migration.

The effect of fermentation upon the banding patterns varied according to the source of the milk and the bacterial strain used. The coagulation and precipitation of the proteins in peanut milk fermented with *L. bulgaricus* were less extensive than those in cowpea milk. Proteins had range of molecular weights from 515,000 to less than 29,000. The electrophoretic pattern produced in peanut milk fermented with *S. thermophilus* contained no preeminent bands. One reason for this may be that more protein had been irreversibly coagulated because of the greater amount of acid produced by *S. thermophilus* compared to *L. bulgaricus* in peanut milk.

The nitrogen solubility profiles of the unfermented seed extracts are typical and similar to many such profiles reported in the literature for legume flours and proteins in general. The nitrogen solubility profiles of the fermented extracts do not appear similar to those reported in the literature for various types of fermented plants products (Quin and Beuchat, 1975; Shieh et al., 1982; Canella et al., 1984).

All unfermented and fermented legume milks had viscosities much greater than those of CBMP. The probable variation in particle size, method of drying, and composition would be expected to contribute to this difference. The viscosities of unfermented powders was greater than those of fermented powders and, considering powders of a given seed type, the viscosities of products fermented with *L. bulgaricus* were greater than those of products fermented with *S. thermophilus* (Table 7). The effect of acid pH on viscosities of legume flour was to reduce viscosity (McWatters and Cherry, 1977). The content of protein in the legume milk may also have influenced the viscosities of the rehydrated powders. The cowpea powder had the greatest viscosity when rehydrated, since it had the highest protein content. Peanut powder had the least viscosity.

Table 7 Viscosity of rehydrated freeze-dried legume milk powders and CBMP

Substrate type	Fermentation treatment	Viscosity (centipoises)
Cowpea	Unfermented	912
	<i>L. bulgaricus</i>	340
	<i>S. thermophilus</i>	273
Peanut	Unfermented	232
	<i>L. bulgaricus</i>	160
	<i>S. thermophilus</i>	127
Soybean	Unfermented	277
	<i>L. bulgaricus</i>	191
	<i>S. thermophilus</i>	168
CBMP	—	25

Regarding water adsorption, they found that the ability of the freeze-dried powders to adsorb water at different relative humidities is similar to that of peanut flour fermented by various fungi (Quin and Beuchat, 1975) (Schaffner and Beuchat, 1986). The ability of the freeze-dried peanut powder to adsorb moisture, however, was much less than that of the other powders. One possible reason for this can be deduced from the composition of the test milks from which powders were prepared (Schaffner and Beuchat, 1986). While the cowpea milk contained 0.1% lipid and the soybean milk contained 0.60%, it was the peanut milk that contained by far the most. This high level of lipid, which is nonpolar and, hence, does not have affinity for water, may reduce the ability of the freeze-dried peanut milk to bind water. It appeared that fermentation did not have great effect on the ability of the powders to take up water under the conditions used in the study.

They concluded that the fermentation of aqueous extract of legume seeds with *L. bulgaricus* and *S. thermophilus* resulted in substantial change in functional properties. The color of unfermented and fermented freeze-dried extracts was darker than that of the CBMP. Fermentation appeared to have a beneficial effect on the colors of the freeze-dried. Overall, the emulsion capacities of the freeze-dried powders were superior to that of the CBMP. The foam capacity and stability of unfermented freeze-dried powders were also superior to the CBMP. The result of disc gel electrophoresis revealed that fermentation reduced the amount of soluble protein in the extract. Nitrogen solubility of unfermented freeze-dried powders was similar to nitrogen solubility of CBMP. Fermentation reduced the nitrogen solubility over a pH range 2–10. The viscosities of unfermented and fermented rehydrated freeze-dried powders were clearly superior to that of CBMP. The water absorption capacities of the unfermented freeze powders were similar to that of the CBMP for both cowpea and soybean powders, but the freeze-dried peanut milk powder adsorbed less water.

COMPOSITION OF PEANUT MILK

According to E. Richard Buckner JR et al. (1979), the composition of peanut milk is shown in Table 8. The chemical

Table 8 Composition of peanut milk

Constituent	% of constituent in Peanut Milk
Moisture	90.6
Ash	0.2
Protein	2.8
Carbohydrate	2.0 ^a
Glucose	0.05
Sucrose	0.63
Pentosans	0.20
Starch	0.20
Fat	4.4
Palmitic (16: 0)	0.40
Stearic (18: 0)	0.07
Oleic (18: 2)	2.30
Linoleic (18:2)	1.30
Arachidic (20:0)	0.07
Gadoleic (20:1)	0.06
Behemic (22:0)	0.1
Lignoceric (24:0)	0.1

^aTotal carbohydrate was determined by difference after determining moisture, ash, protein, and fat.

composition of Miltone is given in Table 9 (Chandrasekhara et al., 1971)

EFFECTS OF PROCESSING CONDITIONS ON CHEMICAL, PHYSICAL, AND SENSORY CHARACTERISTICS ON PEANUT MILK

Rubico et al. (1987), Van (1992), Maltz (1981), Chandrasekhara et al. (1971), Beuchat and Nail (1978), Bucker et al. (1979), and Rubico et al. (1987), investigated the effects of high temperature treatments and homogenization pressures on the composition, emulsion stability, texture, and color of non-defatted peanut (NDP) and partially defatted peanut (PDP) beverages. He reported that the ratio of peanut to water had an impact on the composition and viscosity of peanut milk (Tables 10 and 11).

Temperature was found to be critical for obtaining good emulsion, because a high temperature resulted in more extensive hydration and tenderization of the tissues and caused greater tissue disruption during homogenization Kuntz et al. (1978).

Viscosity was dependent on the composition of the beverage and on homogenization pressures and temperatures. The viscosity of NDPB was significantly lower than that of PDPB, possibly due to higher protein and carbohydrate content but lower fat

Table 9 Chemical composition of Miltone

Constituent	%
Total solids	11.5
Fat	2.0
Nonfat solids	9.5
Protein	4.0
Lactose	2.5
Glucose and maltodextrine	2.5

Table 10 Effects of varying peanut to water ratio on the viscosity, fat and protein contents of nondafatted peanut beverage (NDPB) and partially defatted peanut beverage (PDPB)

Beverage type	Peanut: water ratio	Fat (%)	Protein (%)	Apparent viscosity (mpa.s)
NDPB	1:6	5.23	2.48	385
	1:8	4.36	2.14	220
PDPB	1:6	3.08	3.31	1838
	1:8	2.80	2.35	445

content of PDPB than NDPB while maintaining total solids content approximately 13%.

Homogenization at 3000 psi produced a significantly more viscous beverage than that processed at 2000 psi. NDPB was less chalky, less viscous, and lighter than PDPB. The lighter color of beverages processed at a higher homogenization pressure was attributed to the presence of smaller particles, particularly fat globules that scatter more light and result in a whiter product. PDPB was scored darker compared to NDPB samples and had a lower L value, maybe because of Maillard browning reaction products that are formed in an aqueous solution of reducing sugars and proteins heated at neutral pH (Whistler and Daniel, 1985).

He arrived at the conclusion that emulsion stability was achieved when NDPB and PDPB were heated to 71°C, homogenized twice at 2000 or 3000 psi, and then heated at high temperatures of 110 or 121°C. PDPB was thicker, chalkier, and had a darker color compared to NDPB. Full fat peanuts produced a whiter and better textured beverage. He recommended that processing at a higher pressure of 3000 psi and a lower temperature of 110°C is necessary for producing a whiter beverage.

Rubico et al. (1988) compared the sensory properties of a peanut beverage processed at different temperatures and time conditions (85°C, 100°C, and 125°C for 5, 15, and 25 min) (Table 12). He reported that temperature significantly affected cooked flavor, raw and cooked odors, viscosity, and color. With respect to viscosity, it was found that the higher was the processing temperature, the more viscous was the resulting beverage. This was probably due to changes in protein and carbohydrate structures. Wallace and Khaleque (1971) reported that the viscosity of concentrated soymilk generally increases during sterilization because of the progressive unfolding and aggregation of proteins.

The volatiles components that are present in peanut beverage more closely resemble those found in raw peanuts. Volatile components of raw peanuts have been attributed to lipoxigenase (Brown et al., 1979; Patee et al., 1969; Dupuy et al., 1976). Methanol, acetaldehyde, ethanol, pentane, acetone, pentanal, and hexanal constituted most of the volatiles in published reports (Patee et al., 1969; Lovegren et al., 1982).

He concluded that processing at 100°C yielded a peanut beverage with better sensory quality than the product processed at either 121°C or 85°C.

Chan Lee and Larry R. Beuchat (1992) investigated the influence of processing conditions on the chemical, physical, and

Table 11 Mean composition, suspension stability, and viscosity of nondefatted (NDPB) and partially defatted (PDPB) peanut beverages processed at various homogenization pressures and high temperature processing conditions^a

Beverage type	Heating temperatures (°C)	Homogenization pressure (psi)	Component (%)			Stability		Apparent viscosity
			Protein	Fat	Total solids	Total solids	Fat	
NDPB	110	2000	2.54b	4.98a	13.72	1.00	1.02	85g
		3000	2.54b	4.98a	13.40	1.02	1.03	120f
	121	2000	2.56b	5.09a	13.72	1.01	1.13	55h
		3000	2.48b	5.03a	13.84	1.01	1.02	185e
PDPB	110	2000	3.61a	2.50b	13.54	1.05	0.99	1595b
		3000	3.54a	3.02b	13.41	1.01	1.01	1950a
	121	2000	3.04a	3.09b	13.68	1.00	1.00	1250d
		3000	3.31a	3.12b	12.91	1.00	1.00	1400c

a: Means in the same column followed by the same letter are not significantly different ($p \geq .05$).

sensory characteristics of aqueous extracts of peanut (peanut milk) prepared for lactic bacterial fermentation.

They noticed that the pH of peanut milk increased as the concentration of NaHCO_3 soaked in water was increased and as cooking time increased (Table 13). The optimum initial pH of peanut milk to be used as substrate for fermentation by lactic cultures was assumed to be similar to that of cow's milk (6.8–6.9). Based on that characteristic, peanut milk made from peanuts soaked in water containing 0.5% NaHCO_3 would be considered most suitable for that purpose.

The viscosity of peanut milk significantly ($p \leq .05$) increased when made from peanuts soaked in water containing NaHCO_3 compared to water not containing NaHCO_3 (Table 13). But neither the amount of NaHCO_3 (0.5% or 1.0%) soaked in water nor cooking and homogenization significantly influenced viscosity.

The addition of 1.0% NaHCO_3 to soak water resulted in a significant ($p \leq .05$) increase in lightness. Lightness increased when peanuts that had been soaked in water free of NaHCO_3 were cooked for 10 min or more.

All peanut milk samples had negative a values (denoting a slight green tint). Milk prepared from peanuts soaked in water containing 0.5 or 1.0% NaHCO_3 had significantly more negative a value, probably due to increased release of chlorophyll from peanuts. Cooking peanuts resulted in a significant decrease in b values of peanut milk, i.e., yellowness. Soaking peanuts in water containing NaHCO_3 resulted in a significant increase in hue angle, i.e., an increase in the greenish tint of peanut milk. Hue angle increased as cooking time increased.

NaHCO_3 had no effect on chroma, but cooking reduced chroma value of milks produced from peanuts that had been

soaked in water containing 0 or 0.5% NaHCO_3 . This decrease in chroma value represented an increase in brightness. Homogenization did not have a marked effect on chroma value, although it would be expected to reduce the size of the fat globules.

The total solids content of peanut milk decreased as cooking time increased (Table 14). The exposure of peanut proteins and other heated components resulted in denaturation and decreased solubility. Cooking time should, therefore, be minimized to avoid low total solids content in milk. Neither NaHCO_3 treatment of peanuts nor homogenization pressure significantly affected total solids content of peanut milk.

With respect to protein content, they reported that neither the concentration of NaHCO_3 in soak water nor homogenization pressure influenced the amount of protein in peanut milk (Table 14). However, the protein content in milk decreased significantly as cooking time increased. This change was probably due to structural changes of proteins that render them less soluble. Since higher total solids and protein contents are desirable to increase nutrient availability for lactic acid bacteria, minimal cooking time should be given to peanuts for ultimate use as a fermentation substrate.

Regarding the lipid content, it was found that the presence of 1.0% NaHCO_3 in soak water resulted in a reduction in the amount of lipid in peanut milk (Table 14). However, soak water containing 1.0% NaHCO_3 appeared greasier at the surface compared to soak water containing 0 or 0.5% NaHCO_3 . The lipid content of milk significantly decreased as cooking time was increased. Apparently, oil was released from kernels subjected to the cooking treatment. Homogenization pressure had no effect on the amount of lipid in milk. Investigation in headspace volatile compounds led to the following results. Hexanal content

Table 12 Results of the variance for the overall effect of process variables on sensory attributes of peanut beverage

Process conditions	Flavor attributes			Odor attributes		Texture attributes		
	Raw Beany taste	Cooked	After	Raw	Cooked	Viscosity	Chalkiness	Color
Temperature	ns	*	ns	**	*	**	ns	**
Time	ns	**	ns	ns	ns	ns	ns	*
Temperature $\times$ Time	**	ns	ns	ns	*	ns	ns	**

**Significant at 1% level ($P 0.01$).

*Significant at 5% level ($P 0.05$).

nsNo significant difference.

Table 13 pH, viscosity, and hexanal content of peanut milk as influenced by concentration of NaHCO₃ in soak water, time of cooking at 100°C and homogenization pressure

NaHCO ₃ % in soak water (A)	Cooking time (min) (B)	Homog. pressure (psi) (C)	pH			Viscosity (cps)			Hexanal (ppm) in headspace gas		
			A	A × B	A × B × C	A	A × B	A × B × C	A	A × B	A × B × C
0	0	0	6.68 c	6.21 f	6.21 m	2.95 b	2.74 bc	2.63 cdefg	13.3 a	28.4 a	29.7 ab
		2000			6.27 lm			2.50 defg			29.5 abc
		4000			6.25 lm			3.10 abcdefg			25.1 abcd
	10	0		6.67 e	6.67 ghijkl		3.39 abc	3.53 abcdefg	8.2 c		8.0 gh
		2000			6.59 ijkl			4.28 abcde			8.8 gh
		4000			6.74 fghjk			2.37 efg			7.8 gh
	20	0		6.91 cd	6.95 defgij		3.35 abc	3.86 abcdefg	6.8 c		5.1 h
		2000			6.88 efghi			2.83 bcdefg			7.1 gh
		4000			6.89 efghij			3.37 abcdefg			8.3 gh
	30	0		6.93 bc	6.88 cefghij		2.32 c	1.98 g	8.8 c		8.6 gh
		2000			6.98 cdefghi			2.16 gh			7.7 gh
		4000			6.94 defghij			2.83 bcdefg			10.0 fgh
0.5	0	0	6.92 b	6.40 f	6.37 klm	3.63 a	3.31 abc	2.63 defg	14.2 a	26.6 a	29.6 ab
		2000			6.33 klm			2.97 bcdefg			32.4 a
		4000			6.50 jklm			4.32 abcde			18.1 def
	10	0		7.03 bc	7.19 abcdef		4.06 a	3.55 abcdefg	9.1 c		8.9 gh
		2000			6.88 efghij			3.79 abcdefg			10.7 fgh
		4000			7.01 bcdefghi			4.84 ab			8.3 gh
	20	0		7.15 b	7.13 abcdefg		4.00 a	.61 abcdefg	11.5 c		9.6 gh
		2000			7.14 abcdef			4.86 ab			9.9 fgh
		4000			7.19 abcdef			3.51 abcdefg			14.0 efg
	30	0		7.12 bc	7.18 abcdef		3.14 abc	2.67 cdefg	8.7 c		8.6 gh
		2000			7.09 abcdefgh			3.06 bcdefg			8.4 gh
		4000			7.10 abcdegh			3.69 abcdefg			9.1 gh
1.0	0	0	7.25 a	6.68 de	6.63 ijkl	3.76 a	3.85 ab	4.47 abcd	12.1 a	21.5 b	20.1 de
		2000			6.65 hijkl			3.21 abcdefg			21.9 cd
		4000			6.75 fghijk			3.86 abcdefg			22.4 bcd
	10	0		7.39 a	7.50 a		4.23 a	4.74 abc	9.5 c		11.1 fgh
		2000			7.27 abcde			3.71 abcdefg			8.9 gh
		4000			7.41 abc			4.26 abcdef			9.1 gh
	20	0		7.46 a	7.48 a		3.69 ab	2.50 defg	8.9 c		10.7 fgh
		2000			7.51 a			3.34 abcdefg			6.7 gh
		4000			7.37 abcd			5.21 a			9.9 fgh
	30	0		7.46 a	7.44 abc		3.27 ab	3.79 abcdefg	7.0 c		5.1 h
		2000			7.49 a			3.14 abcdefg			7.2 gh
		4000			7.46 ab			2.88 bcdefg			8.7 gh

^aMean values in the same column which are not followed by the same letter are significantly different ($p \leq .05$).

in headspace gas in sealed containers of peanut milk indicated that NaHCO₃ in soak water did not significantly affect the hexanal content of milk (Table 13). The number and quantity of unidentified volatiles components, however, changed as a result of NaHCO₃ treatment. Homogenization had no influence on the hexanal content of milk. It was hypothesized that changes in protein structure may result in releasing low molecular compounds that are bound to protein molecules. Cooking peanuts kernels would cause the denaturation of the protein structure, evaporating some of those compounds responsible for the off-flavor of raw peanuts, thus greatly reducing the hexanal concentration of the milk (cooking for 10 min).

The sensory evaluation they did in order to determine effects of concentration of NaHCO₃ in soak water on color, flavor, and mouth feel indicated sensory qualities were not significantly influenced by NaHCO₃. However, peanut milk made from peanuts that had been soaked in 0.5% NaHCO₃ generally had the low-

est panel ratings for green/beany, sulfur, bitter, astringent, and cooked peanut flavors and chalky mouth feel.

Based on the chemical, physical, and sensory quality characteristics, the best scheme for processing peanut milk serving as a substrate for lactic acid bacteria fermentation was selected. This set of processing conditions consisted of soaking peanuts in water containing 0.5% NaHCO₃, heating at 100°C for 10 min, and homogenizing at 4000 psi.

PEANUT MILK BASED PRODUCTS PRODUCTION

As early as 1967, a yoghurt-like product (Dahi) was successfully prepared from miltone using lactic cultures, at the Central Food Technological Research Institute (CFTRI) in India (Salunkhe and Kadam, 1989). Yogurts with various flavorings

Table 14 Total solids, protein and lipid content of peanut milk as influenced by concentration of NaHCO₃ in soak water, time of cooking at 100°C and homogenization pressure^a

NaHCO ₃ (%) in soak water (A)	Cooking time (B)	Homog. pres. (psi) (C)	Total solids (%)			Protein (%)			Lipid (%)		
			A	A × B	A × B × C	A	A × B	A × B × C	A	A × B	A × B × C
0	0	0	7.50 a	8.04 a	8.61 ab	2.12 a	2.35 ab	2.52 ab	4.65 a	4.92 a	5.26 ab
		2000			7.55 cdef			2.21 bcd			4.62 cdefg
		4000			7.80 abcdef			2.32 abcd			4.87 abc
	10	0		7.65 abc	7.23 efgh		2.19 abcd	2.08 defg		4.70 ab	4.47 cdefgh
		2000			7.79 bcdef			2.23 bcd			4.80 bcd
		4000			7.93 bcdef			2.27 abcd			4.83 abcd
	20	0		7.77 abc	7.51 def		2.18 bcd	2.08 defg		4.82 a	4.69 cdef
		2000			7.71 cdef			2.17 cd			4.77 bcde
		4000			8.08 abcde			2.29 abcd			5.00 abc
	30	0		6.55 d	6.51 hi		1.77 a	1.76 fghi		4.17 cd	4.15 fghi
		2000			6.63 hig			1.80 efghi			4.25 efghi
		4000			6.52 hi			4.11 ghi			4.11 ghi
0.5	0	0	7.43 a	8.10 a	7.75 bcdef	2.12 a	2.34 ab	2.21 bcd	4.55 ab	4.91 a	4.67 cdef
		2000			7.71 cdef			2.23 bcd			4.68 cdef
		4000			8.83 a			2.58 a			5.38 a
	10	0		7.87 ab	7.84 bcdef		2.34 ab	2.35 abcd		4.73 ab	4.69 cdef
		2000			7.58 cdef			2.28 bcd			4.57 cdefgh
		4000			8.19 abcd			2.43 abc			4.94 abc
	20	0		7.50 bc	7.40 defg		2.14 cd	2.14 cde		4.64 ab	4.51 cdefgh
		2000			7.40 defg			2.13 cde			4.67 cdef
		4000			7.68 cdef			2.14 cd			4.72 cdefgh
	30	0		6.25 d	6.09 ji		1.68 e	1.65 ij		3.91 d	3.83 ij
		2000			6.16 ij			1.67 ij			3.84 ij
		4000			6.51 hi			1.73 hi			4.07 hi
1.0	0	0	7.20 a	8.07 a	7.81 bcdef	2.07 a	2.36 a	2.31 abcd	4.33 b	4.77 a	4.58 cdefgh
		2000			7.80 abcde			2.34 abcd			4.76 bcde
		4000			8.42 abc			2.44 abc			4.98 abc
	10	0		7.87 ab	7.93 bcdef		2.32 abc	2.35 abcd		4.72 ab	4.77 bcde
		2000			7.63 cdef			2.27 abcd			4.57 cdefgh
		4000			8.06 abcde			2.33 abcd			4.81 bcd
	20	0		7.34 c	7.40 defg		2.09 d	2.10 def		4.43 bc	4.48 cdefgh
		2000			7.10 fgh			2.04 defgh			4.29 defghi
		4000			7.51 def			2.14 cd			4.52 cdefgh
	30	0		5.50 e	5.58 jk		1.49 f	1.54 ij		3.38 e	3.47 jk
		2000			5.17 k			1.37 j			3.20 k
		4000			5.76 ijk			1.57 ij			3.49

^aMean values in the same column which are not followed by the same letter are significantly different ($p \leq 0.05$).

have been made to improve the sensory properties of toned milk, and mild heat treatments have been used to improve the physical properties.

The defatted peanut flour has been used in whole-milk yogurt to increase the total solids content up to 15%. The product was significantly improved by heat processing at 70°C for 10 min followed by homogenization Schmidt (1977) and Van (1992). The heating of peanut milk above 80°C has been found to effectively reduce the syneresis and visual sedimentation in yogurts Schmidt (1980) and Van (1992).

By fermenting peanut milk products with *Lactobacillus bulgaricus* and *Lactobacillus acidophilus* and adding sugar and fruit flavorings, Beuchat and Nail (1978) prepared a beverage comparable to flavored buttermilk (Salunkhe and Kadam, 1989; Van, 1992; Matlz, 1981; Chandrasekhara et al., 1971). Although an acceptable custard-like texture develops in peanut milk fermented with *L. bulgaricus* 1909 and *L. acidophilus* B-1910,

excessive whey makes the products somewhat undesirable for yogurt substitutes.

The main conclusion they drawn is that the addition of lactose (2%) to pasteurized peanut milk before fermentation with *Lactobacillus bulgaricus* NRRL B-1909 and *L. acidophilus* NRRL B-1910 for 3 d at 37°C results in a custard-like product that has 0.38–0.53% titratable acidity at pH 4.76–4.43, respectively. The sensory panel evaluations of blended, fermented peanut milks containing added sucrose (2%) and fruits flavorings showed that the products were acceptable and competed favorably with flavored buttermilk. They also demonstrated that fermented peanut milk could be substituted for buttermilk in a corn muffin recipe without alteration of sensory characteristics (Table 15). The flow diagram for preparation of fermented peanut milk is shown in Figure 5 (Beuchat and Nail, 1978).

Bucker et al. (1979) tested 19 lactic cultures and reported that 6 cultures could produce lactic acid in peanut milk (Salunkhe and

Table 15 Sensory evaluation scores for corn muffins^a

Liquid ingredient	Sensory Characteristic				
	Appearance	Color	Aroma	Texture	Flavor
Buttermilk	7.6a	7.5a	7.1a	7.4a	7.2a
Peanut milk					
Unfermented	6.4b	5.3b	6.9a	6.8a	6.4b
<i>L. bulgaricus</i>	7.1a b	7.1a	6.7a	7.1a	6.9a
<i>L. acidophilus</i>	7.1a b	7.7a	7.3a	7.3a	7.3a

^a Values in same column not followed by the same letter are significantly different ($p \leq .05$).

Kadam, 1989; Van, 1992; Maltz, 1981; Chandrasekhara et al., 1971; Beuchat and Nail, 1978). In fact, they examined the ability of 19 lactic acid bacteria to ferment peanut milk prepared from blanched, full fat Runner Variety peanut kernels. *Lactobacillus acidophilus*, *L. brevis*, *L. xylosum*, *L. plantarum*, *Pediococcus acidilactici*, and *Streptococcus thermophilus* after 48 h produced the highest levels of acid in plain PM, producing respectively, 0.25, 0.20, 0.42, 0.17 and 0.27% titrable acidity (TA), expressed as lactic acid. Chemical analysis indicated that sucrose at 0.60% (w/v) was the major fermentable carbohydrate present in the PM. The supplementation of the PM with 1% levels of glucose, sucrose, whey, tryptose, or yeast extract increased acid production by most cultures. Glucose supplementation of PM enabled *L. delbrueckii*, *L. plantarum*, *L. helveticus*, and *L. casei* to produce 0.69, 0.17, 0.75, and 0.73% TA, respectively. Invertase treatment of the PM led to increases in acid production of 0.23–0.30 TA units by cultures previously unable to ferment the untreated PM (Table 16).

In a model system, the addition of 2.3% (w/v) oleic, 1.3% linoleic, and 0.4% palmitic acid to a basal Elliker's broth with 1% sucrose (EB-S), as the sole carbohydrate source, led to 100% inhibition of acid production after 48 h, compared to controls, for cultures of *L. acidophilus*, *L. cellobiosus*, and *S. thermophilus*. For cultures of *L. brevis*, *L. xylosum*, *L. plantarum*, and *P. acidilactici*, the inhibition of acid production by the acids after 48 h was much less, only about 5%.

In 1985, D.W. Schaffner et al. used *Lactobacillus bulgaricus* to ferment the aqueous extract of peanuts (peanut milk) both unsupplemented and supplemented with 2% glucose in semi-continuous stirred tank reactor system. They found that the growth rates of *L. bulgaricus* in unsupplemented, and supplemented peanut milks were similar during the first 2 h of fermentation. In the unsupplemented peanut milk, growth ceased after about 6 h, giving a final population of about 1×10^8 cfu mL⁻¹. Growth continued in the supplemented milk for about 12 h, resulting in a population exceeding 1×10^9 cfu mL⁻¹. These results were found to be consistent with those reported by Beuchat and Nail (1978).

The decrease in pH due to fermentation was much greater in peanut milk supplemented with glucose. The pH of the unsupplemented peanut milk decrease steadily between 2 and 6 h after the initiation of fermentation, with a more gradual drop occurring after 6 h. The pH after 24 h was about 6.2. In the supplemented peanut milk, the greatest change in pH occurred between 2 and 10 h after initiation of the fermentation with the rate of pH change slowing considerably after about 10 h. After 24 h, the pH of the supplemented peanut milk was 3.7. These were found to be in agreement with those of Beuchat and Nail (1978),

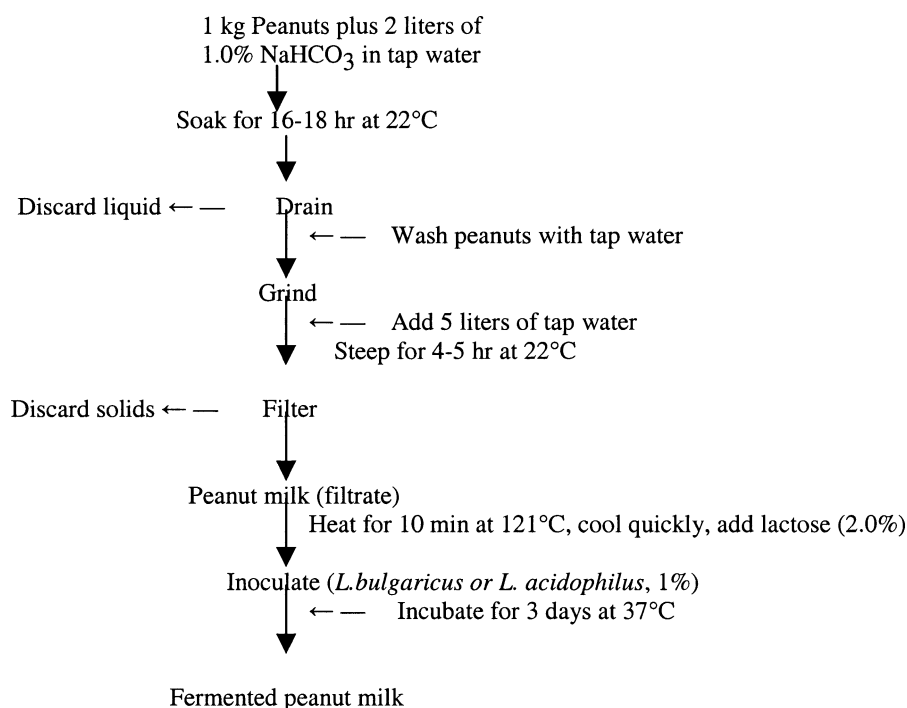
**Figure 5** Flow diagram describing the preparation of fermented peanut milk.

Table 16 Acidities produced by cultures in Elliker's broth (EB), peanut milk (PM), and supplemented PM after 48 h

Organism	% acidity ^a produced in		Change in % acidity ^b produced in PM supplemented with					
	EB	PM	1% glucose	1% sucrose	% whey	1% tryptose	1% yeast extract	Invertase ^c
<i>L. acidophilus</i> NRRL B 629	0.80d	0.25d	0.02d	0.00d	0.25d	0.16d	0.30d	0.07d
<i>L. brevis</i> 1834	0.37	0.20	0.09	0.11	0.02	0.09	0.07	0.12
<i>L. casei</i> NRRL B 1445	0.37	0.00	0.73	0.01	0.54	0.00	0.16	0.30
<i>L. cellobiosus</i> NRRL B 1840	0.55	0.08	0.06	0.00	0.23	0.02	0.29	0.15
<i>L. dulbrueckii</i> NRRL B 455	0.36	0.00	0.69	0.01	0.55	0.00	0.21	0.27
<i>L. fermentum</i> NRRL B 585	0.33	0.00	0.30	0.00	0.10	0.00	0.19	0.32
<i>L. fermentum</i> 42-7	0.12	0.00	0.10	0.00	0.08	0.00	0.00	0.30
<i>L. helveticus</i> NRRL B 176	0.37	0.00	0.75	0.00	0.50	0.14	0.24	0.29
<i>L. xylosum</i> 124-2	0.31	0.42	0.07	0.10	0.09	0.04	0.09	-0.10e
<i>L. plantarum</i> ATCC 8014	0.51	0.42	0.17	0.17	0.20	0.00	0.11	-0.10e
<i>L. cremoris</i> 8081	0.29	0.00	0.33	0.00	0.06	0.00	0.14	0.27
<i>L. cremoris</i> 91404	0.30	0.00	0.36	0.00	0.06	0.00	0.13	0.27
<i>P. acidilactici</i>	0.35	0.15	0.00	-0.01e	0.05	0.25	0.05	0.16
<i>S. cremoris</i> R6	0.44	0.07	0.24	-0.05e	0.22	-0.07e	0.07	0.22
<i>S. cremoris</i> US3	0.40	0.09	0.26	-0.09e	0.19	-0.09e	0.04	0.20
<i>S. diacetilactis</i> DRC1	0.30	0.00	0.30	0.00	0.28	0.00	0.14	0.33
<i>S. lactis</i> C-6	0.39	0.00	0.33	0.00	0.36	0.00	0.17	0.26
<i>S. lactis</i> C-10	0.38	0.00	0.36	0.00	0.36	0.00	0.14	0.26
<i>S. thermophilus</i> ST-4	0.45	0.27	0.02	0.00	0.07	0.11	0.07	-0.09e

^aTitrateable acidity (TA) expressed as % of lactic acid.

^bEach value was calculated as follows: the mean TA of the supplemented PM minus the mean TA of the plain PM at the same time.

^cEnzyme was added to PM to give a final concentration of 5.3 unit/ml. PM was then incubated at 55°C for 5 minutes, tempered to the fermentation test temperature and inoculated.

^dEach value represents the mean of four determinations which resulted from two experiments each with duplicate samples. A difference exceeding 0.05% acidity units between the supplement PM and unsupplemented PM values (excluding the data for EB) in either horizontal rows or vertical columns is statistically significant by the least significant difference (LSD) test, *P* 0.05 (Steel and Torrie, 1960).

^eAcidity decreased by amount shown, compared to the control.

who noted the stimulatory effect of sugar supplementation on reducing the pH of peanut milk fermented with *L. bulgaricus*.

A significant increase in the titrateable acidity was noted when peanut milk supplemented with glucose was fermented, as expected from the changes in pH. The acidity of the peanut milk supplemented with 2% glucose increased more rapidly than did that of unsupplemented milk. These rates and changes in rates of acid production corresponded well to changes in pH. Similar results were obtained by Beuchat and Nail (1978), Pinthong et al. (1980) and Mital et al. (1974) (soy milk fermented by *L. bulgaricus*). Supplemented peanut milk had greater viscosity at several sampling times, but the overall differences were slight between the supplemented and the unsupplemented.

During the course of fermentation, the amount of dissolved oxygen decreased rapidly during the first 4 h of fermentation and remained stable at 5–6% of saturation between 6 and 18 h. The dissolved oxygen content decreased more rapidly in supplemented peanut milk, but the overall value was just slightly higher than in unsupplemented milk.

Change in total carbohydrate and reducing sugars contents in unsupplemented peanut milk are very slight, occurring largely during the first 6 h. In contrast, the changes in total carbohydrate and reducing sugar contents in supplemented peanut milk were greater, with major change occurring during the first 8 h of fermentation. Because of the occurrence of some kind of inhibition in supplemented milk, the rate of sugar utilization was eventu-

ally retarded. This could possibly be due to excessive acidity or the presence of free fatty acids formed by the lipolytic activity of lactic acid bacteria in peanut milk (Bucker et al., 1979). The decrease in total carbohydrate closely followed the decrease in reducing sugars, suggesting that reducing sugars are the substrate being utilized by *L. bulgaricus* during fermentation. Theoretically, two molecules of lactic acid are formed for each molecule of glucose utilized (ratio 1:2). The actual ratio was close to that. In glucose supplemented peanut milk, the ratio is 1.14:2.00.

They summarized that, the effects of supplementation of peanut milk with 2% glucose on fermentation were to increase the population of *L. bulgaricus* after 6 h and to promote a greater decrease in pH and greater increase in titrateable acidity. Supplementation had little effect on the changes in viscosity and dissolved oxygen content during fermentation. The supplementation of peanut milk with 2% glucose resulted in a greater decrease in total carbohydrate and reducing sugar contents during fermentation.

Chan Lee and Larry R. Beuchat, (1991) investigated the effects of fermentation of aqueous extract of peanuts (peanut milk) with *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus*, separately and in combination, on selected chemical and sensory qualities. They reported that the pH of glucose-supplemented peanut milk fermented with *S. salivarius* ssp. *thermophilus*, and a mixture of *L. delbrueckii* ssp. *bulgaricus* and *S. salivarius* ssp. *thermophilus*

decreased more rapidly compared to the pH of milk inoculated only with *L. delbrueckii ssp. bulgaricus*. A pH of 4.5 was obtained within 8–9 h in peanut milk fermented with mixed cultures and within 12–13 h in peanut milk fermented with *S. salivarius ssp. thermophilus* only, suggesting a synergistic interaction between *L. delbrueckii ssp. bulgaricus* and *S. salivarius ssp. thermophilus* during fermentation.

The titratable acidity of fermented glucose-supplemented peanut milk prepared using mixed cultures did not reach that of yogurt made from cow's milk, which is about 1.0% at pH 4.4–4.5. Peanut milk fermented with the mixed cultures of *L. delbrueckii ssp. bulgaricus* and *S. salivarius ssp. thermophilus* had higher titratable acidity values compared to peanut milk fermented with single cultures of *L. delbrueckii ssp. bulgaricus* or *S. salivarius ssp. thermophilus*. The highest acidity was obtained (0.39%) in peanut milk fermented for 24 h with mixed cultures. Strains of combined cultures produced similar amounts of acid throughout fermentation.

Changes in flavor components as determined by the analysis of headspace gas volatile compounds indicated that the concentration of hexanal, which is one of the compounds responsible for an undesirable green/beany flavor associated with legume seed products, steadily declined during fermentation of glucose-supplemented peanut milk. Hexanal essentially disappeared from headspace gas of peanut milk fermented with *S. salivarius ssp. thermophilus* or mixtures of *L. delbrueckii ssp. bulgaricus* and *S. salivarius ssp.* within 9 h. Essentially no difference was noted in the rate of decrease of hexanal content in peanut milk inoculated with *S. salivarius ssp. thermophilus* and mixed cultures. This suggested that *S. salivarius ssp. thermophilus* is mainly responsible for the disappearance of hexanal in glucose-supplemented peanut milk. The rate of decline in hexanal concentration was slowest in peanut milk inoculated with *L. delbrueckii ssp. bulgaricus*, strain 9085 being more effective than strain 1428. This finding was a confirmation of the statement of Pinthong et al. (1980) who reported that the concentration of hexanal was substantially reduced during fermentation of soybean milk with lactic acid bacterial cultures (Hao and Brackett, 1988). An overall reduction of hexanal in headspace gas can be associated with improvement of the flavor and aroma of the fermented product and could be used as an indicator to evaluate changes in sensory qualities of peanut milk during fermentation.

The concentration of acetaldehyde in glucose-supplemented peanut milk increased as a result of fermentation. The concentration of acetaldehyde in peanut milk at the end of the 24 h fermentation period ranged from 12–21 ppm. The acetaldehyde content of peanut milk inoculated with *S. salivarius ssp. thermophilus* and mixed cultures increased after 3 h of fermentation. The highest acetaldehyde concentration (21 ppm) was detected in peanut milk fermented for 24 h with *L. delbrueckii ssp. bulgaricus*, 9085. The amount of acetaldehyde produced in peanut milk was lower than in good-quality yogurt produced from cow's milk, which ranges from 23–41 ppm (Rasic and Kurmann, 1978).

Table 17 Intensity scores for unfermented and fermented peanut milk supplemented with 0 and 2% glucose a

Sensory attribute	Fermented					
	Unfermented		Culture 14128		Culture 9085	
	0%	2%	0%	2%	0%	2%
Flavor						
Creamy	1.08 b	1.57 b	2.41 a	2.48 a	2.23 a	2.39 a
Beany/green	4.38 a	3.83 a	3.03 b	2.29 b	2.88 b	2.71 b
Cooked	2.01 a	2.12 a	1.25 b	1.62 a b	1.16 b	1.64 a b
Peanut	2.01 a	1.38 a b	1.19 a b c	0.83 c	1.00 b c	0.68 c
Sulfur	0.60 b	0.52 b	5.17 a	4.71 a	5.07 a	5.01 a
Sour	1.09 b c	2.37 a	0.56 c	1.19 b	0.85 b c	1.28 b
Sweet	2.48 a	1.72 b	1.29 b c	0.99 c	1.36 b c	0.97 c
Bitter	2.67 a	2.30 a b	2.16 a b	1.62 c	2.14 a b	1.96 b c
Astringent						
Color						
Whiteness	1.14 b	1.23 a b	1.35 a	1.70 a	1.60 a	1.35 a b
Mouthfeel						
Chalky	2.09 a	2.07 a	2.43 a	2.15 a	2.43 a	1.95 a
Viscosity	1.39 b	1.30 b	4.01 a	3.58 a	3.57 a	3.58 a
Gummy	0.18 b	0.18 b	0.92 a	0.79 a	0.79 a	0.73 a
Smoothness	0.55 b	0.60 b	2.36 a	2.06 a	2.28 a	1.94 a

Based on the observation of the synergistic interaction between *L. delbrueckii ssp. bulgaricus* and *S. salivarius ssp. thermophilus* during fermentation of peanut milk, yogurt-like products were made from peanut milk using both single and mixed cultures. Both 2% glucose-supplemented and unsupplemented peanut milk were used as substrates. Sensory evaluations were done to determine if changes in flavor, color, and mouth feel occurred as result of fermentation. Analysis revealed that creamy flavor significantly increased ($p \leq .05$) and, the green bean flavor significantly decreased upon fermentation of peanut milk (Table 17). Fermentation was also effective in significantly reducing sulfur, sweet and bitter flavors, and increasing the sour flavor of peanut milk supplemented with 2% glucose. The results from sensory analysis correlated with those obtained from analysis of headspace gas volatiles. The decrease in hexanal and increase in acetaldehyde concentrations in headspace gas after fermentation of glucose-supplemented peanut milk appear to be positively correlated with improved flavor. Hexanal has been associated with the green bean flavor in soybean milk, and acetaldehyde is a major compound in yogurt. Lactic acid production during fermentation resulted in significantly increased intensity scores for sourness, which, in turn, may also affect scores for other sensory attributes, e.g., the green/beany flavor thought to be caused, in part, by hexanal. On the other hand, the significant decrease in green bean flavor scores may actually be a result of decreased hexanal content as a result of catabolic activities of lactic acid bacteria.

The whiteness of peanut milk tended to increase upon fermentation. Mouth feel of fermented peanut milk differed greatly from that of unfermented milk in terms of viscosity, gumminess, and smoothness. All three attributes were significantly enhanced, presumably due to curd formation caused by reduction in pH. The significant increase in gummy mouth feel without the

addition of gelling agents is undoubtedly a reflection of rheological changes resulting from fermentation.

The conclusion was that the chemical and sensory qualities of peanut milk change significantly upon fermentation with *L. delbrueckii ssp. bulgaricus* and *S. salivarius ssp. thermophilus*. Mixed cultures exhibited a synergistic interaction during fermentation. The major changes in headspace gas volatile compounds in fermented peanut include a decrease in hexanal content and the production of a considerable amount of acetaldehyde. These changes are correlated with results of sensory evaluation, which showed a significant decrease in, green/beany flavor and a significant increase in creamy flavor upon fermentation of peanut milk.

Clavero et al. (1993) investigated the changes in the catalase content of peanut milk in which *Aspergillus parasiticus* was cultured over a 10 d period at 30°C. A 3- to 10-fold increase in catalase content was detected after 6 d of incubation, while the content of uninoculated (control) peanut milk decreased by about 50% after 3 d of incubation. The pH of uninoculated catalase-supplemented peanut milk increased from 6.7 to 9.2, whereas the pH of inoculated peanut milk essentially remained unchanged. The production of catalase by *A. parasiticus* could be a basis for developing a hydrogen peroxide treatment for separating mold-contaminated kernels from sound kernels.

The discovery made by Hao et al. (1993) is a milestone in the struggle of mankind against aflatoxin (Hudson, 1987; Jasper, 1973; Pripke et al., 1980; Hao and Brackett, 1988). In fact, Hao evaluated the potential of using *Flavobacterium aurantiacum* NRRL B-184 for removing aflatoxin. Preliminary experiments determined that this bacterium grew in both non-defatted peanut milk (NDPM) and partially defatted peanut milk (PDPM). The growth was not inhibited by the presence of aflatoxin B1 in either case. Other experiments were designed to assess the ability of 10 million resting (stationary) cells of *F. aurantiacum* to remove aflatoxin B1 from phosphate buffer (PB), NDPM, and PDPM. After 24 h at 30°C, *F. aurantiacum* decreased aflatoxin B1 by 40% in PB, 23% in NDPM, and 70% in PDPM. Proteolysis of PDPM before inoculation with *F. aurantiacum* increased recovery of toxin by about 30% over nonproteolyzed samples. This increase in recovery was not observed when NDPM samples were proteolyzed, suggesting that some of the toxin may be bound to the groundnut proteins and may not be available for removal by *F. aurantiacum*.

Peanut cheese is reported by Ramamurti et al. (1964) to be good quality protein that is easily prepared and cheaper in term of cost (Jasper, 1973; Pripke et al., 1980; Hao and Brackett, 1988; Salunkhe and Kadam, 1989; Van, 1992; Maltz, 1981; Chandrasekhara, et al., 1971; Beuchat and Nail, 1978; Bucker et al., 1979; Rubico et al., 1987, 1988; Chan and Beuchat 1991, 1992; Shurpalekar et al., 1964; Chandrasekhara et al., 1964; Schaffner and Beuchat, 1986; Schaffner et al., 1985; Ramamurti et al., 1964). It is a novelty item that may compete in price and quality with animal cheese. Ripened cheese-like products have been prepared from peanut milk or peanut protein isolates, similar to cheese being made from cow's milk. The manufacturing process involves dispersing the peanut protein isolate in an aqueous solution of suitable electrolytes (with the following composition 2% w/v each of sodium citrate and dipotassium hydrogen phosphate in the ratio 5:1 by volume), stirring for 30 min, adjusting the pH to 8.5, homogenizing for 5 min at pH 5.5, and heating to 94°C for 5 min (result in a coagulum suitable for cheese preparation), filtration of the coagulum through a muslin cloth after adding a starter (*S. lactis*, *S. citrophilus*, and *S. cremoris*, and sodium chloride, and lactose(1%)), thorough mixing, and standing overnight to be hooped and pressed. The resulting cheese contained about 30% moisture and was held from 4 to 8°C with 85% RH. The biochemical changes that occurred in cheese-like products during ripening are listed in Table 18 (Ramamurti et al., 1964).

A processed cheese spread has been prepared from peanut protein based toned milk (Krishnaswamy et al., 1968). The spread had a smooth consistency and milk flavor.

Similarly, non-fermented cheese analogs have been made from peanut protein isolates and peanut oil substituted for milk fat. Chen et al. (1979) have prepared a series of peanut cheese spreads and analogues (Figure 9) containing 10–85% peanut protein isolate and Ca/Na caseinate with varied levels of peanut oil (10% or 23.33%) or other oils (butter and hydrogenated vegetable oil) (Tables 19 and 20) (Van, 1992; Maltz, 1981; Chandrasekhara et al., 1971; Beuchat and Nail, 1978; Bucker et al., 1979; Rubico et al., 1987, 1988; Chan and Beuchat, 1991, 1992; Shurpalekar et al., 1964; Chandrasekhara et al., 1964; Schaffner and Beuchat, 1986; Schaffner et al., 1985; Ramamurti et al., 1964; Shioh-Long et al., 1964).

They concluded that peanut protein isolate and oil can be successfully used in the manufacture of cheese analogues.

Table 18 Biochemical changes in cheese-like products during ripening

Sample no.	After 30 days			After 60 days			After 90 days			After 120 days		
	M%	A%	NPN mg%	M%	A%	NPN mg%	M%	A	NPN mg%	M%	A	NPN mg%
22	43.9	1.17	0.51	43.2	1.35	8.6	42.3	1.44	492.0	40.9	1.8	661.5
23	45.6	1.26	0.17	45.4	2.70	94.6	45.2	4.50	806.4	42.7	5.4	803.4
27	35.4	0.90	12.1	35.4	1.08	241.8	35.1	1.62	308.7	35.2	1.8	335.4
32	37.1	1.08	192.2	37.8	1.98	296.0	37.5	2.52	391.0	36.8	2.7	652.0
33	50.1	1.44	190.0	50.2	2.25	454.0	50.2	2.34	598.0	50.1	2.5	727.0
37	46.2	1.98	183.0	45.9	2.07	239.0	46.1	2.25	359.0	45.7	2.3	460.0

M, moisture; A, acidity as % lactic acid; NPN, nonprotein nitrogen as mg%.

Samples 22, 23, 27, 32, 33, and 37 seemed most promising among the forty formulations.

Table 19 Textural and melting properties of commercial dairy cheese

Samples peanut protein isolate: Ca/casei nate (%)	Textural properties					Melting properties	
	Compression force (newtons)	Cohesiveness (A1/A2, %)	Adhesiveness (newtons)	Springiness (mm)	Fracturability (newtons)	Diameter increase (%)	Shape
0:100	177.87 ± 8.71	38.02 ± 1.20	—	2.76 ± 0.08	58.4 ± 1.51	72.00 ± 1.22	R
10:90	145.75 ± 4.26	38.44 ± 1.23	—	2.73 ± 0.01	45.33 ± 4.04	50.00 ± 0.00	R
20:80	131.33 ± 4.93	35.44 ± 1.12	—	2.67 ± 0.05	41.17 ± 1.73	96.93 ± 0.05	R-E
30:70	105.47 ± 3.40	34.29 ± 1.40	—	2.41 ± 0.05	26.83 ± 1.61	114.00 ± 4.56	E
40:60	75.13 ± 2.01	31.71 ± 0.51	0.03 ± 0.00	2.27 ± 0.05	17.5 ± 1.51	94.40 ± 4.62	E
50:50	53.81 ± 1.79	29.56 ± 0.04	2.27 ± 0.75	1.67 ± 0.05	11.43 ± 0.51	61.95 ± 4.50	E
60:40	46.87 ± 0.90	18.86 ± 0.49	6.97 ± 0.90	1.04 ± 0.04	8.37 ± 0.12	8.00 ± 0.00	R
75:25	29.20 ± 1.30	13.84 ± 0.76	9.57 ± 0.09	0.67 ± 0.07	4.6 ± 0.27	0	R
85:15	21.43 ± 1.25	13.30 ± 0.55	8.33 ± 0.06	0.65 ± 0.04	2.97 ± 0.06	0	R

R, means round.

R-E, means shape between round and elliptical.

Replacement levels of 40–50% peanut protein appear to be optimum for producing cheddar, mozzarella, and processed cheeses. At 85% levels, cheeses suitable for use as cream cheese and cheese spreads are produced (Hudson, 1994).

E.J. Concerton and R. L. Ory reported that ice creams have been blended with partially defatted peanuts or peanut butter, and that consumers preferred the peanut butter-supplemented dessert, which was made with 8% milk fat. When 40% of the milk solids non-fat of the soft served frozen dessert was replaced with peanut protein prepared by a membrane isolation process the product was as acceptable in color, flavor, odor, and texture as the unsubstituted dessert (Hudson, 1987).

Generally peanut curd has been prepared by obtaining peanut milk in a manner similar to that of soybean milk, but, adding a starchy substance, a powder of Konjac (*Amorphophallus konjac*), agar or the like, to increase the rigidity of gel and cooling the resulting material to solidify the same. However, the drawback is that the resulting curds develop an undesirable roasted taste and flavor.

The purpose of the process developed by Mochizuki et al. (1979) US Patent 4,177,296; was to prepare a tofu peanut curd with a sufficiently high rigidity of gel, in addition to a desirable roasted taste and flavor. In fact, the process was carried out by roasting raw peanuts with the red skin intact for 60 to 15 min at a temperature of 110 to 120°C, removing the red skin, pressing the deskinners peanuts to partially remove oil in an amount of

10 to 30% by weight of the roasted peanuts, pulverizing the pressed peanuts to about 325 mesh at a temperature of –40°C or below, dissolving the pulverized peanuts in from 5 to 8.5 parts by weight of water per part of pulverized peanuts (the water being at a temperature ranging from 5 to 50°C), boiling the resulting mixture for 1 to 5 min, cooling the mixture to 70 to 80°C, and adding a coagulant to solidify the cooled mixture, thereby obtaining peanut curd.

Another variant of the above process is raw peanuts charged in a rotary wire-netted drum-type roaster and roasted for 60, 40, and 30 min, wherein the temperature of hot air had been adjusted to heat the peanuts at 110°C. After being roasted and the testa removed, the peanuts were pressed by hydraulic press to remove 30 parts by weight of oil content per 100 parts by weight of the roasted peanuts. The roasted and partially defatted peanuts were then treated by hammer mill at –70°C to obtain peanut powder. 180 parts by weight of water at 20°C was added to 30 parts by weight of peanut powder, and then the mixture was stirred for 10 min to homogeneously disperse and dissolve the powder. The mixture was then heated to boil for 1 min and then cooled to 70°C. To the cooled mixture, 0.72 part by weight of glucono-δ-lactone was added. The mixture was poured into a mold (12 cm × 12 cm × 16 cm), allowed to stand for 1 h at room temperature, and cut to pieces to obtain 200 parts by weight of the tofu-like peanut curd with desirable roasted taste and flavor.

Table 20 Effect of different oils or fats on textural and melting properties of cheese analogs

Type of oil	Textural properties					Melting properties	
	Compression force (newtons)	Cohesiveness (A2/A1, %)	Adhesiveness (newtons)	Springiness (mm)	Fracturability (newtons)	Diameter increase (%)	Shape
Butter	61.10 ± 0.96	17.64 ± 0.32	4.40 ± 0.36	1.25 ± 0.07	13.97 ± 0.68	52.24 ± 2.50	Elliptical
Hydrogenated ^a vegetable oil	70.00 ± 0.51	17.56 ± 0.45	5.83 ± 0.76	1.18 ± 0.05	16.40 ± 0.36	51.78 ± 4.63	Elliptical
Peanut oil ^b	53.87 ± 1.80	29.56 ± 0.03	2.27 ± 0.75	1.65 ± 0.05	11.43 ± 0.51	61.95 ± 4.50	Elliptical

^aWith Wiley melting point about (35°C) 95° F.^bStandard formula.

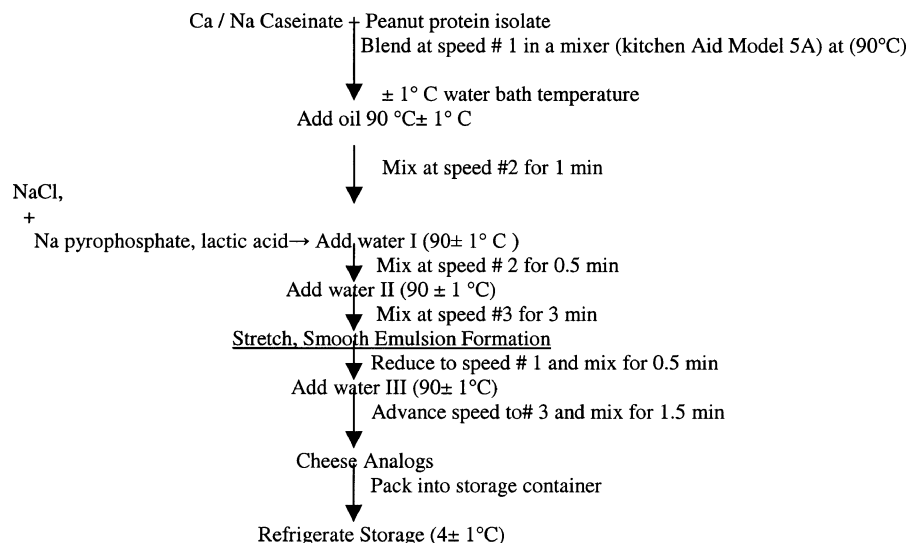


Figure 6 Flow diagram for the manufacture of cheese analogs.

CONCLUSION

Based on the above information, it is evident that numerous methods are available for the manufacturing of peanut milk. This compilation of findings has also revealed that peanut milk, once produced, can be converted into a multitude of high nutritious products; the only limitation is one's imagination and inventiveness. Throughout this compilation it is demonstrated that most research has placed greater emphasis on the improvement of the stability and sensory properties by physical and chemical treatments or by toning animal milk. Although some advances and achievements have been made at aiming to removing the nutty flavor from the fermented products, the problem remains with the unfermented products. As technology in the milk industry improves and research progress, the years ahead may witness peanut milk with better sensory properties from which more products will be developed. Hopefully, the expected products are more stable, more palatable as nutritious as the currents, and more appealing to consumers all over the world.

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