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SOYBEANS, FOOD TECHNOLOGY, AND IMPROVED NUTRITION IN SOUTHERN ASIA

by

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A major problem in most tropical countries is what is known as PCM (protein-calorie-malnutrition). It is particularly evident among children. In extreme cases this appears as kwashiorkor or marasmus, but there are countless cases where the PCM is moderate, and kwashiorkor and marasmus do not appear. The main symptom of moderate PCM in children is underweight. PCM is also associated with lethargy and mental dullness.

PCM is a major problem in the Philippines. The death rate among 1 to 4 year olds in the Philippines is one of the highest in the world as shown by table 1. India is not far behind the Philippines in this respect.

Table 1. Deaths Among Small Children

Country	Deaths among 1 to 4 year olds / % of total deaths in population
Philippines	18.9
Pakistan	19.0
India	17.6
Thailand	15.5
China (Taiwan)	11.4
Japan	1.4
Australia	0.9
U.S.A.	0.9

(from U.N. Demographic Yearbook 1965)

There are several factors causing this high death rate am small children. One important factor is insufficient food; insu cient in both quantity and quality. A survey made in the Philip pines in 1968 showed that just over 50% of Philippine children a malnourished, based on weight to age ratio and using an interim WHO reference scale as standard.

It might be said that this is a problem for the nutrionist, and such a statement is partly correct, but the food technologist has a very important role to play in building acceptability and lo cost into nutritious foods. This is something the nutritionist ca not do because he does not have the technology to control the fac tors that make for quality and acceptability in foods and he does not know how to measure the acceptability of a food among a give population.

The food technologist is deeply concerned with the quality factors of food, how they can be measured, and how they can be manipulated by means of the processing techniques that are avail able. By quality we mean appearance, texture, flavor, convenience, price, and nutritional value. Nutritional value definitely comes last on the food technologist's list of quality factors, and there is a very good reason for this. People eat food primarily for the enjoyment that comes in eating. If the appearance, texture or flavour are offensive or unappealing, the food will not be

consumed, no matter how high the nutritional value.

Every piece of food has to pass through the mouth before it reaches the stomach. The mouth is a highly sensitive, highly discriminating, highly biased and often unpredictable monitor that selects which foods are to pass through it. The mouth is not at all concerned with the nutritional value of the food and yet it must be satisfied before the food can reach the stomach where the nutritional values of the food can be utilized. Therefore the food technologist, with good reason, places texture, color and flavor ahead of nutrition. These attributes of color, flavor and texture are called "acceptance".

In my opinion nutritionists make a big mistake when they talk about the nutritional value of a food, because a food has zero nutritional value until it reaches the stomach. I think nutritionists should use the term "potential nutritional value" in describing foods because this would remind them that the food has no nutritional value until it has passed through the highly opinionated mouth.

Some years ago the U.S. army Quartermaster Corps instituted a lengthy study on feeding soldiers. They wanted the U.S. soldiers to be the best nourished in the world in order to give them fighting strength and stamina. The army nutritionists developed rations that "guaranteed" that every soldier would have an abun-

dance of every known nutritional requirement. In extensive feeding studies in the field it was found that the soldiers did not like many of these highly nutritious foods, and they refused to eat them. After receiving a meal they would scrape off their plates into garbage cans those items they did not like. This led to the claim that the U.S. army possessed the best nourished garbage cans in the world. The Quartermaster Corps realized that their goal was to have the best nourished soldiers, rather than the best nourished garbage cans and they began to hire food technologists to build acceptance into the army rations.

I do not tell this story to belittle nutritionists, because nutritionists have done, and continue to do a most important task. I do want to emphasize that humans are not like cattle, who will eat almost anything that is put before them. Human beings must enjoy a food before they will consume it, and this is an aspect of human nutrition that is too often overlooked. It is not sufficient to bring food to hungry or malnourished people and tell them to eat it because it is good for them. It is part of the perverseness of humans that they will refuse to eat that food unless it pleases the palate.

In recent years a high protein low cost nutritious food for young children was introduced into Peru. It had the backing of the Peruvian Government, the Public Health groups, nutritionists

and the medical profession. This food was called Peruvita. It was well advertised. It should have been the answer to the PCM problem in Peru. It started out well, but within a month of its introduction, sales had fallen almost to zero and no amount of promotion could lift sales. What went wrong? The answer was simple-lack of acceptability. The product had a bad odor when cooked. People claimed that it smelled like wet dog, and it did, and they refused to use it. The food technologist has just as an important role as the nutritionist in building up strength in a country. He can build acceptance and low cost into foods. If these two factors are absent, no amount of nutrition education or government support will persuade people to accept them. Disasters similar to Peruvita have occurred in other countries for the same lack of food technology in the development of the product, and I predict that similar disasters will occur again in the future whenever the acceptability factors are ignored.

The soybean is an excellent source of protein. Its protein content is high; the protein quality is very good, and the soybean is cheap. In the Philippines the soybean provides the cheapest source of protein available among the usual foods. Table 2 shows that the soybean provides almost twice as much protein per peso as its nearest competitor, mungbeans; and nineteen times more protein per peso than pork.

Table 2. Comparison of Soybean with other protein sources in the Philippines

Food	grams protein per kilo (as purchased)	grams protein per peso (as purchased)
Soybean		559
mungbean		287
maize		263
peanut (shelled)		213
dried shrimp		210
rice		123
skim milk powder		115
bread		101
pork		29
sweet potato		21

(based on prices at Bayambang, Philippines, Jan.-June, 1965)

The nutritionists have been telling us for decades that the soybean is a rich source of high quality protein. After all these years of education we find that direct human consumption of soybeans is low. When we ask the question, "Why is the consumption of soybeans so low ?" The answer is easy to find. Soybeans are not very appetizing to eat. The acceptability is low. Many soybeans require long cooking times to render them soft, and even then they do not taste as good as regular beans. There has therefore been a

search for processes that will make the soybean more acceptable.

Table 3. lists the types of foods that are made from soybeans.

Table 3. Food made from Soybeans

1.	Soymilk- tofu, cheese	7.	Roasted soybeans
2.	Spun fiber	8.	Fried soybeans
3.	Flours- full fat, defatted	9.	Canned in sauce
4.	Soysauce	10.	Precooked and dried
5.	Sausages	11.	Green beans
6.	Tempeh	12.	Cooked dry beans

The Food technology group at Cornell have devoted most attention to soymilk because it is simple to make, and being a liquid it can easily be introduced into the diet of all age groups in the form in which it is made. It need not be incorporated into other foods. Considerable attention has also been given to tempeh, roasted beans, and precooked dried beans.

I am often asked why we concentrate our attention on soybeans and is it possible to make a milk from other common beans. The answer to this question is that the soybean in entirely different in nature and composition from other beans. Table 4 contrasts soybeans with other beans.

Table 4. Comparison of soybeans with common dry beans

	Soy beans	Regular beans (navy, kidney, etc.)
Potanical name	Glycine max	Phaseolus vulgaris
Protein	30-40%	16-23%
Fat	18-21%	1-3%
Starch	0	60-65%

The soybeans contains about twice the protein and ten times the fat of common beans and no starch while the common beans are about two thirds starch. The content of essential amino acid in soybeans protein is considered to be in better balance than it is in regular beans. In other words, the soybean not only has more protein than regular beans, its protein is of better quality. The absence of starch in the soybean enables the food technologist to perform certain processing operations more easily than is possible with common beans.

When soybeans are ground to a fine state with water, most of the protein and fat is taken up in the water to form a stable protein-fat emulsion. After grinding, the fiber and other insoluble constituents can be filtered off giving a milky-looking liquid which is called "soymilk". Soymilk has approximately the same protein content, and a little less than half the fat content of cows milk. The distribution of the protein and soybean solids is shown in Table 5.

Table 5. Materials balance in manufacture of soymilk

1. Dry whole soybeans-100% solids, 100% protein.

   soak in water 5-10 hours. Discard soak water.

2. a) soaked beans-98.5% solids, 99.5% protein.

   b) soak water - 1.5% solids, 0.5% protein.

   grind with water and filter.

3. a) soymilk (filtrate) 65% solids, 83% protein

   b) insoluble residue (filter cake) 33.5% solids, 16.5% protein.

Soymilk is very nutritious, it is cheap, and easy to make. The Chinese discovered the process about two thousand years ago. It looks as though it should be a major contributor to the protein-calorie malnutrition of tropical countries. The problem however is that soymilk has a strong and disagreeable flavor. The flavor has been described as "beany", "bitter", "painty", "throat catching". No matter what you call the taste, most people find it objectionable.

About ten years ago the Food Technology group at Cornell University became interested in the soybean as a rich source of low-cost protein. They quickly came to the conclusion that soymilk provided a good vehicle to bring a nutritious, low cost protein food to people in the developing countries but that the bad flavor of soymilk was the principal obstacle to its widespread acceptance. A lengthy study of the chemistry, biochemistry and nutritional

value of the soybean was initiated. At the present time, this work is being supported by a research grant from the U.S. Agency for International Development. Particular emphasis has been placed on determining the origin of the bad flavor of soymilk. For some years the experimental soymilks tasted so bad that it was difficult to find people who would consent to be on the taste panel.

Eventually it was found that the enzyme lipoxidase, which is naturally present in the soybean, was the cause of the trouble. As soon as the soybean is ground with water the lipoxidase acts on the unsaturated fatty acid chains producing a large number of smaller molecular weight compounds. By means of modern sophisticated chemical techniques such as gas-liquid chromatography, mass spectrometry, nuclear magnetic resonance, and infra-red and ultra-violet spectrometry eighty volatile compounds were isolated from soymilk and 41 of them were identified. They are listed in Table 6.

The majority of these compounds are aldehydes, ketones or alcohols. At least 31 of these volatile compounds have some flavor impact, and with few exceptions, the flavor of the compound is unpleasant. One compound in particular has a typical "beany" note. This is ethyl vinyl ketone. The addition of 5 ppm of ethyl vinyl ketone to a bland flavored milk impacts a distinct "beany" flavor.

Table 7 shows the postulated mechanism of formation of ethyl vinyl ketone from the linolenic acid portion of the fat component of soymilk. The ethyl vinyl ketone is formed in six steps through free radical and peroxide intermediates and is catalysed by the enzyme lipoxidase.

The problem was, how to inactivate the lipoxidase before it caused flavor damage. Heating the milk immediately after grinding did not work because the lipoxidase acted so rapidly that the beany flavor was evident no matter how quickly the milk was heated. Heating the beans before grinding inactivated the lipoxidase and solved the flavor problem, but it also rendered the protein insoluble, thus giving almost no milk. After many trials the answer to the problem was found, and it proved to be a very simple solution. Instead of grinding the beans with water at ambient temperature, beans were ground with boiling water. This simple modification of a centuries-old technique inactivates the lipoxidase before it produces the bad flavor, and at the same time it brings the protein into solution before it is rendered insoluble by the heat.

The so called "boiling water" grind produces a soymilk that is bland and pleasant tasting. The objectionable beany flavor is entirely missing providing the temperature is maintained above 80°C (180°F) throughout the grinding process. A pleasant odor and taste is present that resembles cooked cereals. Only one

volatile compound is present in detectable concentration in the milk. The compound is 1-octen-3-ol. It is formed in the intact beans during the initial soaking period. The flavor of 1-octen-3-ol is mildly pleasant. In fact it is one of the constituents of mushroom flavor.

The boiling water grind technique has not been patented is available free and without license to any interested party.

Research is now under way with the Food Technology group of the University of the Philippines, College of Agriculture, at Los-Baños to adopt the boiling water grind technique to Philippine conditions and to make a soymilk that is highly acceptable to the Philippine palate. This research effort is working along two tracks.

Track I consists of developing a commercial process for a sterilized soymilk in 7 oz. bottles that will appeal to the Philippine palate. This phase is almost complete. The bottled product that we make will keep a good flavor for 4 to 6 months in common storage in a tropical climate without refrigeration. We hope to interest a commercial processor to market this product in the same manner as carbonated beverages. We believe that it can be marketed at the same price as carbonated beverages. Every bottle will supply at least six grams of high quality protein. Extensive taste studies with hundreds of children and adults in the Philippines has shown that a bottled sterilized soymilk with 7% added sugar

and 20 ppm of a commercial essence of vanilla gives an acceptability ranging from 83% to 96% depending upon temperature of serving and time of day. We are very encouraged by this consistent high level of acceptability. We are prepared to demonstrate the complete process to any interested party at the Food Technology pilot plant in Los Baños, Philippines.

Track II consists of developing a boiling water grind technique suitable for the village level. The goal is to develop a process that will produce five gallons of good quality milk per hour, using manual power only, and with the capital cost for equipment not to exceed fifty dollars (U.S. $50.00). The objective here is to produce a milk locally each day and sell it loose, without sterilization and without refrigeration. This product should have a shelf life of about 8 hours before spoilage. In rough cost calculations we estimate that such a process would be able to sell milk at a slightly less than two cents (U.S.) per serving and make a net profit that is 30% higher than the minimum Philippine daily wage of six pesos per day on a sales volume of 10 gallons daily. At present there is no suitable process that meets these goals but we are working towards this end.

I would like to see as many home grinding machines as possible while in India. May be one of them will provide the answer to our problem.

Table 8 shows the procedure for making a sterilized soymilk in bottles and a loose milk to be dispensed from a container. This procedure will give a milk with approximately the same protein content as cows milk and a fat content about one third that of cows milk. The exact final composition will depend upon the fat and protein content of the soybeans that are used, and on certain processing variables. The calcium content is much lower than cows milk but it can be increased to any desired level by fortification with calcium salts. The fat content can be raised by adding a bland oil and homogenizing. The protein efficiency ratio of this soymilk is in the range 2.2 to 2.4 adjusted to a casein standard with a PER of 2.5.

Table 9 gives a "ball park" cost estimate for the ingredients of a 7 fluid oz. serving a soymilk. Other cost factors such as labor, fuel, overhead selling expenses will have to be added. The important thing is that for less than one cent ingredient cost, a substantial contribution can be made to the daily protein intake by means of a highly acceptable refreshing beverage.

Table 10 shows the percent of daily protein intake supplied to various age groups by one seven fluid oz serving of soymilk. Two standards of reference are listed. One is the FAO-WHO recommended daily protein intake. The other is the WHO-Interim Standard for the Western Pacific which is about 20% lower than the FAO-WHO world standard. Using either scale it can be seen that one

serving of soymilk can supply a significant proportion of the daily protein requirement to every age group. In the age group most susceptible to protein-calorie-malnutrition, the preschool child, a single serving of soymilk can supply as much as 50% of the recommended daily protein intake.

The milk that is made by the boiling water grind is bland in flavor, and acceptable to most people. It can be formulated in many different ways in order to comply with regional taste preferences, traditions, or with special nutritional needs. The soymilk can be flavored with chocolate, coconut, raspberry, caramel, and most other flavors. It can be fortified with extra fat, or with minerals and vitamins. The sugar content can be changed to suit the taste of any group. It can be used successfully to tone the high fat milk of water buffalo in order to reduce the fat content to that of cows milk without reducing the protein content. It lends itself to adaptation to almost any situation.

I believe that there is a great potential for soymilk in India. Now that the major off-flavor problem has been solved, all that is needed is to develop a flavor formulation that is highly acceptable to the Indian palate

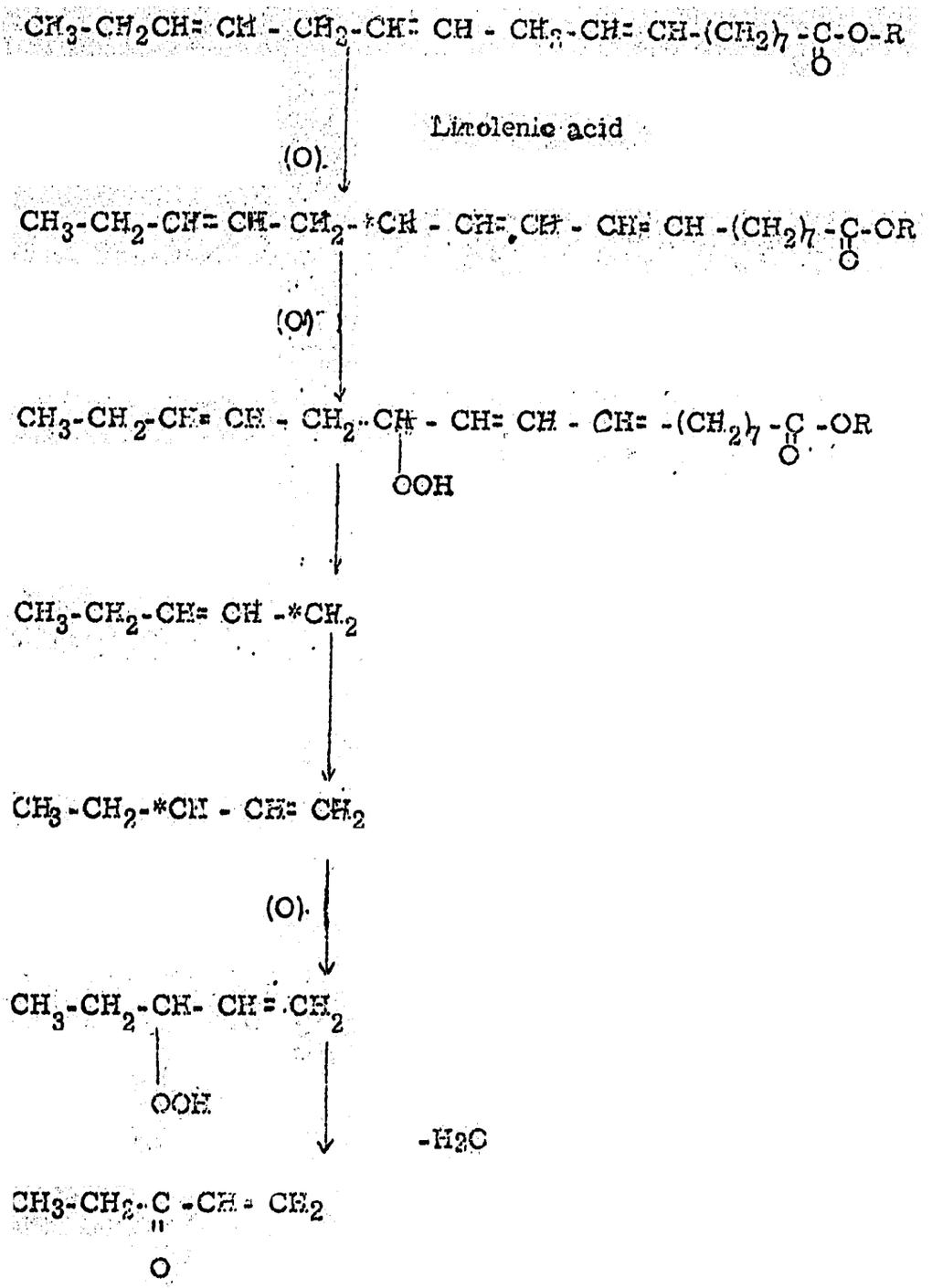
In short, we believe that the boiling water grind technique is an elegant example of how food technology can convert a cheap raw material into a highly acceptable food product thus bringing im-

proved nutrition to the peoples of Southern Asia at low cost.

Table 6. Volatiles Found in Cold-Grind Soybeans

PENTANE	2 NONENAL
PENTANAI	DECANE
1 PENTEN-3-OL	HEPTADECANE
HEXANAL	VINYLETHYLKETONE
HEXANOL	VINYL AMYLKETONE
2 HEXENAI	PROPYLFURAN
2, 4 HEXADIENAL	PENTYLFURAN
HEXANOIC ACID	BENZALDEHYDE
HEPTANAL	N-PROPYLBENZENE
2 HEPTANONE	N-BUTYLBENZENE
HEPTANOIC ACID	BENZATHIAZOLE
OCTANAL	DIPHENYL ETHER
OCTANOL	GAMMANONALACTONE
3 OCTANOL	2 TRANS-4 CIS HEPTADIENAL
3 OCTANONE	2 TRANS-4 TRANS-HEPTADIENAL
2 OCTANONE	2 TRANS-4 CIS-DECADIENAL
2 OCTENAL	2 TRANS-4 TRANS-DECADIENAL
1 OCTEN-3-OL	2 TRANS-4 CIS-NONADIENAL
2 OCTEN-1-OL	2 TRANS-4 TRANS-NONADIENAL
1, 7 OCTADIENE	5 HYDROXYMETHYLFURFURAL
NONANAL	

Table 7 Postulated Mechanism of Formation of Ethyl Vinyl Ketone in Soymilk



ETHYL VINYL KETONE

Table 8. Boiling-Water-Process for Soymilk

1) Soak whole beans in water at ambient temperature 5-10 hours. Discard soak water.

2) Preheat grinder. (with boiling water)

3) Grind cold beans with boiling water.

9 parts water by weight plus 2 parts by weight soaked beans.

minimum slurry temperature 80°C. at all times.

4) Filter. (Filter cake is used for animal feed or human food.)

	Bottled Soymilk	Fresh Soymilk
5)	Formulate (sugar, fat, minor nutrients)	Hold at boiling point for 30 to 60 minutes to destroy antitrypsin
6)	Fill into 7 oz. bottles, seal	Formulate (sugar, flavoring)
7)	Sterilize . 12 mins at 250°F	Refrigerate
	Shelf life: 6 months	Shelf life : 1-5 days with refrigeration. 8 hours without refrigeration.

Table 9. INGREDIENT COST OF SOYMILK

(estimated)

	U.S. $
1.0 kg Soybeans at 20 cents/kg	0.200
0.65 kg Sugar at 22 cents /kg	0.143
0.3 ml Flavoring at $6.00/kg	0.002
Total Ingredient Cost	$ 0.345

Yield of soymilk: 50 x 200 ml servings per kg beans.

Ingredient cost per serving $\frac{0.345}{50}$ = 0.69 cents

(feed value of filter cake has not been taken into account)

Table 10. Protein Supplied by Soymilk

Type of Person	WHO-Western Pacific Interim Standard for Daily Protein Intake		FAO-WHO Recommended Daily Protein Intake	
	Standard grams	% of standard supplied by 7 fl oz. soymilk	Standard grams	% of standard supplied by 7 fl oz. soymilk
Toddler (1 to 3 years)	11.7	51	14.3	42
Preschool (4 to 6 yrs.)	14.6	41	17.5	34
Schoolage (7 to 9 yrs.)	18.4	33	24.9	24
Schoolage (10 to 12 yrs.)	22.4	27	31.0	19
Schoolage (13 to 15 yrs.)	32.8	18	41.1	15
Adult male	39	15	46	13
Adult female	35	17	39	15
Lactating female	38.5	16	54	11

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