

Nutrition vs. Taste - Meet the Soya Challenge

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ABSTRACT

Soybean is nutritionally a great food when properly cooked. It is low in cost and easy to process into protein and mineral rich food products. These foods selectively lower the bad cholesterol, and aid in reducing the chances of different types of cancers. They even minimize the menopause symptoms. Their use has been rather limited outside the Orient due to rancid-oil-like "beany" taste most soy food products have. This bad taste is caused by lipoxygenase enzyme that becomes active when soybeans are disintegrated. While heating soybeans can destroy this enzyme, such treatment causes premature denaturing of soy protein and adversely affects the functional and organoleptic properties of soyfoods.

This paper discusses a new patented process that has been used to produce good tasting dairy-like soyfoods and beverages at home, commercially, and industrially in varying capacities. While a household soymilk machine (currently being evaluated for the NASA's manned mission to Mars), produces about 2 litres of soymilk at a time, there are machines that can produce 10,000 L/H of finished soymilk beverages. A 30 L/H batch machine has been found to be ideally suited for cottage industry in India and elsewhere. Several hundred such machines are in use worldwide which are now manufactured in India and Russia.

INTRODUCTION

The virtues of the soybean - high yield and protein content - were recognized in Asia over two thousand years ago making the soybean a staple of the Asian diet. These same virtues still exist today as evidenced by the fact that soyfoods are a main part of the diet of the people of Japan, China, Korea, Indonesia, etc. Recently, the West realized the virtues of soyfoods, where the use of soymilk, tofu, tempeh and related products has been growing by leaps and bounds.

Mahatma Gandhi introduced soybean use in India in 1935 in the form of cooked whole or split beans. However, because of the extensive cooking required to make them digestible by humans, soybeans did not enter the Indian diet at that time. More recently, soybean use is gaining acceptance in the form of textured vegetable protein (TVP), popularly known in India as soya vadi or soya nuggets. Many companies have tried introducing soymilk, tofu, and other soya dairy products in India, but they have not been very successful due to either high price or low quality of the product, perhaps both.

Soybean has been in use in the form of soymilk and other foods in China since about the 2nd century B.C. John Kellogg, the founder of Kellogg breakfast cereals, popularized soymilk in the West around 1930. In 1940 K.S. Low started selling soymilk in Hong Kong like dairy milk in bottles. Clearly, the cultivation and subsequent consumption of soya based products have come to transcend the boundaries of both time and culture.

It is well known that protein yield per hectare by growing soybeans is the highest among all sources of protein - plant or animal, FIG. 1. Protein content of the soybean is about 40%. Compared to other natural sources of protein, FIG. 2, soybean based protein is clearly the leader.

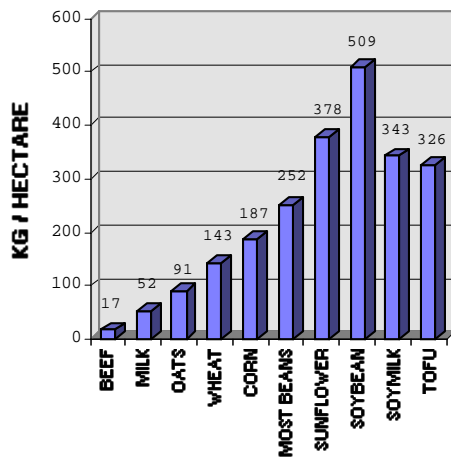


Figure 1: Protein yield in cultivated foods

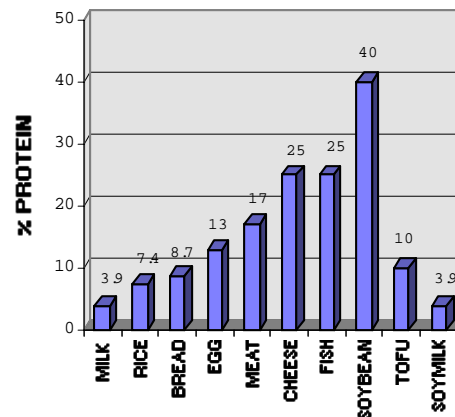


Figure 2: Protein in common

Since soybeans can be cultivated in most regions of the world, at least in quantities required for the production of soyfoods at the cottage industry level, the acceptance of soyfoods can greatly reduce protein deficiency in developing countries, as well as animal foods-related health problems in the West. In addition to these benefits it is worth noting that soya protein is the most nutritionally balanced plant protein for human consumption, FIG. 3.

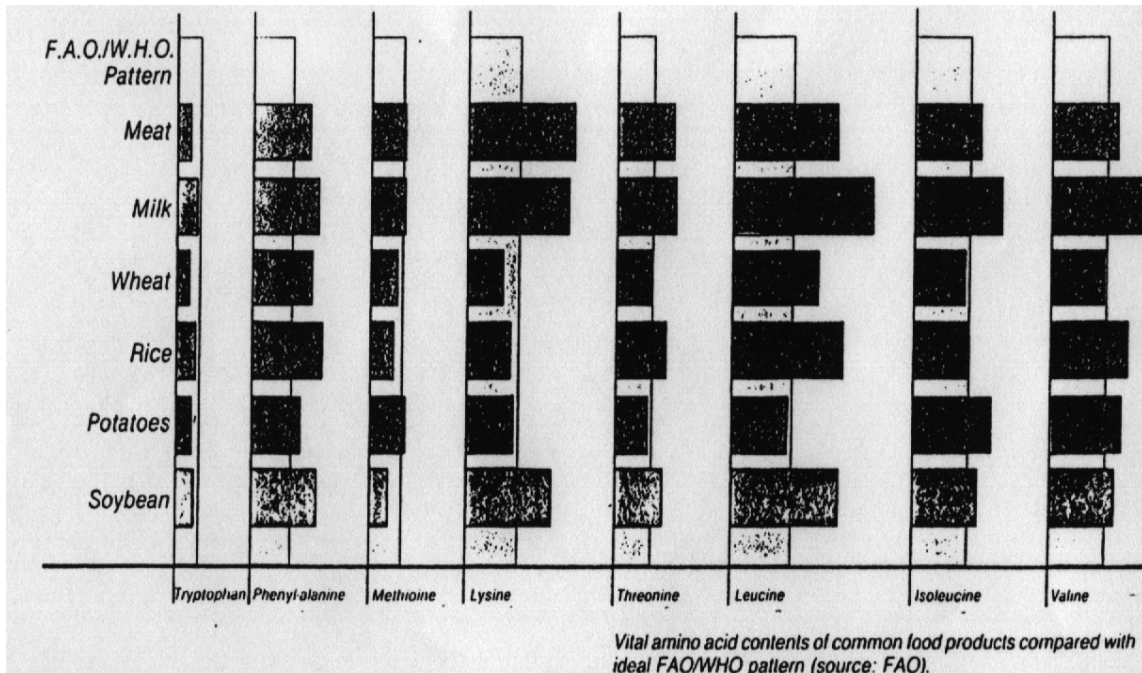


Figure 3 Vital amino acid contents of common food products compared with ideal F.A.O./W.H.O. pattern.

Based on 1994-95 statistics (Soya Bluebook Plus, 1997) world cultivation of soybean was 138 million metric tons. Soybean production of the largest soybean producing countries are shown in FIG. 4

In spite of very high protein content, soybean is cultivated mainly for its oil content. The protein in the oil cake or meal left after oil extraction is used mostly as animal feed. This is because of the characteristic off-flavour and bitterness in the meal making it costly to produce palatable protein foods from the meal. Even when the oil is not extracted, it is rather difficult to make functional protein foods from soybeans which are free of bitterness and off-flavours. The composition of an average soybean variety is shown in FIG. 5.

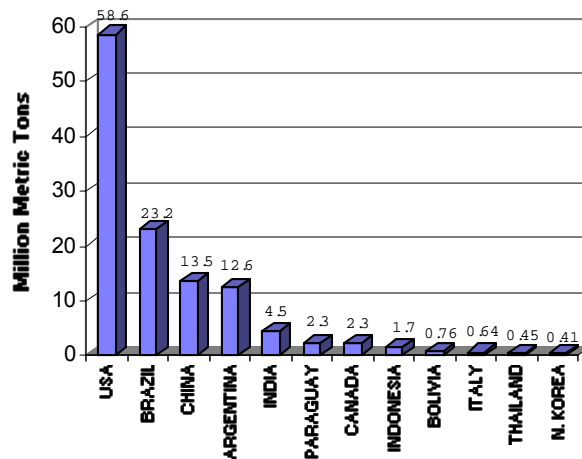


Figure 4 World soybean cultivation by the largest producers (1994-95)

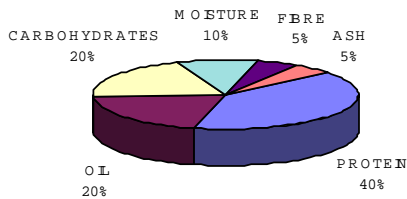


Figure 5: Soybean Composition

CONCERNS ABOUT SOYBEANS

Concerns related to soybeans include:

Lipoxygenase enzyme:

This enzyme is responsible for causing the development of characteristic "beany" off-flavour and bitterness in protein foods and the fishy smell in oil extracted from soybeans. The enzyme has to be inactivated or its activity controlled in order to make palatable foods. The enzyme is inactivated by heat treatment or pH control, often both, of soybeans prior to their disintegration for the extraction of oil or protein. However, such treatment causes the water soluble

solids, especially protein, to get bound to the insoluble fibrous solids of soybean. The degree of such binding depends on the severity of the treatment. This leads to a greatly reduced yield of protein in aqueous extract of soybeans (soymilk) and a mouth feel that reminds one of the milk of magnesia. Any foods and beverages made from such soymilk are not very acceptable by most people.

The challenge thus was to develop a method of processing soybeans into soymilk which neither had rancid or fishy taste nor the chalky mouth feel.

Trypsin Inhibitor:

Unless thoroughly inactivated, this enzyme could limit the growth of growing humans and animals as inferred from studies on laboratory animals. Trypsin inhibitor can be inactivated by heat treatment and chemical means - FIG. 6.

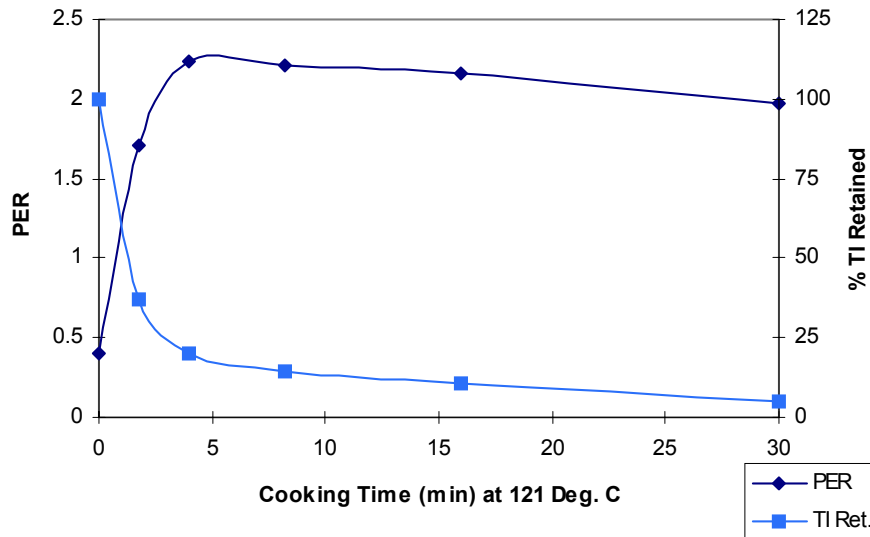


Figure 6: Protein efficiency ratio (PER) and retained trypsin inhibitor in soymilk vs. cooking time at 121 °C.

Oligosaccharides:

These are complex sugars, raffinose and stachyose, in soybeans. Together these make up about 5% of the soybean. They can cause flatulence and stomach upset. It is desirable to reduce them in palatable foods. Soaking of soybeans in water for making soymilk and removal of fibrous residue gets rid of a large percentage of oligosaccharides.

Protein Efficiency Ratio (PER):

The PER, a measure of protein quality relative to casein (dairy milk protein) standard of 2.5, of raw soybean is rather low. However, with adequate cooking, it can be increased to 2.2 or higher value, FIG. 6.

BENIFITS OF SOYBEANS - Nutritious and Thereputic Qualities

Soybeans are known to make highly nutritious foods with theraputic and medicinal qualities. Many books have been written about the virtues of soybeans as they have no cholesterol, are high in lecithin, and they produce an oil that is rich in polyunsaturated fatty acids. Soybean hulls have iron in the desirable ferrous form rather than in the poorly used ferric form. The ferrous form of iron is readily absorbed in blood but ferric form is mostly rejected. Soybeans are the only known vegetable source of ferrous iron.

There are other significant health benefits associated with the consumption of soya based products. According to Earl Mindell (1996) in his recent book "Scientific research has discovered that adding two ounces of soy to your daily diet can help fight breast and prostrate cancer, battle coronary artery disease, ease menopause symptoms, lower your cholesterol, and give a boost to your immune system".

Mindell's book provides a good understanding of the therapeutic and medicinal qualities of the soybean as it condenses a wealth of research conducted worldwide on soy as food into a book that is easy to read and understand. The scientific terms and outcomes, as well as the numerous research findings are clearly explained and related to human well-being.

A glance at the book contents quickly reveals the interesting topics covered in the book, including:

- Does soy prevent cancer?
- Heart and soy
- Just for women: Rx for menopause and osteoporosis
- Just for men: Rx for prostrate problems
- Kids, cancer, and heart disease
- Tips for vegetarians
- Thirty-Seven miracle foods from the pacific rim
- Earl's pearls: a guide to vitamins and minerals
- Savvy substitutions
- Cooking with soy
- Breakfast the soy way

and Seventy super soy recipes.

The extensive bibliography will be useful to those wishing to delve deeper into research findings summarized in the book. Overall, the book will be of interest to an uninitiated reader as well as to those who are knowledgeable about soy.

Another authoritative book on the subject is *The Simple Soybean and Your Health* by Messina, and Messina (1994).

When used as an alternative to dairy milk, soymilk has no cholesterol or lactose. Also, its protein constitution is somewhat different from dairy milk. In spite of the highly balanced protein structure of soymilk, which some claim is even better than dairy milk, it is not a true replacement of dairy milk. Soymilk is nutritionally compared to cow's milk in FIGS. 7 and 8.

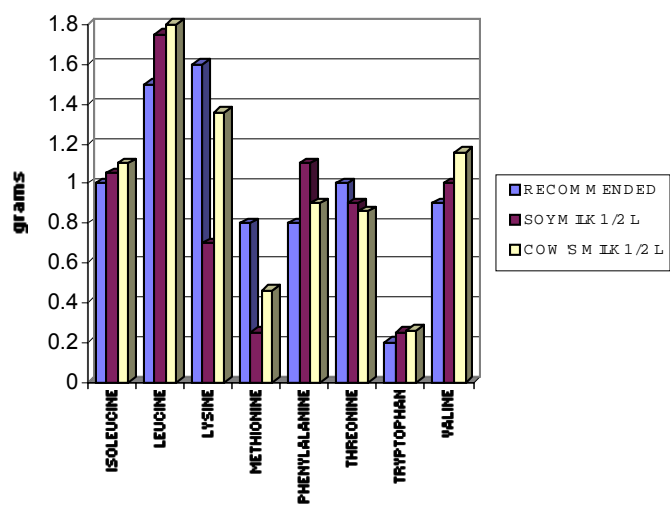


Figure 7: Essential amino acids in soymilk and cow's milk as compared to the recommended daily intake by an adolescent.

FIG. 9 compares the nutrients in mother's milk, cow's milk, and soymilk

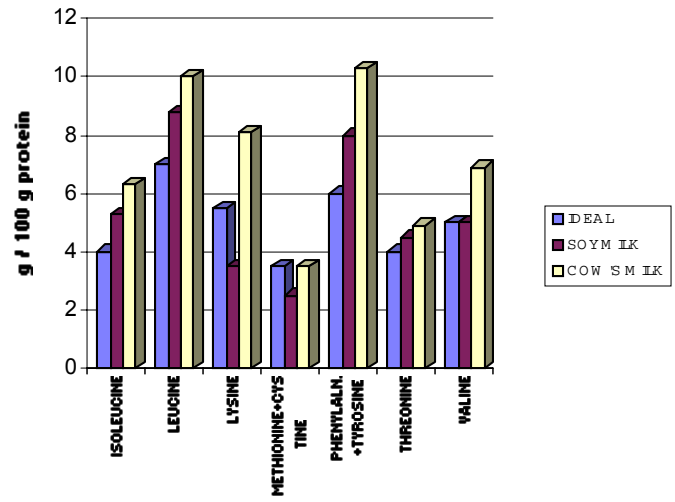


Figure 8: Essential amino acids in soy milk and cow's milk as compared to an ideal protein source.

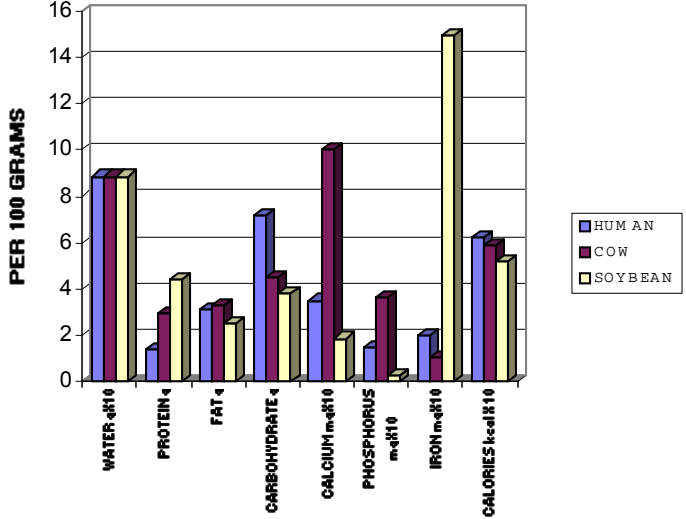


Figure 9: A comparison of nutrients in mother's milk, cow's milk, and soy milk, normalized to the same water level.

MEETING THE CHALLENGE

Although, the milk extracted from soybeans by traditional methods has been shown scientifically to be an inexpensive source of balanced protein, it has a characteristic odour of rancid oil or fresh paint which is not liked by the people outside eastern and

south-eastern Asia. This odour is usually called "beany" but is unique to the soybean. Traditional Chinese and Japanese methods do not have the chalky mouth feel. Thus, one thing is clear that for the best mouth feel the preferred approach should be to use the soaked soybeans and ground them with cold or warm water prior to heating and cooking the resulting slurry. The enzyme activity must therefore be controlled without the application of heat at least until the soybean soluble solids are released from soybean fiber into water.

Based on the above analysis, it was found by Gupta and Gupta (1990) that the lipoxygenase enzymes catalytic activity can be made ineffective in producing off-flavour volatiles, e.g. aldehydes, furans, and ketones, by processing soybeans in an environment that is reduced in free oxygen to a few parts per million (ppm) level, for none of these volatiles can be created in the absence of oxygen.

Until this finding, the methods to get rid of the beany odour in making soymilk were either inadequate, or very expensive, in fact both. For the first time, the patented Canadian invention (Gupta and Gupta 1990) has made it possible to produce high quality soymilk even at the cottage industry level.

Methods of Making Soymilk:

Basically, there are four methods for making soymilk: the traditional cold grind method, the hot grind method, the hot blanch method, and the Canadian method. Main steps for making soymilk with these processes are given in Table 1, along with a comparison of product quality and basic plant cost. The cost advantage is very significant at the cottage industry level or at the small-scale industry level. When automated to produce and aseptically package soymilk, the complete plant cost becomes quite high using any of the methods. Nevertheless, the product quality is substantially improved by the Canadian method.

As a means of meeting the world demand for nutritious but flavourful soya beverages and related products, a small soymilk making machine, the SoyaCow Model SC20, was developed using the Canadian process. Henceforth, the production of high quality soymilk and the foods derived from soymilk came to be within the reach of the small-business entrepreneur. This machine is currently manufactured in Canada, India, and Russia.

Larger systems, with capacities 2000 L/H and more, have been built and installed in Canada and Russia, and are currently in the process of being installed in the UK and India. Because of the simpler design, these plants appear to have a significant cost advantage over soymilk plants using alternate methods.

Table 1: A Comparison of Basic Soymilk Processes

	Traditional	Hot Grind	Hot Blanch	Canadian +
BEANS	Whole Any Type	Whole or Dehulled High Quality	Whole or Dehulled Good Quality	Whole or Dehulled Any Type
PROCESSING CHEMICALS	None	NaHCO₃ HCl, etc.	NaHCO₃ HCl, etc.	None
SOAKING	Yes	Optional	Hot Blanch	Preferred
GRIND	Cold Cook / Filter Or Filter / Cook	Hot Cook / Filter	Hot Cook and High Press. Homogenize	Airless / Cold Cook / Filter or Filter / Cook
SOYMILK	Dissolved Solids	Mostly Dissolved Solids	Mostly Suspended Solids	Dissolved Solids
ODOUR	Rancid	Less Rancid	Roasted Nut	Cereal
FLAVOURING	V. Difficult	Difficult	Easy	Easy
MOUTH FEEL	Smooth	Chalky	Very Chalky	Smooth
PROTEIN YIELD	70 - 90%	60 - 80%	98%	70 - 90%
BASIC PLANT COST	Low	Medium to Very High	High	Low to Medium
AVAILABLE FROM	Sato Kawanishi Kurihara Takai, etc.	Alfa-Laval Kibun Mitsubishi STS, etc.	U Illinois Kibun Pant Nagar	ProSoya Inc. ASSOY SSP

+ Uses special equipment based on the Canadian airless cold grind process patent

SOYFOODS PRIMER

The knowledge of making traditional soymilk (and tofu from soymilk) is important to appreciate how the other three methods differ from it. The traditional method is therefore discussed here briefly.

SOYBEANS

The basic raw material for making soymilk and tofu is good quality soybeans free from dirt, stones, and other foreign matter. They contain 8% to 14% moisture. Moisture levels should be kept as low as possible if soybeans are to be stored for any length of time. There are over 100 varieties of soybeans. In the USA, the good varieties include

AMSOY, CORSOY, and VINTON. The Canadian good varieties are ????. In India, PUNJAB I is a good soybean variety. Premium quality soybeans for soymilk production are also grown in the provinces of Ontario and Quebec in Canada.

The best soymilk flavour and yield is obtained using soybeans from the most recent crop which have been stored properly in a cool dry place. In many countries, soybeans may not be readily available year round making it necessary to stock them for three or more months. They may be stacked in sacks or stored in metal or plastic bins. The stacks should not be higher than 1.2 to 1.5 m (4 to 5 feet), and should be placed on a wooden pallet as a means of providing ventilation. A good way of providing adequate ventilation is to make stacks in an open-centre configuration.

Soybean Soaking:

Soybeans are washed thoroughly and soaked in about three times their volume of water for a period sufficient to swell them completely. FIG. 10 may be used to determine soaking time at any soaking water temperature. The soaking process softens the beans for grinding and leaches out flatulence-causing oligosaccharides. In the tropical climate, especially in summer, one should avoid soaking the beans for too long. Four to six hours of soaking time in the summer and eight to twelve hours in winter is sufficient in most locations. One kg of whole soybeans yields about 2.2 kg of soaked beans, having a volume of about 3 litres. For production measurements, the following table may be completed for the soybean varieties available locally.

Table 2 Soybean Soaking

SOYBEAN TYPE	DRY		SOAKED	
	VOLUME	WEIGHT	VOLUME	WEIGHT
STANDARD	1 liter	0.8 kg	2.4 liters	1.8 kg
	1.25 liters	1 kg	3 liters	2.2 kg
TYPE A	1 liter	0.7 kg	2.6 liters	1.7 kg
	1.4 liters	1 kg	3.6 liters	2.4 kg
TYPE B	1 literkgliterskg
liter	1 kgliterskg

Properly soaked beans will show very small foam patches on the surface of water used for soaking the beans. If the foam is everywhere on the water surface then the beans have been over soaked which will make inferior quality soymilk and tofu. Excessive over soaking or long storage of soaked beans may result in the beans that yield no soymilk at all; the beans become fermented and sour, and the

soymilk curdles even before it is extracted.

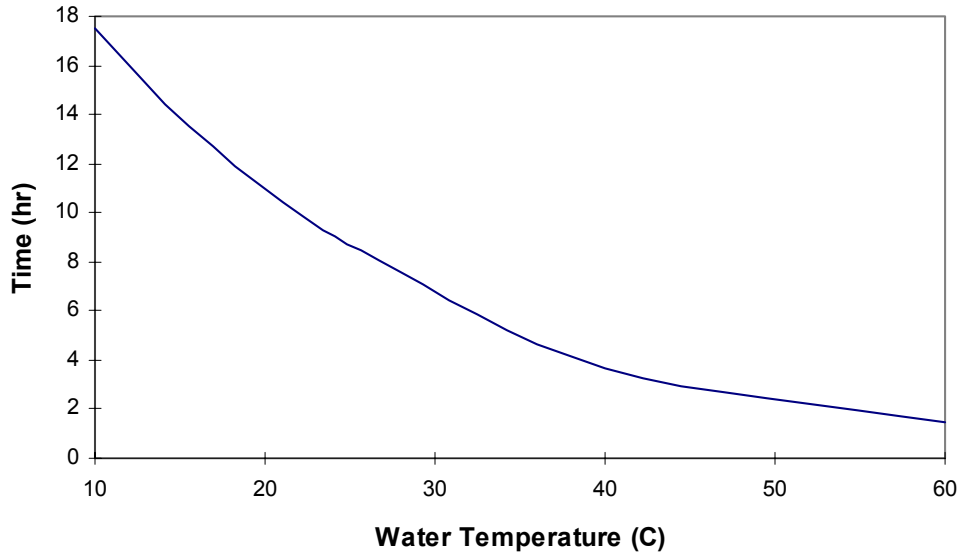


Figure 10 Soybean soaking time vs. temperature.

A close examination of the soaked soybeans can help determine if the beans are adequately soaked. The seedcoat or skin of a properly soaked soybean is smooth and taut whereas an over soaked bean has a wrinkled seedcoat. Upon opening a bean into its two halves, they will show a uniform colour and flat surface where the soybean halves contact each other. An under soaked seed half will be darker at the centre, and the two halves will be slightly concave. The halves break easily with a snap for the well soaked beans whereas they are flexible and rubbery for the under soaked beans.

Grinding and Cooking:

Soaked beans are drained of water and rinsed well. These are then ground with about 1 1/2 times water (1 cup of well soaked beans in 1 1/2 cups of water) to make the slurry of medium roughness using a stone mill or by some other means. Depending on the soymilk thickness desired, the soybean to water ratio could be higher or lower.

The slurry is transferred to a pressure cooker and cooked to a pressure of 1 kg/cm² (about 15 psi) by the infusion of culinary steam at a pressure of 1 to 3 kg/cm² (15 to 45 psi). The temperature of the slurry in the pressure cooker is allowed to reach 115 °C (about 240 °F). Every 4 kg of the slurry will take about 1 kg of steam to cook to 115 °C. However, the actual amount of steam condensed will depend on the temperature and air circulation in the work room, duration of heating, the initial slurry temperature, and most of all on the steam quality (the

steam quality is poor if it carries a significant amount of water). Adequate cooking time (holding the slurry at the cooking temperature) is 3-4 minutes. This denatures the soya protein enough to be highly digestible and inactivates the undesirable trypsin inhibitors, FIG. 6.

If soymilk is to be used for making tofu then the denaturing of the protein is minimized in order to obtain well formed tofu. The slurry is heated to a lower temperature (100 to 105 °C) and the cooking (holding) time is reduced to a minimum. Since the trypsin inhibitor and other soya anti-nutrients are rejected with the whey when tofu is made, extensive cooking of soymilk is unnecessary.

Separating Soymilk and Okara:

From the cooked slurry, soymilk is extracted by filtering and mechanically pressing the fibrous residue called okara. The soymilk thus obtained has about 70% of the protein originally in the soybean, most of the remaining being in the okara.

When made by grinding soybeans in room temperature water under atmospheric conditions, the soymilk will have a beany odour which becomes greatly noticeable when the soymilk is tasted cold. For most people, it is not palatable as such, in spite of the fact that nutritionally it is comparable to cow's milk, FIGS. 8-9

SOYMILK

The soymilk typically has 3.5 - 4% protein and 7-8% total solids. Adding 3-4% sugar and about 0.05% salt will bring soymilk to a sugar, salt, and total solid level approximately identical to toned (2% fat) cow's milk, i.e. about 12 to 13%. This can be consumed as such or after sweetening and diluting. Alternatively, it can be made into yogurt (dahi), or tofu (paneer) or used directly in cooking. When soymilk is made using a process which reduces or eliminates the beany off-flavour, it can be made into tasty flavoured drinks.

Shelf Life:

Soymilk should be stored and distributed in manner similar to that of dairy milk. Its shelf life depends on the processing conditions, storage, and packaging. Soymilk lacks the antibodies of dairy milk and thus is an ideal medium for bacterial growth. A typical shelf life curve is shown in FIG. 11. It is therefore extremely important to employ sanitary practices at all levels of processing, i.e. by sanitizing the equipment before starting the day and after finishing the day's work, by using a sanitary extractor, by quick cooling soymilk, and by using

sanitary containers and packages. For extended shelf life, storage and transportation of soymilk should be at 4 °C or a lower temperature. One way would be to extract soymilk, formulate it to enhance flavour and taste, heat it to 85 °C or higher temperature, and then fill it into sterilized bottles, pouches, or cartons, seal them quickly to prevent the air from getting in, and then rapidly cool them. Depending on the sterility of the product and packaging, and on refrigeration temperature, the shelf life may vary from 1 to 6 weeks or longer without preservatives. Sweetening also extends the shelf life of soymilk. Freezing of soymilk may cause it to curdle on thawing and so freezing conditions need to be avoided.

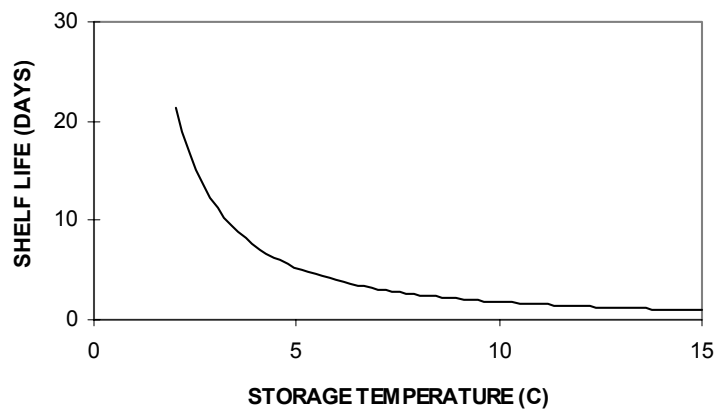


Figure 11 A typical shelf life curve for soymilk. This may also be applied to tofu.

SOYA YOGURT

Another way to extend the shelf life of soymilk is by culturing it with dairy yogurt cultures, e.g. *Streptococcus thermophilus* and *Lactobacillus acidophilus*. Culturing has the added advantage of reducing flatulence causing sugars, the oligosaccharides stachyose and raffinose, especially when using *L. acidophilus* culture. While cultured soya drinks can be made using thin soymilk, well formed soya yogurt requires thick soymilk (10 to 13% soymilk solids). A starter of 30 mL good quality yogurt is thoroughly mixed with 1 L of warm soymilk (45 °C) and incubated at 35 °C for 12 hours or 40 °C temperature for approximately 12 hours. Actual temperature and incubation time should be determined experimentally for the culture used. Whey separation may be prevented by adding a stabilizer like agar, gelatin, or arabic gum to the soymilk. The stabilizer also gives a firmer consistency to the yogurt.

OKARA

Okara, being already cooked adequately, is also a good source of high quality protein with dietary fibre. One kg of dry soybeans yields 1-2 kg of okara, depending on the bean quality and the slurry pressing method used. It can be used to prepare many nutritious foods. Unless dried to a moisture level of 10% or lower, its shelf life without refrigeration is rather limited. Properly refrigerated okara can be kept for two weeks or longer and it can be used in making snacks, bread, and a variety of other foods.

TOFU

For making Tofu, soymilk is cooked to 100-105 °C, and not to 115 °C as when soymilk is used for drinking, yogurt making, etc. It is coagulated with some food chemical such as calcium chloride, magnesium chloride, calcium sulphate, glucono delta-lactone, or white vinegar to form curd. Coagulation of soymilk is a craft and the quality of tofu strongly depends on the coagulant and the coagulation method used. The curd obtained from coagulation is transferred to perforated forming boxes, lined with cloth, to drain the whey under externally applied pressure. The tofu slab thus obtained is cut to desired sizes and the tofu pieces cooled in a tank having flowing cold, clean water entering at the bottom and leaving near the top. Upon cooling, tofu firms up significantly, so it is necessary not to press curd too hard, unless extra firm tofu is to be made.

Most soybean anti-nutrients, e.g., trypsin inhibitor and oligosaccharides, are rejected with the whey in the process of making tofu. Also, the anti-nutrients are leached out in the tofu cooling water and into the tofu storage water.

Tofu may be eaten as such when fresh with salt and pepper or with soya sauce, or after further processing. It may be sold in bulk by weight or by portion, or packaged in water in plastic tubs, or in pouches that are heat sealed with a minimum amount of trapped air. Tofu should always be kept immersed in fresh cold water until used, with the water being changed every day. Water has two major functions - a) it keeps air from coming in direct contact with tofu and thereby limiting the oxygen supply to the bacteria that cause spoilage, and b) it keeps tofu from crushing under its own weight or under the weight of other tofu pieces or packages.

Shelf Life:

Tofu that is cooled and packed in clean (preferably filtered and sterilized) and cold water will keep for more than two weeks under proper refrigeration. The tofu shelf life curve is similar to that of soymilk, FIG. 11. However, in tropical countries refrigeration conditions are such that a shelf-life of more than a week should not be expected. Although freezing extends tofu life substantially, it is not advised because the tofu becomes meaty in texture upon thawing. Those who like chewy preparations may want to try freezing tofu before using it. It is suggested that in tropical areas tofu packages kept under refrigeration show "sell-by" dates

within three days of manufacturing and a consumer should be advised to use it as soon as possible upon purchase. Tofu should be used as fresh as possible. It usually has a faint natural aroma. Stale tofu is that which has developed any of the following, a) tastes very sour, b) smells rotten, c) floats unpacked in water. Slightly sour tofu can be used after boiling in water.

When refrigeration is not practical, tofu shelf life can still be extended to 10 to 15 days in tropical climate by using a simple technique. Tofu is pressed very firm under high pressure. This very firm tofu is then put in a solution of water (boiled and cooled to room temperature), 4% salt, and 10% lemon juice. The solution has a pH of 4.5 or less to prevent the growth of bacteria. Acetic acid (vinegar), citric acid, tartaric acid, or any other food grade acidic product can also be used to bring the pH of salted water below 4.5. Tofu thus kept can have a shelf life of up to 15 days at up to 37 oC temperature. However, this tofu has a sour taste.

Another technique recently tried in India used glyoxyl, which is derived from hydrogen peroxide using a proprietary Dutch method, mixed in very small quantity with the water used for packaging tofu. Glyoxyl slowly releases hydrogen peroxide which continues to kill bacteria while the tofu is stored. Heating the product prior to its consumption breaks down the remaining glyoxyl into its harmless constituents.

TOFU YOGURT

Tofu can be cultured with yogurt to make tofu yogurt. For this, tofu must be thoroughly disintegrated and homogenized in a blender or mixer before and after mixing the culture. The same cultures may be used as for making dairy or soymilk yogurt. The shelf life of tofu yogurt is significantly longer than that of tofu, especially when adequate refrigeration is not possible. Tofu yogurt feels and tastes like spread cheese (cream cheese) with very low fat, and it can be used in a similar way.

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Messina, M. and Messina, V., *The Simple Soybean and Your Health* (Avery Publishing Group, New York, 1994). Mark Messina, PhD, MS, is a leading authority in the field of soyfoods and cancer prevention and Virginia Messina, MPH, RD, is a registered dietitian. The paperback sells for US\$12.95.

Gupta, R.P., and Gupta, R.R., Food Processing in Oxygen Free Environment, US Patent #4,915,972 (1990). This patent has been issued in many countries including Canada, India, UK, France and Germany. Many additional patents have been obtained and filed for equipment that use the above patent.