FUTURE OF FERMENTED FOODS

C. W. HESSELTINE*

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Foods prepared by fermentation, aside from those well known in the West, will increase in amount and use and will spread to other parts of the world, including the western developed countries. The author discusses the factors influencing the greater use of traditional fermented foods.

Introduction

A look at where fermented foods are going in the next few years seems to be an appropriate exercise. One can speculate wildly about the future and, at the time of writing, no one can fault the opinions given. The author's only qualification to look into the future is that the Northern Regional Research Center has been involved in sporadic research from the late 1940's to the late 1950's, at which time research on a small, but continuous, scale was initiated; it is still continuing today. Besides the author's work, people from various countries (Brazil, Thailand, Indonesia, and Japan) have worked on programs in this laboratory. PL 480 funds have supported projects in Israel, India, Taiwan, and Japan on fermented soybean foods. These contacts have done much to give us cultural, economic, and scientific information and understanding about foods produced by fermentation.

In this paper fermented foods exclude alcoholic beverages and well-developed Western foods such as bread, cheese, sausage, sauerkraut, yogurt and pickles. Rather, the fermented foods dealt with here were not produced in the West until recently, or are still unknown outside the native area in which they have been produced for centuries, many going back even before recorded history.

In making a projection on fermented foods, a number of conditions are having a positive effect while there are others having a negative one. At least six positive factors suggest a greater role for traditional fermented foods:

1. All food preparation requires various inputs of energy. Energy costs have increased dramatically, and there is no indication that cost ever will be reduced. These costs affect people of less wealthy countries even more than those of the prosperous countries. Energy is required in four different phases of food production; namely, the amount used for agronomic activities (ploughing, seeding, cultivation, harvesting, etc.); transportation to market from the farm and from the factory to the consumer; preservation (chemical preservatives, drying, canning, and refrigeration); and processing (physical and chemical modification and packaging). Each step requires energy. Because energy is recognized worldwide as a critical economic and political issue, there is a mounting interest in ways of reducing its use in all processes, including the production of food.
2. Because of the increasing world population, the food supply now has become critical and will be even more so in the future without worldwide control of the birth rate or the decimating factor of war. This suggests that one of the strategies in the future must be to produce more food and to do a better job of saving it from decay, insects and rodents. The world's crop losses from disease represent 11.1% of the soybean crop and 9.4% of the corn crop, and may go as high as 23% of the banana crop.[1]
3. Besides considering the energy input, the pollution that usually accompanies processing must also be considered. The added pollution results in either the use of money to control the problem or the deterioration of the environment and its consequent adverse effects on man, directly or indirectly. In addition, much food is lost in the processing. For example, in modern and Western society more and more wood products are being used for packaging of food and nonfood products. As a result, of the increased production, more wood sugars are being dumped in streams; these sugars could be fermented away with the addition of a cheap nitrogen source to make single cell protein. To a small extent, this product is now made from paper manufacturing wastes which is used in human foods as a source of protein and vitamins.
4. Losses due to spoilage by bacteria, yeasts, and fungi have increased as the distances and time required to transport the product have increased between the farmer and the consumer. Ripe tomatoes grown in the Peoria area can be harvested and sold directly to the consumer, resulting in very little loss due to microbial spoilage; but tomatoes grown in Mexico and shipped to New York offer a different problem. The trend in the last few years has been to concentrate production of crops in certain areas which, in turn, supply the whole country. This applies to field crops as well as vegetables and fruit. Likewise, because of labour costs, there is a strong trend towards more mechanical harvesting and handling at a higher moisture content (as in the harvesting of corn) with more mechanical damage due to crushing and breaking, all conducive to more microbial spoilage. All organic matter is subject to attack by microorganisms within a proper moisture and temperature range.
5. Tillable land is decreasing throughout the world for the production of food. This suggests that one of the strategies is to bring into use a better utilization of plant and animal products now unfit or not used for human food. A good example is the waste fish, such as undesirable parts and small fish, which could be upgraded by fermentation to make desirable, acceptable, and safe foods high in protein and acceptability. Although this process currently is being used to contribute to the food economy, still the process is greatly under utilized.
6. Food habits are slowly turning towards more foods of vegetable origin, partly because of food costs and partly due to a belief, at least in the West, that a bulky, low-meat diet is beneficial to the consumer. Some are advocating that foods with less processing are more healthy because of increased fibre, less food additives, and a higher vitamin content. This latter feeling is a controversial matter; nevertheless, it does affect the food habits of a great number of people.

Opposed to the positive forces encouraging increase in production of fermented foods, the following six are negative factors. (1) In any microbial process there will be a loss in the starting material for the simple reason that energy is required for growth of the microorganism. In vigorous fermentations, such as tempeh making, the loss is appreciable even though the fermentation lasts only a matter of hours. (2) Fermenta-

†Presented at the VIth International Fermentation Symposium, London, Ontario, Canada, July 20-25, 1980.[2] The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

*The author's address is Northern Regional Research Center, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture,[2] Peoria, Illinois 61604.

tions require some knowledge of microbiology, or at least some specialized training with the microorganisms one is using. Without some knowledge of microbiology, disaster is just around the corner. For example, copra is sometimes used as an adulterant in making tempeh; however, if the fermentation becomes contaminated with *Pseudomonas cocovenenans,* illness and death occur due to a poison that affects the central nervous system. (3) Because all fermentations can be considered as controlled spoilage of the substrate, there are some hazards from bacterial and mold toxins. In koji-making, strains of *Aspergillus oryzae* are used to make enzymes. But, a closely related species, *A. flavus,* which has the same growth appearance and growth requirements, will produce varying amounts of aflatoxin. When selected strains of *A. oryzae* are obtained from reputable culture collections supervised by expert mycologists, no problem occurs. (4) Various fermented food products have special inherent disadvantages due to their characteristics. For example, shoyu and miso have a high salt content that allows the product to be kept for long periods of time without refrigeration. However, this high salt content limits the amount of product that can be consumed at a meal. Fresh tempeh cakes, on the other hand, must be consumed within 1 or 2 days or the mold proteolytic enzymes will cause ammonia to form, which results in an undesirable taste. (5) It is obvious that even the simpler fermentation processes involve added costs because of the extra handling, labour, and fermentation equipment. (6) Some people find products made by fermentation objectionable. Western people in general reject any product made with molds. The only mold products they are acquainted with are certain cheeses in which *Penicillium* is used, and even these familiar products are rejected by some.

Trends in production of fermented foods

In looking at the future of traditional fermented foods, it is instructive to see what has happened in the past few years to some of these products, both in the United States and abroad. Unfortunately, the actual amounts of materials consumed usually are not known, and some of the data may be questionable. Data will be presented by country rather than by food product, because the foods are different from one country to another.

Korea

Fermented soybean products (paste and soy sauce) go back at least to 634 A.D.[2] In 1976, the consumption of soybeans per capita was 12 kg. The annual production and import of soybeans has been going up as shown in Table 1 (taken from the above reference). The breakdown of the use of these soybeans is shown in Table 2 (adapted from Fig. 1[2]). Thus, about 35% of the 442,803 metric tons of soybeans is fermented.

Table 1. Annual production and import of soybean in Korea

Year	Production (M/T)	Import (M/T)	Total (M/T)
1970	231,994	36,291	268,285
1971	222,302	60,573	282,875
1972	223,939	31,468	255,407
1973	245,822	72,964	318,786
1974	318,576	66,370	384,946
1975	310,555	61,000	371,555
1976	294,949	147,854	442,803

Table 2. Consumption pattern of soybean foods in Korea

Curd (tofu)	24.5%
Shoyu (soy sauce)	10.6%
Paste (miso)	18.3%
Hot soy paste	6.6%
Oil and defatted meal	28.5%
Sprouts	9.0%
Milk	0.14%
Other	2.4%

about 75,000 tons of soybeans as compared to 41,000 tons for tofu.[3,4] The daily consumption of tempeh is from 30-120 g per capita.[4] Tempeh is becoming an important food in Malaysia. Table 3 shows the amounts of soybeans used in Indonesian fermentations.[4]

Table 3. Amounts of soybeans used in Indonesian fermentations

	Tons	Value R_p in billions
Tempeh	75,600	16.1
Kecap	501	0.371
Tauco (like miso)	415	0.882
Tofu (not fermented)	41,405	8.8

Indonesia

In Indonesia the tempeh industry uses 83,845 tons of soybeans are used in Indonesia, with a U.S. dollar value of 39 million.[5] Tempeh is produced in 41,200 shops by 128,391 workers, with the largest factory producing 422 tons per year. This tempeh is sold at about $0.23 per pound on the retail market.

Japan

Shoyu has been produced in Japan for 1500 years.[6] The annual production of shoyu in this country is about 120,000,000 kilolitres per year; this figure has remained almost unchanged since 1974. With 3600 shoyu producers in Japan, five companies account for half of the total production. Consumption per capita averages 12 litres per year; of this 63% is consumed in the home and 37% is used in food industries and restaurants. Daily consumption of about 34.1 g per day contributes 14.0 calories, 2.4 g protein, 0.2 g fat, and 5.8 g salt to the diet.

Natto is of two kinds: hamanatto, which resembles miso in taste, and itohikinatto, made with *Bacillus natto*[7]. The 100,000 metric tons produced in 1970 has increased to 158,000 in 1979.

The total production of fermented soybean foods have gone from 932,000

Table 4. Utilization of soybeans and soybean meal in fermented foods and tofu in Japan[4]

Category	1973	1974	1975	1976	1977	1978
			(1,000 metric tons)			
Frozen & dehydrated tofu						
United States	28	24	28	26	28	29
Chinese	5	9	7	3	0	1
Total:	33	33	35	29	28	30
Shoyu (in terms of beans)						
United States	249	240	231	230	240	251
U.S. beans	16	14	11	10	8.5	6
Natto						
United States	3.7	3.7	3.0	40	45	46
Chinese	66.1	72.7	71.0	24	15	15
Japanese, domestic	3.7	4.1	4.0	5	10	10
Total:	73.5	80.5	78.0	69	70	71
Miso						
United States	38	27	16	98	130	11
Chinese (PRC)	132	132	169	80	40	129
Canada	—	—	1.5	2	5	5
Japanese, domestic	17	17	12	10.5	10	40
Total:	187	176	198.5	190.5	185	185
Tofu and aburage						
United States	379	371	357	383	402	420.5
Chinese (PRC)	20	20	20	10	5	5
Brazil			1	2.5	2	1.5
Canada			5	6	8	10
Japanese, domestic	10	11	10	10	10	8
Total:	409	402	393	411.5	427	445

metric tons of soybeans in 1971 to 946,000 tons in 1976.[8]

It is instructive in determining the status of fermented food to see the amounts of soybeans being used over the last few years in Japan for fermented foods. These data are shown in Table 4.

It is apparent from Table 4 that total usage for tofu has increased somewhat but that other products have stayed constant. The country of origin for soybeans in the various fermentations is not the same. For example, until recently the Japanese bought mostly Chinese soybeans for miso making, whereas almost all the shoyu is made from U.S. soybean meal.

South Africa

One of the fermented food products in South Africa for which production figures are available is kaffir beer. This is a native beer that is consumed more as a nutritious food than as a drink for pleasure. Data on this fermentation over a period of 4 years are shown in Table 5.

Table 5. Production of kaffir beer by industrial fermentation* in South Africa

Year	Bulk millions of litres	Pack beer millions of litres	Total millions of litres	Total value (million rand)
1974	425	518	943	68
1975	409	504	913	76
1976	342	501	843	82
1977	348	531	879	90

*Home production may be nearly as much.[9]

Table 6. Consumption of fermented shoyu in the United States and Japan

Year	*Gallons of liquid shoyu consumed*		*Pounds of shoyu solids consumed*	
	United States*	Japan	United States*	Japan
1974	2,600,000	311,676,000	8,840,000	1,059,698,000
1975	2,900,000	293,331,000	9,860,000	997,325,000
1976	3,300,000	320,728,000	11,220,000	1,090,475,000

Annual per capita consumption in: Japan 12,000 ml
U.S. 57 ml

*Domestic production plus imports from the Orient.

United States

The four products to be considered here are shoyu, tempeh, miso, and a traditional but nonfermented product, tofu. However, in the Orient, tofu is sometimes fermented to make sufu, a fermented soybean cheese product. Data has been presented (shown in Table 6) on shoyu consumption in the U.S. as compared to consumption in Japan.[6] U.S. consumption is increasing rapidly but is less than 1/200th of that in Japan.

Tofu (precipitated soybean milk) is growing rapidly in popularity in the United States among the non-Oriental population. Table 7 shows the increase in number of tofu shops and soy dairies in North America and in other Western countries (Europe, Australia, and South America).

The number of tofu shops in the United States run by non-Orientals rose from zero in 1975 to 96 in just 4 years. According to Richard Leviton, editor of the journal *Soycraft,* the estimated retail value of tofu in the United States is $33,750,000, representing sales of 188 companies which employ 680 people. Today, tofu can be purchased in many supermarkets and usually is displayed in the fruit and vegetable section. The number of shops selling Tempeh (an Indonesian fermented soybeans product) has risen from a total of 22 shops in 1978 to 29 in November 1979. Unfortunately, no data on the amount of miso imported or made in the United States could be obtained. It is reported that one company makes about 500 tons of miso yearly in the United States.

From this admittedly sketchy and incomplete data on the use of fermented foods, it appears that in those countries where production figures are available and where fermented foods have been made for centuries, the amount produced is staying approximately constant. For the less developed countries, there is no data on the consumption of fermented foods and no one can even make an estimate, but it is probably surprisingly high. However, in the West, it now appears that several foods (shoyu and tofu) are becoming known and being accepted by non-Oriental people, especially among those interested in vegetarian diets.

Table 7. Tofu shops and soy dairies in the West*

Year	North American Caucasian	Oriental	Other West	Total
1975	0	53	2	55
1978	63	51	10	124
1979	96	68	36	200

The reasons for no growth or decline in consumption of fermented foods in some countries is not known. One can surmise that several factors, acting together, could bring this about. As incomes increase, there is a trend towards replacement of vegetable protein by red meat, dairy products, and poultry. Added to this, perhaps, is the inability of the manufacturers to change and adopt to the younger generation's changing food habits. The more progressive companies are beginning to adjust in various ways. Some miso companies are now developing a low-salt miso and suggesting ways of using miso in sauces for Italian types of food now popular in Japan. Another factor that may be working against traditional fermented foods is the desire to eat new foods brought in from the West. For example, beer sales in Japan have adversely affected the sale of their traditional drink, sake.

There now follows a look at what the future may hold for fermented foods, aside from those well known in the West. An increase in consumption of these traditional foods in countries where these foods were not formerly produced may be expected and a spreading of fermented products to other parts of the world. They will undergo modification in taste and appearance and, in some instances, will be used in other ways than the traditional ones. It is hardly expected that soybean paste will ever be used as a base for a hot breakfast food in the West, but it is likely to find use as a flavouring agent in sauces, salad dressings and spreads. On the other hand, tempeh will probably be sold as a protein food, just as it is used in the East Indies. Shoyu is already sold widely in the West as a modified sauce, such as teriyaki sauce for use in barbecuing poultry and meat.

There are a number of factors that may have an effect on the wider use of fermented foods in the West and in countries where those foods already are known.

1. Prevention of food poisoning. The fermentation of a commodity often will result in a product that is protected from food-poisoning microorganisms that grow and produce toxins. Typical food poisonings are caused by the botulinal toxins, which cause a number of deaths each year in the United States (114 cases reported in 1977), and the enterotoxins, which although not fatal, cause acute illness. The conditions during fermenting that prevent the growth of such toxins are the low pHs encountered due to the growth of lactic acid bacteria, the high salt content, and the presence of antimicrobial agents. The use of fermentation is such an effective method that it is still used in the highly developed countries for processing cabbage, olives and cucumbers. These methods are still used because the fermentations (1) yield certain desired organoleptic qualities, (2) provide a means for extending the processing season, and (3) require little mechanical energy input.[10] The Food and Drug Administration has found no reported illness due to botulism in commercially processed fermented foods in the United States, Canada, the United Kingdom, and Japan.[10] Besides the rapid lowering of the pH, lactic acid bacteria produce compounds that are antagonistic to spoilage bacteria. *Clostridium botulinum* growth is prevented

at a pH of 4.6 or below and by a 10% NaCl content. When the low pH and the high salt content are combined, an even less favourable environment for growth exists for toxin-producing bacteria.

2. Fermentation can increase the shelf life of some products. Quite aside from the prevention of the formation of bacterial toxins is the effect of fermentation on the growth of spoilage bacteria, yeasts, and moulds. Spoilage microorganisms result in off-flavours and appearance and undesirable enzymatic changes. The high salt and low pH have the effect of preventing microbial growth. This results in the product having a long shelf life without the use of canning, drying, or refrigeration; all requiring quantities of energy. Also, it is not generally recognized that the high population of selected microorganisms encountered in fermentations prevents low population of undesirable organisms from increasing and may, in fact, reduce their numbers because of population pressure. The desired fermentation organisms occur in enormous numbers either because of the large amounts of inoculum used or because of the ecological conditions established to promote the rapid growth of the desired species.

3. World's population increase will force more people to consume more plant material. It is assumed that the world population will continue to increase in number and, as it does, more food will be required to feed this increased population. But at the same time, the amount of land available for food production is finite and it is decreasing in size. This is due to the use of land for buildings and roads; to the erosion of tillable soil from the land; and to the exhaustion of water supplies. The consequences of these factors will be that more and more people will be forced to obtain their food from plants rather than through the inefficient conversion of plant material into pork, beef and poultry. Today, this situation is already true for millions of the world's people. Problems are also encountered with a purely vegetable diet. For example, B_{12} is an essential vitamin for humans, but it is obtained from either meat or products made from microorganisms. It is well known that the poorer people of India, who survive on a purely plant protein source, consume a great deal of fermented products; undoubtedly, this is how their B_{12} requirement is satisfied. Vegetable diets tend to be dull; therefore, any processing or addition which enhances the flavour is most desirable. All the traditional fermented foods have enhanced flavour and some even resemble meat.

4. Interest in a variety of natural products of plant origin. In recent years, an interest has developed in returning to more natural foods, especially those of plant origin. Literally thousands of shops have opened to promote and sell these products, including fermented foods such as yogurt and starter cultures for all kinds of fermented dairy products. The young adult population especially has been interested in naturally fermented food products with which they have not had previous contact, such as miso and tempeh. This interest is not only in the nutritional aspects of natural foods but also in exotic flavours and appearances.

5. Increased scientific interest in fermented foods. In recent years, there has been an explosion of interest in processes using microorganisms and in the products they make. Genetic engineering is currently receiving much publicity but what impact it will have on producing useful products and activities is yet to be seen. With the increased cost of nitrogen fertilizer, there is a renewed interest in various ways nitrogen is fixed by microorganisms. The energy crisis has increased interest in producing alcohol to add to gasoline. Applied microbiologists have done a great deal of research on producing protein from microorganisms grown on waste material. Recently there has been a renewed interest by food scientists and technologists in the processing of food by using microorganisms. The direction of this research has been towards: (1) the processes used to upgrade agricultural commodities such as soybeans to more pleasant and acceptable foods; (2) the changes in the nutritional properties of fermented foods; (3) the safety of the product from spoilage and toxin-producing organisms; research in several laboratories demonstrated that molds such as *Rhizopus* can reduce the quantity of aflatoxins; and (4) the actual modification of the process to make a commercially viable product in the West.

6. Interest in more healthy food. Many people, although not strict vegetarians, believe that our animal fat consumption needs to be reduced, especially for those persons who live a more sedentary life. Typically, since World War II, the consumption of animal fats has increased because of the careful feeding of animals to produce meat that is tender and tasty. Much of the beef produced today is finished not on pastures but in confinement feeding operations. Some fermented food products, such as shoyu and ontjom, are made from oilseeds from which most of the oils have been removed or from the fermentation of cereals low in fats; also, the vegetable oils are modified by the lipolytic enzymes formed by the fermentative organisms or are actually used for energy by them.

7. Modification of the soybean. The public is becoming aware of the fact that soybean protein is excellent but that the soybean must be modified or fractionated to make an acceptable human food. One of the oldest and still widely used methods of upgrading soybeans as human food is to ferment them. In the Orient where soybeans were domesticated, soybeans traditionally have been prepared for food by germinating the beans to bean sprouts and making soybean milk, which then may be precipitated to make soybean curd (tofu) or to ferment beans, either by themselves or in combination with cereals such as wheat or rice, to make shoyu and miso. Soybeans are fermented by themselves for products such as tempeh, natto, sufu, and similar products that are produced over a great area of Asia (including China, Taiwan, Korea, Phillipines, Indonesia, Indochina, Singapore, and Malaysia). Western countries are becoming aware of some of this technology. Fermented shoyu made in the United States can be found in almost any supermarket in the United States. And, as noted above, the number of shops making tofu has grown rapidly in the United States. The author predicts that tofu will become as successful in the United States as yogurt, provided the public is educated in the proper ways to use it in Western cooking. In all the Oriental methods of handling soybeans, the beany flavour disappears or is greatly reduced, as in the case of soybean milk.

8. Cultural and religious grounds. Apart from health concerns, millions of people in the world consume only vegetable proteins for cultural and religious reasons. For example, many but not all Hindus depend exclusively on vegetable products, mainly legumes, along with milk for their entire source of protein. It is not appreciated by most of the world that a large amount of legumes and milk are fermented by Indians and used as regular items in their daily diet. No data exists on how much vegetable protein is consumed by this population. An account of the popular fermented foods of India has been published which studies the nutritional qualities of idli (prepared by fermentation of rice and black gram), dhokla (prepared from rice and Bengal gram), and khaman (fermented Bengal gram).[11] Each of these foods is fermented without the use of pure cultures and depends on the normal flora of the grain for the inoculum.

9. Movement of people. Since World War II, there has been a great surge in travel by people from both the East and West to other parts of the world; as a result, foods have been encountered which were not appreciated earlier, including fermented products. Also, in recent times, large numbers of refugees from countries that use fermented foods have migrated to countries in the Western world, thus introducing new fermented foods into other parts of the world.

At the present time, the future of fermented traditional foods in the West looks very promising. This is suggested by the recent increased use of fermented soy sauce and the rapid development of the market for yogurt. Both products are now known and used by large numbers of people. It is expected that some of the other fermented or traditional foods will likewise become commonplace, especially in view of the need for more flavour in convenient foods. In the East, the future of fermented food does not seem to be so bright; in recent years, consumption of traditional fermented foods has remained constant. However, if the producers adapt to the changing food habits of their people and have a good education programme to instruct the consumer, it seems to be that consumption of these foods should go up.

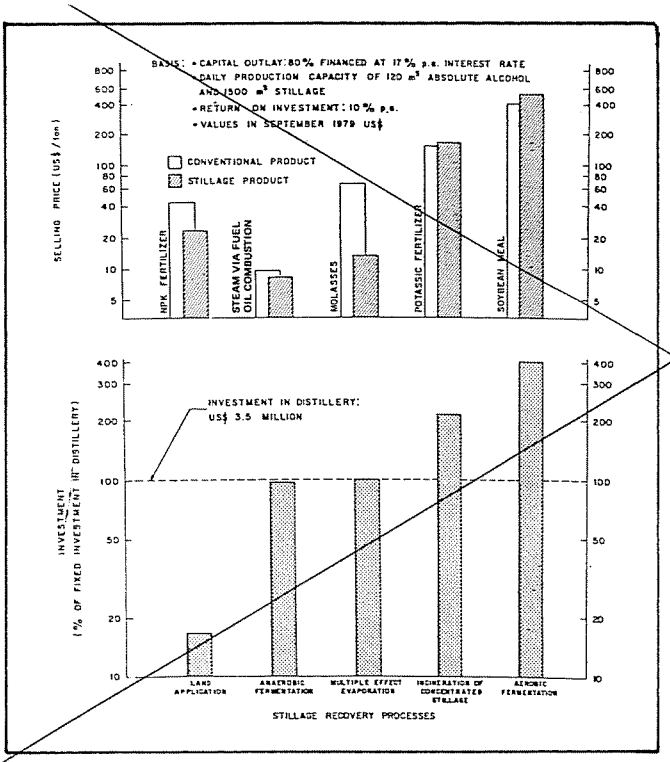

Fig. 5 Comparison of stillage processing alternatives with return on the investment over 15-year span — byproduct distillery[18]

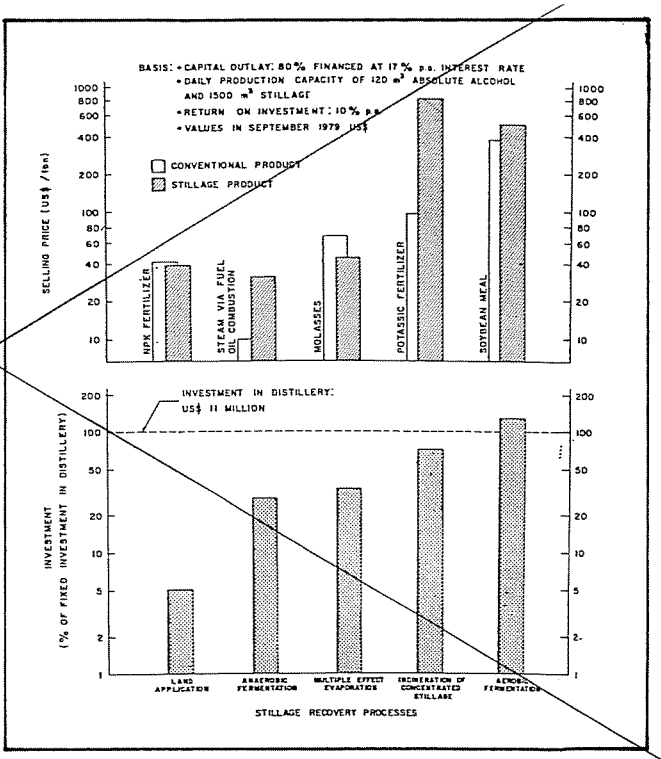

Fig. 6 Comparison of stillage processing alternatives with return on the investment over 15-year span — independent sugar cane distillery[18]

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