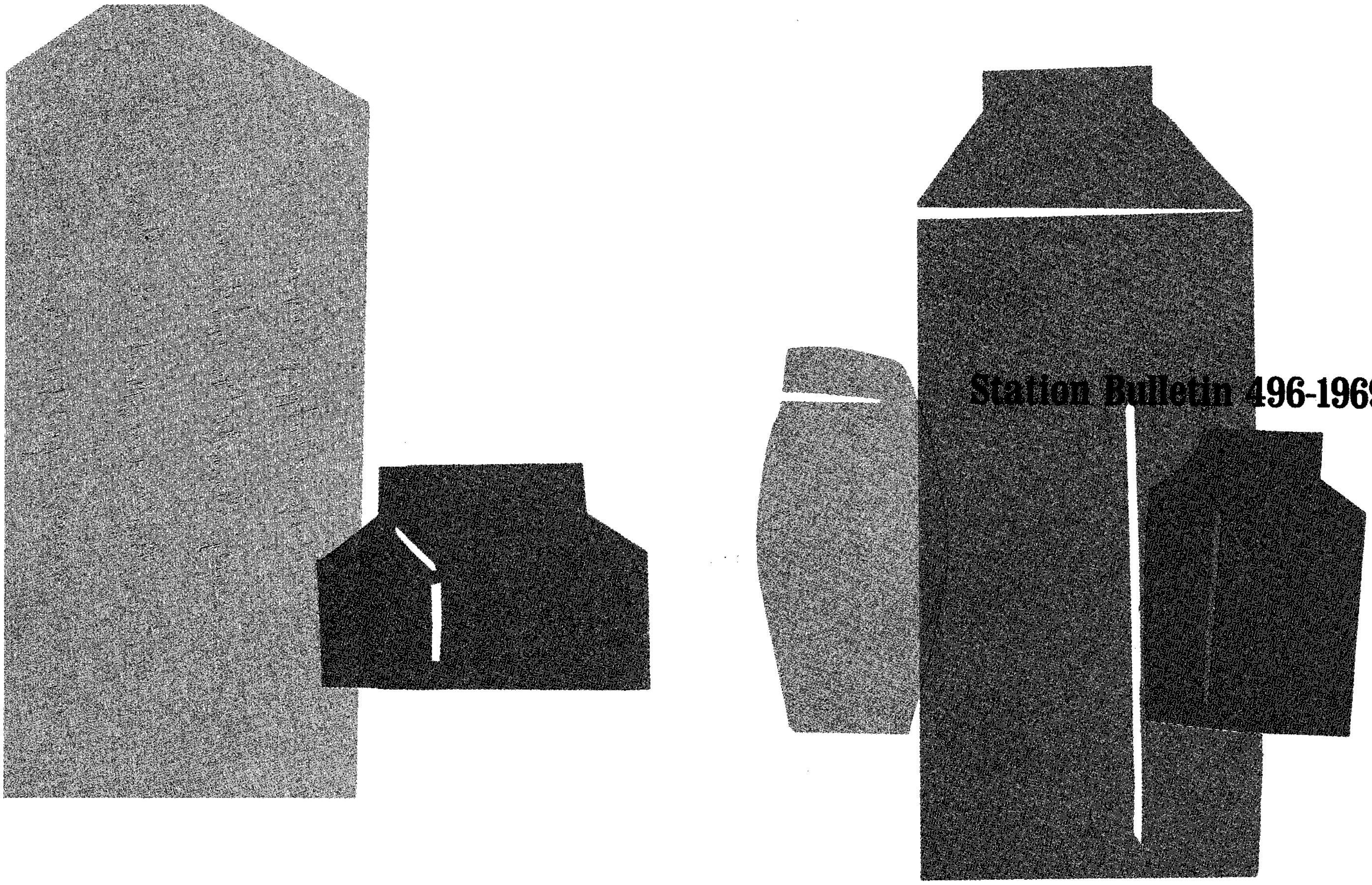

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Nutritional, Technical, and Economic Aspects of MILK SUBSTITUTES

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AGRICULTURAL EXPERIMENT STATION
UNIVERSITY of MINNESOTA

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Nutritional, Technical, and Economic Aspects of Milk Substitutes

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While the introduction of filled and imitation milk into the nation's markets has been of interest to consumers, it has been viewed apprehensively by members of the dairy industry. Production and sale of these products could significantly alter an important branch of agriculture. In years to come, modern technology will have a heavy impact upon traditional methods of food production. Development of milk substitutes will just be part of overall research designed to produce synthetic food substitutes.

This bulletin, prepared upon request by the administration of the Institute of Agriculture, presents a comprehensive statement of the opportunities and problems associated with these products. It is designed to provide a basis for Institute of Agriculture policies regarding developments in this area. It has three specific objectives: (1) to provide some background on the status of milk substitutes, (2) to describe nutritional, technical, and economic issues that might arise from the development of these products, and (3) to indicate the role of the Institute regarding these products. Some of the issues considered here reach far beyond the immediate problem of filled milk. Substitutes for other traditional foods have appeared on the market and this trend is expected to continue.

Filled milk is a product in which vegetable or other fat replaces the milk fat. *Imitation milk* is a product that resembles milk, but it is of nondairy origin. These two names are not used universally and products vary from manufacturer to manufacturer.

Filled milk is not a newly developed product. Its sale in this country has been prohibited by laws for many decades. Imitation milk is not entirely new either: nondairy baby foods have been sold for a number of years. What is new is the legal sale of these products in several states as a direct replacement for pasteurized and homogenized fluid milk.

This inquiry is pertinent because food constituent selection is increasingly shifting from the kitchens of homes and institutions to those of processors. Products sold under the federal government's Standards of Identity must conform to standards of the Food and Drug Administration (FDA). However, there are no Standards of Identity for many products sold under fanciful names.

Economic pressure forces food processors to use the lowest cost ingredients and formulation that are consistent with legal requirements or company standards. Also, new packaging methods or development of new foods, such as frozen meals, might necessitate a change in the formulation of food items for reasons of stability rather than economic or nutritional considerations. This does not imply that food processors are not concerned with nutritive values of their products. However, it does mean that to an increasing extent food processors are setting the nutritional levels of their products without any actual or implied responsibility for their nutritional adequacy.

This contrasts markedly with products that are prepared for pets or even farm animals. Processors assume almost total responsibility for nutritional adequacy. From the standpoint of the objective sought — the health of the pet, the weight gain per pound of food and per day — results have been highly favorable. A similar responsibility has been accepted by processors of infant and baby foods.

After infancy, the child selects from a wide variety of foods and the nutritional adequacy of his diet then becomes, partially, a matter of individual choice. However, the question of what responsibility the food processor has in assuring an adequate diet remains open for public consideration. Public agencies such as the University of Minnesota clearly have a responsibility to explore and illuminate potential problems. Nondairy products sold under the semblance of milk are a case in point.

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Development of Filled and Imitation Milk

During World War II the U.S. Army Quartermaster Corps found that milk reconstituted from nonfat dry milk and milk fat usually tasted better than reconstituted dry whole milk. This led to establishment of reconstituting plants (nonfat dry milk and milk fat) to serve military installations in the Western Pacific. Extension of this practice into civilian use in the Western Pacific and, ultimately, substitution of less expensive coconut fat for milk fat followed. Eventually, the process returned to this country through Hawaii, then California and Arizona, and finally to other states.

Imitation or nondairy products are not entirely new. Gruel made from soybeans had been used for centuries in many parts of the world. Baby formulas based on soy protein preparations and vegetable fat had been sold for several years in this country, largely for infants allergic to cow's milk.

Imitation milk did not evolve from baby formulas, but rather from technology used to develop nondairy creaming agents. They are made from vegetable fat, corn syrup solids, sodium caseinate, and emulsifiers and bodying agents. Modern technology developed vegetable fat preparations and corn syrup solids sufficiently bland for use in these products. Adding a proportioned mixture of these ingredients to water produces a liquid that looks and tastes much like milk. Sodium caseinate is relatively bland, but the amount which can be used is limited for flavor reasons. Soybean protein preparations that are sufficiently bland for creaming agents have not yet been developed.

Laws and Regulations

Economic control of filled and imitation milk takes two forms: (1) outright restriction of the manufacture and sale of products and (2) the imposition of pricing provisions of state and federal market orders for milk. In addition to the Federal Filled Milk Act, at least 30 states prohibit the manufacture and sale of filled milk. Several states also prohibit the sale of nondairy substitutes.

Economic controls were enacted for several reasons. Some were proposed by the dairy industry to protect its markets and to reduce economic pressure to substitute less expensive vegetable fats for milk fat. Crossing state boundaries with any product containing milk, cream, or skim milk combined with fats or oils other than milk fat and made to resemble milk was prohibited by the Federal Filled Milk Act, passed in 1923. Many states, including Minnesota, have enacted statutes to prohibit the production and sale of such products.

Undoubtedly, these laws and regulations were imposed to protect the interests of the dairy producer. But certainly legislators were concerned with insufficient and improper labeling of substitute milk products and with the special place milk is considered to have in the human diet.

If it is in the public interest to prohibit the production and sale of "filled" milk, then it seems inconsistent that the laws of the same state permit the manufacture and sale of nondairy milk substitutes. This inconsistency partially reflects the growing trend toward honesty in identification and labeling, but not banning of the sale of the actual wholesome food. Federal Food and Drug laws permit the production and sale of food items under two general requirements: (1) Standards of Identity, which require that a product sold under a name for which there is a standard of identity shall conform to the requirements for that product; (2) other products may be produced and sold under fanciful names if they conform to general Food and Drug laws and are formulated from constituents and in amounts approved for food use. Constituents must be listed on the package.

The constitutionality of the filled and imitation milk acts is uncertain. The Federal Filled Milk Act was challenged in 1938 and 1944 in the Supreme Court. In both instances it was upheld. But most likely its constitutionality will be challenged again in the future. The U. S. Supreme Court has also upheld two state filled milk laws, the Ohio Act in 1918 and the Kansas Act in 1944.

State laws have not fared nearly as well when challenged in state courts. In 1931 the Illinois filled milk law was declared unconstitutional. In 1936 another Illinois law and the Nebraska and Michigan laws were declared unconstitutional. The Washington and Arizona laws were declared void in 1967. A suit was brought against the Wisconsin Act in 1968. In one state court case, Pennsylvania in 1938, the validity of the filled milk law was upheld.

Thus, the dairy industry's ability to maintain legislative restriction on fluid milk substitutes appears to be declining. Already, nondairy substitutes are outside the purview of the federal act and most state acts. In addition to unfavorable court rulings, urban-dominated legislatures are likely to repeal some of these acts. Such a move is underway in Virginia. Finally, the precedent set by margarine litigation points to the inevitable failure of restrictive legislation.

Another means by which the dairy industry has sought to control the sale of filled and imitation milk is through state and federal marketing orders. These programs do not impose direct restrictions but, instead, set prices on ingredients used in milk substitutes.

In the Central Arizona federal milk order market, nonfat dry milk used in filled milk is priced according to the value of its fluid skim milk equivalent, which is available from local market areas. As a result of this provision, filled milk is made from locally produced skim milk rather than nonfat dry milk produced in other market areas. But filled milk sales, as a proportion of total fluid sales in that market, indicate that the program does not eliminate the incentive to produce and market filled milk. The USDA has recently recommended that a similar provision be included in all federal milk orders.

An attempt is being made in Hawaii to impose pricing provisions on any fluid beverage resembling milk that displaces local fluid milk sales. This provision requires processors to pay an amount for ingredients that will make their product equivalent in price to locally produced fluid milk. If all the ingredients are originally purchased for less than the amount set by pricing provisions, the difference is paid into an equalization fund. These proceeds are then paid back to milk producers to compensate them for the drop in fluid milk sales. However, the legality of pricing provisions of state orders is already being questioned in Hawaii's courts.

Additional regulations under the Federal Food and Drug Act have been proposed for imitation milk products. The FDA has proposed standards of identity and quality for imitation milk and cream. These products are identified as follows: "18.550. Imitation milks are the foods that are not filled milks as defined in 21 U.S.C. 61(c), but which are made in semblance of and intended to be used in substitution for skim milk, low-fat milk, part-skimmed milk, milk, and high-fat milk in single strength liquid, concentrated, dried, or frozen form or half-and-half (milk and cream) in liquid form containing one or more of the optional ingredients listed in paragraph (b) of this section and having the edible oil or fat content specified in paragraph (d) of this section."[1]

The proposal includes standards of nutrient levels, stated as follows: "18.552. Imitation milks; quality; label statement of substandard quality . . . the following is the standard of quality for imitation milks. On the basis of an eight-fluid ounce serving, if necessary reconstituted in accordance with label directions, the imitation milks shall contain nutrients as follows in amounts not less than those specified:

Protein (biological value equivalent to casein)	8.5 grams
Calcium	290 milligrams
Phosphorus	220 milligrams
Vitamin A	375 U.S.P. Units
Riboflavin	0.40 milligrams
Optionally, vitamin D — when added, not less than	100 U.S.P. units

"(b) If the amounts of nutrients in imitation milks fall below any of the levels specified in paragraph (a) of this section, the label shall bear the statement 'Below standard in quality _______' the blank to be filled in with a statement declaring the deficient nutrient or nutrients; for example, 'low in protein' or 'contains no vitamin A.' "[2]

Presumably, hearings will be held on the proposal. The Milk Industry Foundation has recommended that the term *imitation* be reserved for *filled* milk and milk products, and denied to nondairy milk and milk products.

The American Medical Association has recommended that the FDA set aside their proposal for identifying substandard imitation milk. The AMA recommendation states that the proposal would negate the principle of nutritional equivalence. An inferior imitation milk might be used by price-conscious families, despite the "substandard" labeling, if the substitute were available at a lower cost than nutritionally superior products.[3]

Other AMA recommendations were: (1) "that the description 'imitation' or 'simulated' be reserved for products which are nutritionally equivalent to or superior to whole cow's milk and cow's milk products, and (2) that nondairy products which are nutritionally inferior to whole cow's milk be identified by name, color, flavor and/or package design in such manner that they could not be reasonably mistaken for cow's milk, simulated milk, or their products."[4]

They also recommended that imitation milks should contain the same amounts of nutrients as an equal measure of whole cow's milk: calcium; phosphorus; riboflavin; thiamine; niacin; vitamins B_6, B_{12},

[1] Federal Register, May 18, 1968.

[2] op. cit.

[3] Breeling, J. L., Paper presented at Dairy Products Institute, University of Minnesota, St. Paul, Minnesota. September 11, 1968.

[4] Ibid.

E, and C; folacin; and pantothenic acid in addition to vitamins A and D.

The AMA statement further urged that vitamin D requirements be made mandatory rather than optional, and that 100 U.S.P. units per 8 fluid ounces be set as the upper and lower limits. Additionally, simulated milk should not contain larger amounts of sodium and potassium than whole cow's milk, and optional trace nutrients should include iron, magnesium, copper, zinc, and manganese.

In summary, these are just a few of the statutory and judicial determinations that have influenced and will continue to influence the development of markets for filled and imitation milk. It appears that a large system of state and federal laws will have to be modified before large substitution can take place. However, this process could occur in a relatively short period of time. Absolute legal barriers to the sale of milk substitutes are not likely to prove effective for an indefinite period of time.

Nutritional Issues

Milk is generally considered to have a special place in our diets, especially for the very young. Evidence that dairy products contribute a large proportion of several vital nutrients is presented in table 1. They supply about one-fourth the protein, three-fourths of the calcium, and one-half of the riboflavin consumed by the U. S. population, as well as significant amounts of other nutrients. While food sources other than dairy products could supply all the required nutrients, current cultural and economic considerations suggest that there is a continuing need for dairy products.

Table 1. Percent of total nutrients contributed by dairy products in the United States, 1965*

	Dairy products excluding butter	Butter
Food energy	12.5	1.8
Protein	23.8	†
Fat	14.6	4.5
Carbohydrate	7.5	†
Calcium	76.9	0.2
Phosphorus	38.4	0.1
Iron	2.3	0.0
Vitamin A value	12.1	3.4
Thiamine	10.5	0.0
Riboflavin	44.8	0.0
Niacin	1.9	0.0
Ascorbic acid	5.1	0.0

* Food Consumption, Prices, and Expenditures, USDA, ERS, Ag. Econ. Report No. 138. Table 39. Washington, D.C., July 1968.
† Less than .05 percent.

Faced with the prospect of increasing use of filled and imitation milk and the availability of a wide variety of other new food products, an attempt to assess their relationship to good nutrition is in order.

Almost certainly, the question of nutritional adequacy will become an issue: What evidence should be accepted as proof of nutritional adequacy? Are feeding tests that determine the biological value of protein an adequate supplement to analytical data, or should long-range feeding trials with human subjects be required? The American Academy of Pediatrics' Council on Nutrition has stated, "Improvements in food technology promise the appearance of new infant formulas containing new types of protein combined with new sources of carbohydrate and lipids. In addition, modifications of milk or other proteins may permit preparation of formulations with either enhanced nutritional value or even decreased nutritional value. For example, modification of proteins may also remove certain trace elements for which no previous essentiality has been demonstrated. While the Committee welcomes potential benefits to infant nutrition afforded by new products, it believes that properly designed and conducted clinical trials of these products should be mandatory prior to marketing. In the past, new formulations have occasionally been sold to the public without prior evidence of efficacy, and occasionally to the detriment of a considerable population of infants. It must be demonstrated that a new formulation does not increase the nutrient requirements for specific substances."[5]

The current guideline for nutritional practice in the U. S. and for its evaluation is the Seventh Revised Edition (1968) of "Recommended Dietary Allowances," a report of the Food and Nutrition Board of the National Academy of Sciences, National Research Council.[6] In this report, recommended allowances judged to be adequate for practically all of the U. S. population are listed in quantitative terms for calories and 16 nutrients. These nutrients are protein; the minerals: calcium, phosphorus, magnesium, iron, and iodine; the fat-soluble vitamins: A, D, and E; and the water-soluble vitamins: ascorbic acid, folacin, niacin, riboflavin, thiamine, vitamin B_6, and vitamin B_{12}.

Approximate quantitative requirements for certain other nutrients are indicated. The need for all other essential nutrients is discussed in qualitative terms. For many of these, further research is required before quantitative amounts can be recom-

[5] *Pediatrics*, November 1967.

[6] Publication 1694, National Academy of Sciences, Washington, D.C. 1968.

mended. It is significant that allowances for seven of the nutrients (phosphorus, iodine, magnesium, and vitamins E, B_6, B_{12}, and folacin) are listed for the first time. Increased emphasis on the possible dangers of excessive intakes of calories and some nutrients, notably saturated and polyunsaturated fat, vitamin A and vitamin D, is apparent in the 1968 report.

The present state of nutrition education in the U.S. is still largely confined to a general emphasis on a balanced diet. A variety of selections from each of four major food groups is recommended for daily requirements: (1) milk and dairy products; (2) meat, fish, or eggs; (3) vegetables and fruits; and (4) breads and cereals. With adequate selections from each of these food groups, it is likely that daily nutrient requirements will be satisfied. However, if an imitation product that is low in vital nutrients is substituted for a natural product, nutritional deficiencies might be expected. This could be a serious problem among low-income families whose choice of foods is restricted or whose lack of education prevents them from selecting other foods to supplement their diets.

While most people still depend on traditional foods and plan meals from the four major food groups, increasing numbers of people are becoming more knowledgeable about their food needs. Some have acquired this through formal education, while others have learned from medical experiences, self-study, communications media, extension and public health programs, etc.

The reliability of the public's knowledge may sometimes be less than adequate, but they are at least familiar with their specific nutrient needs. And, to a lesser extent, many know how to meet their dietary needs by selecting the right foods. As the number of better informed consumers increases, demands for accurate labeling of foods and for greater producer responsibility can be expected.

Issues that have arisen from the creation of new food products can be further examined in light of some of the major nutritional considerations.

Protein. For many purposes, protein is best viewed as a natural mixture of several nutrients, the amino acids, joined together into characteristic entities. However, in practical nutrition, it is still useful to consider protein as a single entity and to speak of its total quantity in a food or diet. However, its quality or biological value must be discussed in terms of individual amino acids, some of which are absolutely required in the diet and others which serve a less essential or supplementary role.

Most U.S. consumers' diets contain more than adequate quantities of protein. Selections from a wide variety of foods, including meat, eggs, and dairy products, provide the quality required in daily diets. However, in some population segments, protein intake may be insufficient and the quality inadequate. Among these people, protein malnutrition is a possibility, as attested to by reports of outbreaks of kwashiokor among children in poverty areas. While its incidence is not widespread, the possibility of malnutrition must be recognized and constant attention to this possibility must be part of everyone's total nutritional concern.

Some new food products promise to augment the protein need of the nation's consumers, while others might actually undermine protein nutrition. In the case of filled milk, this is not a factor because the protein component remains essentially unchanged from its natural source. However, imitation milk poses a serious problem. The quantity of protein in products currently being marketed is lower than natural dairy products. Also, there is a possibility that proteins lower in quality than milk caseinate may eventually be used. If these products are widely used by people who once relied on milk for large quantities of their high quality protein, then protein malnutrition might develop. This would most likely affect growing children, for whom milk and dairy products contribute significant portions of required protein.

Minerals. As a group, minerals are absolutely essential to our diets. But because each mineral is nutritionally unique, any consideration of them as a group tends to be limited and overgeneralized. Actual quantities required vary considerably. Some minerals are needed only in trace amounts. Some minerals are more readily absorbed by the body than others. Several minerals are nutritionally interrelated. For example, the calcium-phosphorus ratio may be as important as the quantity. For adequate nutrition, nutritionists recommend reliance on a wide varied selection of foods in customary use.

In relative terms the quantities of required minerals are much lower than those of protein, carbohydrates, and fats. The practice of supplementing foods with minerals or taking direct doses of mineral supplements is feasible, but it adds an unnecessary burden to the family food budget and is not generally considered to be a satisfactory procedure.

Synthetic foods are constituted from purified ingredients and usually are deficient in minerals, which are removed during processing. To bring them into nutritional equivalence with their natural counterparts, minerals must be added. It is unlikely that this will be done unless public demand or the law spurs producers to do so.

Filled milks do not present a calcium nutritional problem, but imitation milk raises a potentially serious problem. As data in table 1 indicate, dairy products supply three-fourths of the calcium in U.S. diets. Because liquid milk is the major contributor of this calcium, substituting products that contain only one-sixth as much calcium as normal milk would markedly reduce calcium intakes (see tables 2 and 3). While other foods generally less rich in calcium might be selected to meet calcium needs, it is unlikely that this would be done by or for *all* individuals. Calcium deficiencies could occur, particularly in infant and child feeding, during periods of pregnancy and lactation when calcium requirements are especially high. Obviously standards or adequate labeling will be required.

Phosphorus is also needed in a relatively high quantity, and dairy products presently contribute more than 33 percent of the phosphorus to our diets. Again for infants, milk is the principal source of phosphorus, and deficiencies may arise from use of substitutes. However, because many foods are relatively high in phosphorus, serious deficiencies are unlikely beyond infancy.

With respect to other minerals needed in our diets, widespread deficiencies have not been encountered. The public has generally relied on a balanced diet of mixed foods from natural sources to provide adequate quantities of other minerals.

Vitamins. Like minerals, vitamins cannot be treated as a group in a comprehensive discussion of the nutritional implications of their level of concentration in certain foods. They are a diverse group of compounds; each presents a unique set of nutritional properties and problems. All are required for body functions, but not all are required under all conditions nor are absolute requirements known for all vitamins.

Most present-day diets contain well-balanced selections of customarily available foods and provide sufficient vitamins to meet normal requirements. Widespread vitamin-deficiency diseases, such as pellagra, have been virtually eliminated in the U. S. by legislation calling for enrichment of flour with niacin, thiamine, and riboflavin (as well as iron). Enrichment procedures are relatively inexpensive; however, appropriate standards should be adopted.

The individual vitamin content of a new synthetic or imitation food product can be expected to vary greatly from one manufacturer to another, depending on the nature of the ingredients. Some may be completely lacking in certain vitamins. Others may contain excessively high amounts of some vitamins if the additives are not carefully monitored. Overdoses of vitamin D, and vitamin A to a lesser extent, can cause serious side effects while other vitamins appear to be harmless. Their exact effect has never been fully evaluated. Consequently, it seems appropriate that major concern should center on establishing minimum quantities.

Filled and imitation milks being marketed now contain varying amounts of the fat-soluble vitamins A and D because these vitamins are associated with the fat portion. When the added fat happens to be purified coconut oil, the resulting product lacks both vitamins unless they are deliberately added. However, filled milks would provide essentially the same quantities of water soluble vitamins of the B complex as natural milk.

Riboflavin merits specific mention because dairy products contribute approximately 45 percent of the riboflavin consumed in U. S. diets. This vitamin, as well as most of the other important B-vitamins,

Table 2. Comparison of nutrients in market milk and "synthetic milk"

Nutrient	Market milk*			"Synthetic milk"†		
	Percent	Gm/qt	Gm/gal	Percent	Gm/qt	Gm/gal
Carbohydrates	4.90	48.00	192.00	6.80	66.00	264.00
Fat	3.50	34.00	136.00	3.10	30.00	120.00
Protein	3.50	34.00	136.00	0.80	7.30	29.20
Ash	0.70	7.00	28.00	0.50	4.90	19.60
Calcium	0.12	1.15	4.60	0.02	0.18	0.72
Phosphorus	0.09	0.91	3.64	0.05	0.45	1.84
Sodium	0.05	0.49	1.96	0.07	0.68	2.72
Potassium	0.14	1.41	5.64	0.36	3.50	14.00

* Based on the composition of fluid whole milk in *Newer Knowledge of Milk*, 3rd edition, National Dairy Council, Chicago, Illinois, 1965.
† Based on an analysis of a simulated milk product purchased on the Twin City market.
Source: Coulter, S. R. and Manning, P. B., "The Challenge of Imitation Milk," Paper presented at the Annual Dairy Industry Conference, Department of Dairy Science, University of Arizona, Phoenix, Arizona, February 14, 1968.

Table 3. Comparison of certain dairy products and their simulated counterparts (constituents per 100 grams dry matter)

		Gross composition				Minerals				Vitamins		
		Carbohydrates*	Fat	Protein†	Ash	Calcium	Phosphorus	Sodium‡	Potassium‡	A§	Riboflavin¶	Total solids
		grams				mg				IU	ug	
Milk, fluid, whole		38.9	27.8	27.8	5.6	936	738	396	1,143	1,112	1,350	12.6
Imitation or nondairy..	A	52.8	31.7	7.4	4.0							
milk	B	61.8	27.7	6.8	4.5	25	248	...	....	....	....	12.1
Coffee (light) cream ..		14.6	72.7	10.5	2.2	136	673	636	3,270	....	....	11.0
Coffee whiteners												
Dry	A	48.5	39.9	4.9	2.8	353	280	182	331	3,020	509	27.5
	B	49.1	36.5	5.0	2.7							
	C	46.1	37.2	5.0	2.7	12	718	293	788	110	....	98.9
	D	48.7	35.8	4.9	3.0	16	625	258	768	110	....	98.9
Liquid	A	50.2	47.9	3.0	1.5	46	561	290	606	440	108	98.9
	B	42.0	48.0	5.0	2.0	12	62	146	1,040	200	219	98.5
	C	49.1	40.5	8.6	2.7	23	30	543	6	2,170	....	26.7
	D	37.9	52.6	2.6	1.1	70	155	245	300	250	....	20.0
Whipping (heavy) cream		7.8	85.3	5.6	1.2	72	212	496	121	....	....	22.2
Whipped toppings						52	57	...	....	....	....	21.1
Dry	A	40.8	43.2	4.6	1.0	190	149	98	134	3,510	268	41.0
	B	40.6	45.4	5.7	0.6	17	32	100	48	800	....	99.9
Liquid	A	25.7	58.5	..	0.5	12	46	97	6	1,370	....	98.9
	B	31.6	55.3	2.0	0.2	15	3	198	13	1,040	....	39.3
Aerosols						14	20	20	2	2,220	....	49.1
Dairy base	A	22.0	58.0	10.7	2.3	310	276	255	310	2,540	145	35.5
	B	20.4	63.3	8.5	2.3	274	267	413	209	2,650	189	41.2
"Nondairy"	A	29.2	58.7	...	0.5	10	3	243	11	1,130	....	39.1
	B	23.9	67.7	7.6	0.5	23	71	173	6	1,370	....	39.3

* Modification of method for total carbohydrates of Dubois, M. et. al., *Anal. Chem.*, 28, 350 (1956).
† Protein calculated from Kjeldahl nitrogen data (TPN X 6.78).
‡ Atomic absorption method of Murthy, G. and Rhea, U. J., *Science* 50. p. 313, 1967.
§ Modification of method for total vitamin A activity of Boyer, P., *Ind. Eng. Chem., Anal. Ed.*, 15, 101 (1944).
¶ Scott, M., et. al., *J. Biol. Chem.*, 165, 65 (1946).
Source: *op. cit.*

would be absent from imitation milks unless it was also deliberately incorporated.

Dietary Fat. The type and quantity of dietary fat in food products are receiving considerable attention at the present time. It has been recognized for some time that a high intake of calorie-rich fat is associated with obesity. And more recently, animal fat has been implicated as a contributing factor in the growing incidence of coronary heart diseases in this country. Though a causal relationship between diet and heart disease is difficult to prove, there is increasing evidence that such a relationship will be ultimately established. The American Heart Association has recommended that coronary-prone patients should avoid or correct obesity by reducing their caloric intake as a measure to restrict saturated fat, cholesterol, and simple sugar intakes and to increase the proportion of polyunsaturated to saturated fat.[7]

Various studies have indicated that these recommendations help to reduce blood cholesterol levels. Growing evidence suggests that elevated blood cholesterol increases the likelihood of coronary attacks. It is reasonable to assume that as more experimental evidence accumulates, similar recommendations concerning dietary fat will be made for broader segments of the public.

These recommendations will be pertinent to legislative action designed to restrict the type and quantity of fat in filled milks or imitation milk products. At present, coconut oil is widely used for these purposes, and it is as high in saturated fatty acids as any fat commonly used today. Further, because it is a fat from a plant source, it is described on product labels simply as "vegetable fat." However, coconut oil differs greatly from many other vegetable fats which are lower in saturated fatty acids and higher in the polyunsaturated ones. The need for specific identification of the type of fat used in these products should be obvious.

Technical Issues

In the production of fluid milk substitutes, the real issue is not whether industry can produce a beverage that looks and tastes exactly like milk. Instead, the issue is centered upon the question of whether a nondairy product can be produced at sufficiently low cost to take the place of milk and still meet all nutritional requirements and food desires of consumers.

Beverage milk, of course, is of primary concern. However, if the market for fluid milk is lost, this might seriously affect the availability of milk for other uses. The extent to which substitutes for other dairy foods could be supplied would then become a matter of critical importance.

Simulated milk products sold in the Minneapolis-St. Paul area during 1967-68 had the appearance and general taste characteristics of milk: They were slightly sweet, contained certain flavor constituents common to milk, and created physical (feel) sensations similar to those of milk. They could be distinguished from milk by the rather characteristic flavor of sodium caseinate. If held for several days in the refrigerator, samples of these products exhibited some separation, characterized by the appearance of a whey-like liquid at the bottom of the container. These simulated milk products were very low in protein and minerals. If they are sold in semblance of milk or as imitation milk, the requirement for nutritional equivalence is hardly unreasonable. The problems associated with producing an imitation milk with physical characteristics similar to cow's milk will be discussed, therefore, under the assumption that nutritional equivalence is required.

Protein

Protein in these products must be essentially flavorless and should be capable of dispersing itself throughout an aqueous solution so there is no evident physical separation during pasteurization or after storage for at least 2 or more weeks. Possible proteins include:

Caseinates. Acid casein has been an article of commerce for generations. When added to alkali and water, the acid casein may be redispersed. Sources of flavor include products of the browning reaction (lactose protein interaction). The lactose content of casein varies widely, depending on the thoroughness of washing. Commercial casein contains sufficient lactose so that flavor, a result of the browning reaction, depends upon temperature, moisture content, and time.

The characteristic flavor of casein is often described as gluey. This association derives from the fact that one of the principal uses for casein once was in glue. In addition to the stale, gluey flavor, alkali caseinates may also have a somewhat soapy flavor. The flavor characteristics of caseinates can be suppressed through careful control of manufacturing and storage conditions. Also, other methods of preparing caseinate could be developed with the technology presently available. The physical stability of redispersed caseinate should not present any major problems.

[7] "Risk Factors and Coronary Disease: A Statement for Physicians," American Heart Association, December 1967.

Soy protein isolates. The major problem in using soy protein preparations in imitation milk is flavor. Purification of the protein reduces flavor intensity, but it has not been completely eliminated in the best preparations. Flavor is also a factor with other cereal proteins. Production of a sufficiently bland cereal protein is technically possible, although substantial research will be required. There is every reason to believe that products with adequate physical stability in aqueous suspension can be produced. Because the flavor constituent(s) of protein differs from one source to another, a blend of proteins could conceivably minimize the flavor intensity of any one protein and standardize flavor.

The first imitation products contained little protein due to the fact that the flavor of the product would have been less acceptable at higher caseinate levels. The caseinate might have been supplemented with another protein which, although it contributed additional flavor, would not have intensified the casinate flavor. Flavor materials might be added to cover up or mask the flavors from the protein.

Minerals

A breakdown of the average number of milligrams of milk salt constituents in 100 milliliters of skim milk is as follows: sodium, 50; potassium, 45; calcium, 120; magnesium, 13; phosphorus, 95; chloride, 100; sulfate, 10; carbonate, as CO_2, 20; and citrate as citric, 175.[8]

Calcium and phosphorus are the only salt constituents that present a problem in manufacturing imitation milk. These also are the two salt constituents that milk supplies in important quantities (see table 3). An integral part of the casein molecule contains part of the phosphorus and also binds calcium very tenaciously. Part of the calicum and phosphorus is in the form of dissolved and colloidal salts. Salts of calicum and phosphorus, such as dicalcium and tricalcium phosphate or mixtures of the two, could easily be added to supply the same levels of calcium and phosphorus as whole milk. However, they are only partially soluble in water. Dispersing them so they are not palpable to the tongue upon tasting is a problem difficult to resolve. But soluble salts such as calcium chloride, calcium gluconate, and disodium phosphate might be used. Citric acid and sufficient alkali could then be employed to neutralize the hydrogen-ion concentration of the imitation product.

[8] Jenness and Patton, "Principles of Dairy Chemistry," John Wiley and Sons, Inc., New York, 1959.

Other Ingredients

Other major ingredients of milk, apart from water, are carbohydrate (lactose) and fat. For flavor, a suitable corn syrup solids product is available for the carbohydrate, bland coconut oil or other vegetable fat preparations as fat.

Milk contains a long list of minor constituents, including vitamins. Vitamin fortification of milk substitutes to the same levels as commercial homogenized fluid milk is neither difficult nor expensive. Compounds are available which, if used in correct proportions, will produce flavor characteristics resembling those of natural milk. There is no evidence that deficiencies in any of the other minor constituents of milk would have significance.

Economic Consequences

Recent market growth of substitutes for fluid milk has caused more concern in the dairy industry than any product since margarine. Sales of filled milk more than doubled from November 1967 to March 1968, but leveled off since (see table 4).

The number of markets selling these products doubled during the 5-month period. However, these data indicate that imitation milk has met with less success than filled milk. Filled milk handlers increased from 41 in November 1967 to 65 by May 1968. Imitation milk handlers increased from three in November 1967 to 20 in February 1968, but declined to five by February 1969 (see table 4).

Filled milk sales, however, represent only 0.4 percent of the fluid milk sales in all federal order markets. In some individual markets, they constitute a much larger share. For instance, filled milk represents more than 12 percent of the fluid milk sales in the Central Arizona milk market.

Few data are available on filled milk sales in nonfederally regulated markets. But at last report about 25 percent of Honolulu's fluid sales were filled milk. In April 1968, filled milk represented about 1.1 percent of total fluid milk sales in California.

The longrun economic consequences of filled and imitation milk, supposing that technical and nutritional problems can be overcome, will largely depend on how effectively milk can compete with substitutes in terms of production costs. In the shortrun, the consequences of these products will depend on the status of laws forbidding or regulating their manufacture and sale, and on price support programs for the dairy industry. Consumer acceptance of the product will be related to their nutritional and technical characteristics, and price.

Table 4. Filled milk sales in Federal Milk Order Markets from November 1967 to February 1969*

Date	Filled milk Nondairy fat and Fluid skim milk	Filled milk Nondairy fat and Nonfat dry milk	Imitation milk Nondairy fat, sodium caseinate and other protein	Total
	(1,000 lbs.)			
November 1967				
Markets	13	9	3	17†
Handlers	30	9	3	44
Volume	1,787	581	‡	2,368
December 1967				
Markets	14	9	9	24†
Handlers	33	21	15	69
Volume	2,417	912	‡	3,329
January 1968				
Markets	15	8	10	26†
Handlers	33	23	14	70
Volume	3,083	876	‡	3,959
February 1968				
Markets	19	8	12	30†
Handlers	37	22	20	79
Volume	3,488	1,078	‡	4,566
March 1968				
Markets	19	11	10	30†
Handlers	41	24	15	80
Volume	4,118	1,072	‡	5,190
April 1968				
Markets	19	11	8	28†
Handlers	43	21	11	75
Volume	4,046	893	‡	4,939
May 1968				
Markets	20	10	7	28†
Handlers	45	17	10	72
Volume	4,202	879	‡	5,081
June 1968				
Markets	18	10	8	27†
Handlers	45	16	11	72
Volume	3,900	723	‡	4,623
July 1968				
Markets	18	10	8	27†
Handlers	46	16	11	73
Volume	4,258	867	‡	5,125
August 1968				
Markets	16	9	8	27†
Handlers	40	15	8	63
Volume	4,428	846	‡	5,274
September 1968				
Markets	16	8	8	25†§
Handlers	41	15	8	64
Volume	4,292	807	‡	5,099
October 1968				
Markets	16	8	8	25†§
Handlers	41	15	8	64
Volume	4,888	753	‡	5,641
November 1968				
Markets	16	9	9	28†§
Handlers	42	11	9	62
Volume	4,532	809	‡	5,341

Table 4. Filled milk sales in Federal Milk Order Markets from November 1967 to February 1969 (continued)

Date	Filled milk: Nondairy fat and Fluid skim milk	Filled milk: Nondairy fat and Nonfat dry milk	Imitation milk: Nondairy fat, sodium caseinate and other protein	Total
	(1,000 lbs.)			
December 1968				
Markets	16	9	8	27†§
Handlers	39	14	9	62
Volume	4,582	732	‡	5,314
January 1969				
Markets	16	8	5	23†§
Handlers	39	14	6	59
Volume	4,994	749	‡	5,743
February 1969				
Markets	17	5	5	22†§
Handlers	41	9	5	55
Volume	4,772	468	‡	5,240

* May not reflect total sales in all other markets.
† Represents number of markets reporting sales of one or more products.
‡ Unknown.
§ Cedar Rapids-Iowa City, Central Arizona, Central Illinois, Cincinnati, Columbus, Corpus Christi, Delaware Valley, Eastern Colorado, Eastern Colorado, Eastern Ohio-Western Pennsylvania, Indianapolis, Kansas City, Miami Valley, Minneapolis-St. Paul, Nebraska, Western Iowa, New York-New Jersey, North Central Iowa, Northwestern Ohio, Oklahoma Metropolitan, Puget Sound, Red River Valley, San Antonio, Southern Illinois, Tri-State, Upper Chesapeake Bay, and Washington, D.C.

Source: "Dairy Situation," D.S. 325 ERS. U. S. Department of Agriculture, Washington, D.C., May 1969. p. 23.

Table 5. Possible combinations of government programs affecting the marketing of filled and imitation milk

	Situation 1	Situation 2	Situation 3	Situation 4	Situation 5
Statutory restrictions on manufacture and sale of filled and imitation milk	none	none	yes	none	none
Dairy price supports	yes	yes	yes	none	altered to put more of burden of return on nonfat dry milk
Pricing provisions of state and federal milk marketing orders with compensatory payments*	not applied	applied	applied	not applied	not applied

* Compensatory payments are additional payments by the buyer in the regulated market on milk or milk products purchased from non-regulated areas. It is usually calculated as the difference between the average producer milk price in the regulated market and the administratively determined price paid by handlers for fluid milk in the market. These returns are then distributed to producers in the regulated market.

Of the many economic regulations possible, only three factors or constraints are likely to be critical: (1) statutory restrictions on the manufacture and sale of the substitutes, (2) the type of price support program for traditional dairy products and (3) pricing provisions of state and federal milk orders. Five possible situations are listed in table 5. Probable consequences of these sets of conditions are discussed in the following pages.

Situation 1. Maintain only the dairy price support program as it is currently used. Under this condition, the production and sale of filled milk would be widespread. Filled milk would be substituted for natural milk because of the substantial savings over natural milk. Filled milk could be produced from either fluid skim milk or nonfat dry milk. If the skim milk was priced at Class I prices under federal and state marketing orders and agreements, then there would be a distinct advantage to using nonfat dry milk from manufacturing milk areas.

The savings from substitution of vegetable fat for butter fat is quite large. Currently, butter fat is priced at about 80 cents per pound and substitute fats are priced from 25 to 30 cents per pound. On a per hundred weight basis, disregarding the reconstituting costs, the savings would amount to at least $1.75.

Numerous calculations have been made in recent months comparing the costs of filled and natural milk. A Purdue study estimated the cost of ingredients for a half-gallon of natural milk and alternative substitutes.[9] The cost for natural milk was calculated at 26.1 cents per half gallon (see table 6). The cost of filled milk made from skim milk priced under market orders was calculated at 19.2 cents per half gallon.[10] If filled milk was made from fluid skim milk purchased at the manufacturing grade milk price, the ingredient cost would be 11.5 cents per half gallon. If filled milk was made with nonfat dry milk, the cost would be 14.5 cents per half gallon. Clearly, on the basis of ingredient costs, all types of filled milk have a distinct economic advantage over natural milk.

Experience indicates that there is greater consumer acceptance of filled milk than of nondairy imitation milk. Furthermore, under the dairy price support program, the ingredient cost for imitation milk exceeds that of filled milk. In the Purdue study, a cost of 15 cents per half gallon was computed for imitation milk made with either sodium caseinate or soy protein.[11] Under this situation, imitation milk is not likely to find a wide market other than for persons with dietary problems associated with natural milk.

Table 6. Ingredient cost relationships for milk and imitation milk, January 1967

Product	Cost/ half gallon
Milk*	cents
3.5 percent butter fat	26.1
2.0 percent butter fat	20.9
Skim milk	13.9
Type I† — Filled milk made from:	
Class I skim	19.2
Class II skim‡	11.5
Reconstituted skim — no compensatory payment§	14.5
Reconstituted skim — compensatory payment¶	23.1
Type II — Imitation milk with sodium caseinate**	15.0
Type II — Imitation milk made entirely from vegetable products††	15.0

* Assumes a Class I price of $6 per cwt. and a butter fat differential of 8 cents per point.

† Includes a cost of 2.04 cents per half gallon for a base of emulsifiers, stabilizers, mono-and diglycerides and corn syrup solids. This base is added at the rate of 0.7 percent. Also, assumes a price of 25 cents per pound for refined coconut oil.

‡ Assumes a Class II or manufacturing price of $4 per cwt. and a 7.5 cent butter fat differential per point.

§ Assumes a nonfat powder price of 22 cents per pound.

¶ Assumes a compensatory payment of $2 per hundredweight — the difference between the Class I and Class II price.

** Total ingredient costs of a sodium caseinate product as given by a single supplier of the Type II product ingredients.

†† Estimate of the cost of a purely vegetable product, assuming a substitution of soya protein for the sodium caseinate in the Type II product.

Source: R. D. Knutson, "The Competitive Position of Imitation Milk," *Economic and Marketing Information for Indiana Farmers*, Purdue University, Lafayette, Indiana, January 31, 1968.

The shift to filled milk has implications for several groups in society. If the cost savings are passed on to consumers in the form of lower prices, then the total consumption of fluid products (filled and natural milk combined) would be somewhat larger. However, because the demand for milk is highly inelastic, total consumption would increase only moderately. Also, due to this inelastic demand, consumers' total expenditures for natural and filled milk would decline.

The processing industry, under these circumstances, would be purchasing much larger quantities of skim and nonfat dry milk. In turn, this would displace purchases of natural fluid whole milk. Sources for skim and nonfat dry milk might be the same producers that previously supplied fluid whole milk or others who are willing to sell at lower prices than the original source. Vegetable fat would be purchased from firms other than dairy plants.

It is probable that the same firms that currently process natural fluid milk products would process filled milk. The total volume of fluid products processed by these firms would be larger. Profits generated from processing and distributing filled milk might be equal to or greater than those earned in processing and distributing natural fluid milk products. Industry personnel indicate that filled milk products now yield a higher profit margin than regular milk. In time, this might change.

The impact of filled milk substitution on milk producers would differ not only from region to region, but also among types of dairy firms to which producers sell their milk. If the product was made from nonfat dry milk, a large proportion of natural fluid milk sales (Class I) would be displaced in state and federal order markets. Class I fluid utilization would decline and the average price to producers in these markets would decrease. Displaced milk would be diverted to manufactured dairy products.

If locally produced skim milk in the respective fluid markets was used for filled milk only, Class I butter fat sales would be displaced. Because the

[9] R. D. Knutson, "The Competitive Position of Filled Milk," *Economic and Marketing Information for Indiana Farmers*, January 31, 1958, Purdue University, Lafayette, Indiana.

[10] This assumes a $6 Class I price, which is higher than Minnesota's but nearer the national average.

[11] Analysis of the product sold to date indicates lower nutritive value than natural milk. A product nutritionally equivalent to milk would undoubtedly cost more than indicated here.

butter fat differential for fluid uses and for manufactured dairy product uses is the same, the average price paid to producers for their milk would not decrease. In fact, increased fluid consumption would result in a somewhat higher average price to producers in these markets.

Butter fat extracted from milk used for filled milk would be used in manufactured products, principally butter. Regardless of what source the nonfat ingredients were derived from, nonfat dry milk or fluid skim, total U. S. butter production would expand. To maintain the support price level in an already surplus market, excess butter supplies would have to be purchased by the government. But as government butter stocks ballooned, strong pressure would be exerted to lower butter support prices.

In fluid markets, where filled milk reconstituted from nonfat dry milk was substituted for natural fluid milk, low prices would force producers to leave the industry. The demand for milk in manufacturing milk areas would probably increase due to the demand for nonfat dry milk in filled milk. Even though commercial demand for large supplies of butter would decline, the government price support program could maintain returns for the fat portion of milk. Thus, returns for milk in manufacturing milk areas could be increased.

Situation 2. Applying state and federal order pricing provisions to filled milk would bring about somewhat different consequences. These provisions eliminate the incentive to produce filled milk from "other source" skim or nonfat dry milk.[12] If filled milk was processed using locally produced skim milk, the ingredient cost would be 19.2 cents per half gallon (see table 6). If it was produced from locally produced manufactured nonfat dry milk, the cost would be 19.2 cents per half gallon *plus* the additional expense involved in drying the skim milk. Thus, producing filled milk from locally produced nonfat dry milk would be an uneconomic decision. The estimated cost of ingredients for filled milk made from "other source" nonfat dry milk, including a compensatory payment of $2 per hundredweight, would be 23.1 cents per half gallon. The price for a half gallon of regular whole milk averages 26.1 cents.

Clearly, the incentive to produce and sell filled milk in state and federal order milk markets would be somewhat reduced. But application of these provisions would introduce a condition that did not exist previously: Imitation milks made with either sodium caseinate or soya protein would be less expensive than filled milk. Therefore, if technical problems of production could be overcome and consumer acceptance achieved, imitation milk could become a threat to fluid milk markets.

The development and widespread acceptance of nondairy milk by consumers would alter the operations of fluid milk processors, particularly their method of procuring raw materials such as proteins, fats, carbohydrates, minerals, and vitamins. Processors might assemble these ingredients individually but most likely they would develop formulated bases containing all the ingredients. In all probability, fluid milk processors would continue to be major suppliers. But it is also probable that other firms, such as the large diversified food and chemical companies, would develop and market imitation milk. Thus, some sales of long-established milk processing and distributing firms would be displaced.

Supplying large quanities of processed protein for this purpose offers an attractive prospect to the soybean processor. Research on such products is and will continue to be supported. Whether research will eventually lead to a large scale investment in production facilities will be largely determined by the opportunities for profit.

For consumers the consequences of these substitutions are similar to those discussed in situation 1. Consumers would buy slightly more fluid products (natural, filled, and imitation milk) and spend somewhat less than if they had purchased only natural milk. But the difference would not be as great as in the first situation.

The effect on producers would be different than in situation 1. Locally produced skim milk would be used in filled milk sold on fluid milk markets. However, some fluid product sales might be imitation milk. This, then, would reduce the total amount of locally produced milk used in fluid products and the average producer price would drop in these markets. In the short run, large quantities of milk would be channelled into the production of butter, nonfat dry milk, cheese, and other manufactured dairy products. However, increased supplies of manufactured dairy products would not reduce prices in manufactured milk areas because of the government price support program. In the long run, some producers in fluid milk marketing areas would be forced out of production.

Situation 3. Restricting the sale of filled milk in interstate commerce is another means of controlling the production and sale of substitutes — one that is

[12] "Other source milk" means milk or milk products from other than local producers for the individual fluid milk marketing areas.

currently employed. This situation assumes that existing state prohibitions would be retained in the years to come. It should be noted, however, that several of the most populous states currently allow the manufacture and sale of filled milk.

If the pricing provisions of state and federal orders were maintained, the incentive to market filled milk would be reduced though not completely eliminated in those states where it was legal. However, as restrictions on filled milk became more prohibitive, the incentive to develop and market imitation milk would become more attractive. If these products became widely accepted and were produced without the use of sodium caseinate, the impact on the dairy industry might be more widespread and severe than if only filled milk was adopted.

An incentive would still exist in federal order markets to manufacture and sell filled milk in states where it was not illegal. But, as indicated in table 6, the ingredient cost for imitation milk would provide a 4.2 cent per half gallon advantage over filled milk.

The impact on consumption would be similar to that under the preceding set of conditions. A somewhat larger quantity of fluid products would be consumed but total expenditures would be less. The magnitude of the change would be less because of the restrictions.

Processors and distributors would be in much the same situation as they are now. Some filled milk sales would be made in those states not restricting its sale outright. Milk processors, food manufacturers, and other firms would devote a major effort toward developing and marketing imitation milk.

Markets for fluid milk would decrease as imitations were developed. Some locally produced skim milk would be used in the Class I (fluid) products in states permitting sales of filled milk. The net change would be a decline in the use of milk for fluid purposes and a decline in average milk prices in these markets. Manufacturing milk prices would be maintained through government purchases of larger quantities of manufactured dairy products.

Situation 4. This situation involves practically no economic regulation whatsoever. From the dairy industry's point of view, such an alternative would undoubtedly be the most unacceptable.

The first adjustment that would take place is a price reduction for butter and butter fat. If the butter fat price fell near that of vegetable fats, the cost advantage of substituting vegetable fat for butter fat would be eliminated. This would occur regardless of what price was placed on the remaining portion of milk. Butter fat prices would not need to fall completely to the level of vegetable fat because of the expense involved in removing butter fat and replacing it with a substitute. Nevertheless, filled milk would no longer be a problem for the dairy industry.

This adjustment would have other important consequences for the dairy industry. To maintain milk prices at present levels, a higher value would have to be assigned to the nonfat portion of the milk. In most fluid product uses, for cheese, condensed whole milk, and other whole milk products, shifting the value to the remaining portion of the milk would not create any problem. Fluid milk processors, cheese producers, and others could pay the same price for milk at average butter fat test. Changing the butter fat differential would merely involve a small redistribution of returns among producers.

The most serious impact would be on the butter powder industry. Cutting the butter fat price in half, from 80 to 40 cents per pound, would mean that an added $1.40 per hundredweight equivalent on 3.5 percent butterfat milk must be obtained from nonfat dry milk to maintain present milk prices. In view of the large powder surplus, maintaining prices would be impossible without large government purchases of powder at a very high price. Thus, the butter powder industry would likely be eliminated. Some milk now used in these products could be shifted to cheese, fluid products, and manufactured whole milk products.

Without an overall lowering of the price of milk, the milk substitute problem would still exist. Even with a change in the butter fat differential, natural fluid milk costs 26.1 cents a half gallon, opposed to 15 cents for imitation milk (see table 6). Under conditions listed at the beginning of this section, the imitation milk challenge would be met only if the price of natural milk in fluid markets fell near to the cost for ingredients of imitation milk.

Reduced producer prices for milk, without other adjustment, would decrease milk supplies. These lower prices would probably force some dairymen out of production. Which area of production would go first, those areas now producing primarily for fluid purposes or those producing primarily for manufacturing purposes, is not possible to determine with the information available. All areas affected by the price decline would experience some decrease in supply. Possibly, the decrease in milk price needed to challenge imitation products would be greater in fluid markets than in the manufacturing milk areas.

Thus, more adjustment in supply could be expected in fluid markets.

Situation 5. This situation is similar to that of situation four except that the price support program would be altered. Instead of eliminating support prices, more of the burden of supporting milk prices would be placed on nonfat products.

The consequences of this set of conditions would be much the same as in situation three. The major differences is the means by which competition from filled milk would be eliminated. The price support program would be used to lower the purchase price of nonfat dry milk and at the same time maintain current milk prices. Butter sales would not only increase, but with no incentives for replacing butterfat with vegetable fat in fluid uses, it is unlikely that government purchases of butter for price support reasons would be necessary. Milk, as indicated earlier, is valuable in many other uses as a complete ingredient. For such uses, producer prices could be maintained without government intervention.

Commercial sales, alone, of butter and nonfat dry milk would not be sufficient to support producer prices at existing levels. The government now purchases large amounts of nonfat dry milk to maintain the price at 23.1 cents per pound. Suppose, for a moment, that a butter fat price of 40 cents per pound would eliminate the incentive to replace milk fat with vegetable fat in fluid milk use. This would mean that the fat portion of 3.5 percent whole milk would be worth only $1.40 per hundredweight equivalent. The current support price for milk at average test is $4.28. Thus, the nonfat dry milk would have to return roughly 34.2 cents per pound plus processing costs to yield a total of $2.88 per hundredweight at the farm level. At this price, the government would have to be the principal buyer of nonfat dry milk. Inevitably, pressures would develop to lower the support price.

Again, imitation milk would be substituted for natural fluid milk because of the price advantage. This means, again, that increased total consumption of fluid products along with a somewhat lower total expenditure would result.

Quantity and Availability Considerations

In all cases we have assumed that ingredients for milk substitutes are available at current prices. However, this is not likely to be the situation. Total U.S. consumption of fluid whole milk has averaged about 50 billion pounds annually in recent years with 10 billion additional pounds of fluid skim milk, low fat (2 percent) fluid milk, and fluid cream products.

From a nutritional standpoint, protein and calcium are the critical constituents of milk. Sixty billion pounds of milk contain about 2.1 billion pounds of protein and 60 million pounds of calcium. A similar quantity of milk is required to secure the same amount of protein in the form of caseinate or milk proteinate, assuming that all the protein could be recovered. Unless the other constituents of milk could be sold at a sufficiently high price to make domestic casein available at a reasonable cost, it would be much cheaper to use the original milk for fluid milk purposes. Milk fat and lactose, the other principal constituents of milk, are already in surplus. Casein has been used as a source of protein because relatively cheap casein is available from New Zealand, Australia, and Argentina. But total milk production in these countries for 1967 was less than 41 billion pounds. These figures are cited simply to point out the absurdity of considering artificial milk that uses casein as the only protein source as a serious longrun threat to fluid milk.

If the sales volume of imitation milk should reach substantial levels, some protein will have to be derived from a source other than milk. A satisfactory protein product in adequate quantities could be developed largely from cereal sources. To supply 2.1 billion pounds of protein would require 6 billion pounds of soybeans, which is roughly 10 percent of the U.S. annual soybean production. It is probable that it would be supplemented by proteins from animal sources or by synthetic amino acids to attain nutritional equivalence with milk protein. If such a development was possible, any substantial threat to the dairy industry would lie well in the future because large quantities of materials and industry adjustments would be needed for such a supply. Nevertheless, these kinds of changes will occur with less perfect substitutes, although not to the extent implied by the discussion.

Presumably, there would be no supply problems for the minerals required in imitation milk provided they are derived from inorganic salts. The organic salts of calcium are relatively expensive. Supplying the large quantities necessary, should there be a major shift to imitation products, might pose a dificult problem. Milk contains about 0.1 percent calcium. For each 0.01 percent calcium furnished by calcium gluconate, 0.056 percent of the gluconate salt would be required: to supply even one-tenth the calcium in 50 billion pounds of milk would require 28 million pounds of calcium gluconate.

Adjustments in Milk Production

The previous analyses are based on the assumption that production costs for milk and milk products will remain the same in relation to the substitutes. However, improved milk production and processing efficiency could maintain the strong competitive position of the dairy industry.

Increasing milk production efficiency to meet the competition of substitutes is not an unrealistic adjustment for the dairy industry. Research recently completed by the Department of Agricultural Economics at the University of Minnesota indicates that high net return for the producer can be achieved at a price of only $3.65 per hundredweight for milk.[13] Such returns require adoption of new technologies, increases in average herd size and breeding and selection for higher yielding cows.

Increased efficiency is not just a theoretical challenge to milk substitutes: Such gains are now being made. In 1945, the average milk production per cow in Minnesota was about 5,200 pounds. That figure nearly doubled by 1967, reaching 9,430 annually. This change was sufficient to increase total milk production even though the total number of cows decreased by about 48 percent during the same period. The average production of Minnesota's DHIA herds has already reached 12,000 pounds per cow. Several of the best herds in the state now average 17,000 pounds or more per cow.

Increases in herd size that result from new techniques of handling dairy cows enable milk to become more competitive with substitutes. Data in table 7 indicate the change in returns to operators by increasing herd size from 40 to 77 cows. Returns from this size of operation, even with $4 per hundredweight milk, appear large enough to make dairying an attractive enterprise.

Animal agriculture, in general, has made tremendous progress in increasing efficiency in feed use and in reducing labor costs. Over the years, many observers have predicted that animal agriculture would decline, largely because of the presumed competition with humans for food from plant sources.

However, animals are not in competition for all plant food sources. A. I. Virtanen of Finland has stimulated interest in the ruminant as a producer of human food. He demonstrated that the cow is able to utilize cellulose, urea, and ammonium sulfate as the primary nutrients for growth and milk production.[14] The study suggests that the potential of the rumen as a mechanized and automated fermentation tank has not been fully explored. Cows need not compete with humans for food. They can utilize materials that are totally useless to humans to produce meat and milk as well as a wide variety of products made from milk.

In summary, potential changes in milk production techniques can make milk more competitive with milk substitutes. And as substitutes make inroads, there is a greater incentive to make the necessary adjustments.

[13] Buxton, B.M., and Hammond, J. W. et. al. "Minnesota's Dairy Industry: Old Problems with New Dimensions," *Minnesota Farm Business Notes*, Special Issue No. 3, March 1968. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

[14] Virtanen, A. I. and Lompila, M. "Production of Cows Milk on Purified Nutrients without Proteins." *Suomen Kenuistilehto B* 35,244, 1962.

Table 7. Estimated net returns to operators of efficiently organized one- and two-man farms at several levels of production cost with milk prices at $4 per hundredweight

	40-cow farm		77-cow farm	
Production costs	12,000 lbs. per cow	12,000 lbs. per cow	17,000 lbs. per cow	17,000 lbs. per cow
1968 input prices	$ 989	$ 6,835	$ 2,489	$13,583
10 percent increase	$9,006	$14,852	$16,744	$28,832
20 percent increase	$6,334	$12,180	$11,993	$23,749
30 percent increase	$3,662	$ 9,508	$ 7,240	$18,666

Source: "Minnesota's Dairy Industry: Old Problems with New Dimensions," *Minnesota Farm Business Notes*, Special Issue No. 3, March 1968. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

Summary and Conclusions

The preceding discussion leads us to several general conclusions regarding the development and use of filled and imitation milk.

1. The problem created by filled and imitation milk provides a preview of developments regarding other foods. Substitutes will be developed for many other traditional and natural foods. Because food processors control the nutritional content of these foods, a serious problem of public policy is raised. Should the nutritional adequacy of these products be left to the processors' discretion, with only the price system to serve as a guide as to how products will be constituted? Data presented in this bulletin suggest that this should be an area of special concern.

2. Milk has a unique place in the diets of the U.S. populace. It appears that a viable dairy industry will continue to contribute to the well-being of our entire population and provide a continued supply of natural products of predictable nutritional value for low-income families.

3. Currently, there are technical problems in developing a completely nondairy product that is acceptable to consumers and still approximates the nutritional characteristics of milk. It may not be necessary to duplicate milk completely, however. One problem is to provide at a reasonable cost, a suitable protein that is devoid of flavor, remains dispersed in water permanently, and has no detectable graininess. Another problem is that of providing calcium and phosphorus in amounts comparable to those in milk in a sufficiently dispersed form and at a pH suitable for a beverage. These problems probably could be overcome if substantial profit motives develop.

4. The economic consequences of filled and imitation milk will be greatly influenced by the legal environment in which these products are produced and marketed. Restricting the sale of these products outright or imposing burdensome pricing provisions prevents these products from being marketed in many areas. But such restrictions appear to be vulnerable to change. Undoubtedly, the present system has slowed the adoption rate of filled milk. On the other hand, the system is doing little to eliminate the threat posed by nondairy imitation milk.

If an imitation is to be successful, it likely will be made from a vegetable source protein and some milk proteins or synthetic amino acids. The cost of extracting protein from milk and recombining it with other nutrients probably would be greater than the price of natural fluid milk on most U.S. markets. Low-priced imports of milk protein give imitations an advantage at the present time.

The major longrun threat of both types of milk substitutes, combined with other developments such as the substitution of margarine for butter, the reduction in per capita fat intake, and general substitution of vegetable for animal fat, is to the butter-powder industry. If the butter fat differentials are changed to meet the challenge of filled milk, additional declines in the butter-powder industry are foreseeable. Other milk processing industries, however, are likely to continue using large quantities of natural milk in the immediate future.

Therefore, complete and rapid substitution of imitation for natural milk does not seem to be a serious threat for most of the dairy industry during the next few years. Filled milk in most parts of the U.S. is a profitable operation only because of the present method of pricing butterfat in milk. A change in the differential, with no change in the average price for milk, could eliminate the incentive to produce and market filled milk.

The food industry is changing and it will continue to change. Among the important changes are the kinds of foods that will be produced and consumed. Under ideal conditions, a completely nutritious and pleasing diet should be provided for all people at all times at the lowest possible cost. The lower the cost of meeting food requirements, the greater are the resources remaining to meet other needs and desires. The importance of fulfilling these needs requires little emphasis in view of the current unrest in many countries.

The substitution of other ingredients for natural milk in our diets represents a potential shift to lower resource-using foods. It appears, however, that such a change would call for some human and material adjustment in the dairy industry. Structural unemployment would be created. Some persons might find equally remunerative employment elsewhere in farming or in the nonagricultural sector. For others, these opportunities might not arise.

In conclusion, it is obvious that substitutes for fluid milk are a threat to the dairy industry. But, it is not necessary to conclude that a complete shift to the nondairy fluid imitation is inevitable. The dairy industry is constantly undergoing change. Improvement in farm production, processing, and marketing methods could make milk very competitive. Imitation food products do not represent the only increased efficiency in food production.

Improvements will be made in production and processing of other traditional foods. Therefore, ultimate growth of the imitation milk industry will depend on the relative gain in the production and processing efficiency of natural milk.

Role of the Institute of Agriculture

What should the University's role be in regard to new food products such as milk substitutes? This question is likely to be raised often because in recent years more than 20 percent of Minnesota's farm income has been generated from milk production. Several considerations bear on this question:

1. The University's research on various problems and structures will necessarily involve basic research that is related to the development and use of new products. It may range from gathering fundamental information used in development of new products to analyzing the economic and social consequences of their introduction. If the researcher is to be effective, he must be free to select methods of analysis and to evaluate research results. This may, at times, yield conclusions that are prejudicial to certain groups in the agricultural sector. This does not mean that the University or the researcher is indifferent to the problems of specific groups in our society.

2. Increasing the efficiency of the milk production and marketing processes is the most effective way for the dairy industry to compete with dairy substitutes. Research on milk production obviously benefits not only the dairy industry's ability to compete with substitutes, but is a service to consumers as well. The University has not exhausted the research possibilities related to animal breeding, nutrition, and resource combinations that could reduce milk production costs. It should continue to carry on research in these areas and extend the results of the research to the dairy industry.

3. Universities have contributed and should continue to contribute to society by carrying on research to develop useful new products, techniques, and ideas, and to assist in the development of policies that promote and improve social well-being. Much of the research has been publicly supported for humanitarian considerations. In the case of nondairy milk products, if the interests of mankind can be better served through the use of nondairy milk, the ultimate displacement of the dairy industry cannot be prevented. This issue, however, will not be determined for several years to come.

4. Food substitutes of all kinds will be developed and marketed whether the University becomes directly involved or not. Adjustment to the development and adoption of these products will be required whether or not the University analyzes the consequences. The University's expertise should be brought to bear on the evaluation and forecasting of consequences that arise as a result of these products, techniques, or policies.

5. The University is in a position to aid local dairy and nondairy industries and to develop and formulate policies and programs that ease the process of adjustment. In the case of agriculture, the Extension Service has long aided in this role.

6. The University has a responsibility to study the effect of agricultural production and changes therein on the ultimate consumer of the products. Towards this objective, the University must participate in the development of knowledge concerned with such effects on the consumer.

In conclusion, the University must be free to conduct research that might aid the development and refinement of food substitutes, to analyze problems created by their adoption, and to evaluate policies that will ease adjustment processes for affected industries. If resources allocated to these areas should have a higher payoff than in other areas, then they should be so allocated.