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NEW PRODUCTS FROM LACTOSE-HYDROLYZED MILK

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The hydrolysis of lactose with the enzyme lactase is opening up possibilities for new outlets for milk, lactose, and whey which may result in a whole new family of dairy products.

The major problem with lactose, the not-very-sweet milk sugar, and cheese whey, whose solids consist mostly of lactose, is that the supply far exceeds the demand. And as cheese production increases, excesses of the byproduct whey pile up. Although milk contains about 13 percent solids, 36 percent of which is lactose, whey contains 7 percent total solids, and 70 percent of these solids are lactose. Thus, in the over 30 billion pounds of liquid whey that American cheesemakers produce annually, there is a potential source of 1.5 billion pounds of lactose. The lactose manufactured in the United States in 1973, however, amounted to only 113 million pounds.

Traditionally lactose is used in infant foods and dietary formulations, in the compounding of pharmaceuticals, and in the production of caramel coloring. Recent high prices of sucrose have aroused new interest in edible lactose as a carbohydrate filler to improve the body and mouth-feel of many foods, and also as a humectant.

Lactose is a potential source of sweetness, but it's no match for sucrose and other sugars in this respect. It requires 2.5 to 3.5 times as much lactose to get the same sweetening effect as sucrose. And lactose is

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far less soluble than sucrose. Maximum lactose solubility at room temperature under equilibrium conditions is only 18 percent, compared to about 68 percent for sucrose.

These limitations of lactose are greatly minimized by hydrolyzing the sugar with lactase. This enzyme splits lactose into two other sugars, glucose and galactose, both of which are sweeter and more soluble than lactose.

At this point lactose hydrolysis is a promise, not a solution. Lactase, produced from microorganisms, is available commercially, but it's expensive. So far, only batch methods have been found practical for treating milk or whey with lactase. But the potential for lactose hydrolysis is so great, especially in these days of high sugar prices, that there should be plenty of incentive to improve the process to the point of economic feasibility. In addition, cheaper grades of lactase are becoming available.

The potential for lactose hydrolysis in providing new outlets for lactose and whey is a spin-off from research that initially had a quite different objective. Several years ago it was discovered that many people, principally members of non-Caucasian races, have difficulty in digesting milk and dairy products. One reason is a deficiency of lactase in their digestive tract. Lactose cannot be properly metabolized by the body unless it is broken down by this enzyme into its component monosaccharides. Lactase-deficient individuals may suffer abdominal pain, flatulence, bloating, or diarrhea if they consume substantial quantities of milk or uncultured dairy products.

Lactose intolerance is not rare. Indeed, it may be that Caucasians are in the minority among the world's people in having sufficient lactase in their system to digest milk without difficulty. To make the healthful benefits of

milk and other dairy products available to the lactase-deficient, an obvious approach would be hydrolysis of the lactose prior to product manufacture, using lactase from nonhuman sources. Whether the hydrolysis is done inside or outside the body, the action is the same. The lactose molecule, a disaccharide, is split to form the monosaccharides glucose and galactose.

Work on lactose hydrolysis has been in progress for several years at the Dairy Laboratory of the U.S. Department of Agriculture, now located at the Eastern Regional Research Center in Philadelphia. Scientists there have produced 11 low lactose dairy products, using batch methods of lactose hydrolysis. The enzyme used in these studies was isolated from the yeast Saccharomyces lactis in the form of a colorless, free-flowing powder by Gist-Brocade, Delft, The Netherlands, and made available by the Enzyme Development Corporation, New York, N.Y.

The enzyme was used in a batch process described by the flow diagram shown in Figure 1. Dairy products made from milk treated in this way had 87 to 94 percent of their lactose in the hydrolyzed form. The hydrolysis consisted of preheating fresh whole or skim milk to 31-32°C and treating it with the desired amount of enzyme, usually 300 p.p.m. After holding for 2.5 hours, the milk was ready to be processed further.

This low-lactose milk was used in the manufacture of dairy products on a pilot-plant scale in research facilities in Washington, D.C., by E. J. Guy, V. H. Holsinger, A. Tamsma, and M. J. Pallansch (1). The products included 3:1 milk concentrates, milk powders, ice cream, whey concentrates, and whey-soy beverage powder. After overcoming a few problems in production methodology, the physical and organoleptic properties of these products were investigated.

Pasteurized Whole Milk

Of course, all the products were sweeter than their counterparts made with untreated milk. This gave rise to some difficulties in defining their flavor in taste-panel testing. In judging fluid pasteurized whole milk using the ADSA score card, for example, a definite reciprocal relationship became evident between the amount of hydrolyzed lactose in the product and the flavor score. This is shown by data in Table 1.

When the responses of the judges were closely examined, it was clear that they considered marked sweetness a "foreign" flavor, and so they scored the milks down accordingly. When it became evident that the only organoleptic change they were perceiving was an increase in sweetness, a sweetness scale was developed to simplify reporting the organoleptic changes caused by lactase treatment. Tasters used an unstructured score sheet by which they could equate the results of lactase action with flavor changes associated with the addition of sucrose. The results, as plotted in Figure 2, showed that hydrolyzing 30, 60, and 90 percent of the lactose has just about the same effect on flavor as adding 0.3, 0.6, and 0.9 percent of sucrose, respectively, to the milk.

How acceptable to consumers is this increased sweetness in milk? Some work by Paige at Johns Hopkins University suggests that Negro adolescents, find milk with 90 percent of its lactose hydrolyzed highly acceptable. Paige asked his subjects to evaluate the milk, using the "Smiley" score card shown in Figure 3, after drinking an 8-ounce serving following an all-night fast. All the youngsters but one said they liked the lactase-treated milk and would drink it. It was judged to be sweeter than the untreated control by 56 percent of the respondents.

Frozen 3:1 Milk Concentrates

One highly attractive method of preserving whole milk is the freezing of 3:1 concentrates. Such products keep far longer than fluid milk under normal refrigeration, and when reconstituted they have a flavor virtually indistinguishable from fresh milk. The problem with them has been their tendency to thicken and coagulate on standing. This results from crystallization of the lactose which is brought to its saturation point when milk is concentrated.

Early research by Tumerman and his associates (2) had shown that lactose hydrolysis led to improvement in physical stability of concentrated milks during storage. It was puzzling, therefore, to find that when milk with 90 percent of its lactose hydrolyzed by lactase was concentrated and frozen, it kept only about a month longer before coagulating than an untreated control. This is shown in the two upper curves of Figure 4. Closer examination of Tumerman's results showed that he had heated his samples above pasteurization requirements. As illustrated by the lowest curve in Figure 4, samples that were post-heated at 71°C for 30 minutes after canning showed only a moderate rise in viscosity after 9 months of storage.

Organoleptic evaluation showed no significant difference in the flavor score of the reconstituted concentrate with 90 percent of its lactose hydrolyzed and a fresh whole milk control with sucrose added.

Milk Powders

Skim milk with most of its lactose in hydrolyzed form gave some trouble in drying to a powder. Whole milk was readily spray-dried, but skim milk powder tended to stick to the metal surfaces of the spray dryer. Upon studying the "sticking" properties of low-lactose skim milk powder, it was found that its "sticking" temperature was 10 to 15° lower than that of an untreated skim milk powder of comparable moisture content.

Thus, if lactase-treated skim milk is to be spray-dried efficiently, the surfaces of the dryer's powder-collecting apparatus should be held at temperatures below 60°C. Rapid cooling of the powder after collection is also recommended to avoid clumping.

Whey Concentrates and Ice Cream

Recent decreases in the available milk supply have resulted in an increased use of whey in many foods. Consequently, there was considerable interest in the properties of sweet whey and neutralized cottage cheese whey (pH 6.6), both treated with lactase to convert 90 percent of their lactose to the hydrolyzed form. Such wheys have not yet been successfully spray-dried. They can, however, be readily condensed to high-solids syrups in which the sugar does not crystallize. Such syrups, which take advantage of the presence of sugars more soluble than lactose, should find a variety of uses in the food trade.

One promising use for lactase-treated fluid whey is in the manufacture of ice cream. In today's ice creams, sandiness, which arises from lactose crystallization, is controlled by stabilizers included in the formula. Use of lactase-treated serum solids would permit stabilizer systems to be modified because they would no longer be needed to control sandiness. Ice creams made experimentally using lactase-treated whey to replace 25 percent of the total serum solids showed not only the possibilities for stabilizer modification, but for sucrose reduction as well. Organoleptic tests indicated that acceptable flavor and body could be achieved in these ice creams with a 10-percent reduction in sucrose level.

Whey-Soy Drink

In cooperation with the Agency for International Development, the Agricultural Research Service and several other agencies of the U.S.

Department of Agriculture have developed and are now procuring a beverage powder known as whey-soy drink. This is a substitute for nonfat dry milk and is being distributed abroad under two U.S. Food-for-Peace programs. The beverage powder was designed as a food supplement for preschool children and has also been proposed for pregnant and lactating women, particularly in emergency feeding situations.

Although inability to digest the lactose present has not been a problem with the young children receiving this product, their mothers could have difficulties digesting it. Accordingly, the properties of whey-soy drink manufactured with lactase-treated sweet whey were investigated. Taste-panel tests indicate that such a product would be just as acceptable (and perhaps more so, especially after storage) as the present whey-soy drink. Table 2 shows the flavor scores achieved on a 9-point hedonic scale by two experimental samples of lactase-treated whey-soy drinks as compared to an untreated control. In one of the samples, only the whey was treated with the lactase; in the other, both the whey and the soy were treated. Significant differences did not appear in the flavor scores of the freshly made products, but over the 6-month storage period, a decided preference for the treated samples was evident. The noticeably sweeter taste conferred on the lactase-treated samples was primarily responsible for the difference.

Fermented Products

A variety of fermented products, including yoghurt, cottage cheese, and cheddar-type cheeses have been made experimentally from lactase-treated milk by D. Gyuricsek, V. S. O'Leary, M. P. Thompson, and J. H. Woychik at the Eastern Regional Research Center of USDA's Agricultural Research Service in Philadelphia.

Yoghurt is enjoying a rapidly increasing popularity today, especially the sweetened, fruit-flavored variety that comprises 90 percent of the market for this product. It occurred to the researchers that they might produce a superior yoghurt by taking advantage of the added sweetness of lactase-treated milk. They found that the presence of glucose in this milk speeded up acid production by the organisms of the yoghurt culture. This meant that the set time for lactase-treated yoghurt was reduced to 3 hours from 4 hours for an untreated control. They also noted a more rapid pH drop in the early stages of acid production when the skim milk used was lactase treated. (Both the lactase-treated yoghurt and the untreated control were made from skim milk fortified with 4 percent nonfat dry milk.) In addition to the production efficiencies, the yoghurts made from the lactose-hydrolyzed milks were preferred over the controls, according to an organoleptic evaluation by a consumer-type panel.

This accelerated acid development in skim milk with 90 percent of its lactose hydrolyzed is also of value in making cottage cheese. When the treated milk was used in preparing short-set cottage cheese, the time to reach the required pH of 4.6 was cut by as much as 20 percent. The lactose hydrolysis also produced a firmer coagulum, so that when the curd was cut and milled there was not so much curd shatter and fewer fines were formed. The increased yield obtained, as much as 10 percent in some cases, can represent a significant monetary saving to the cottage cheese manufacturers.

A new cheddar-type cheese has also been made from lactase-treated milk using normal cheddaring techniques. The ripening time for the cheese is accelerated, so that it develops good body, flavor, and texture at least one to two months sooner than that made from untreated milk. Commercial evaluations of cheddar, Camembert, and other types of cheeses are presently

being undertaken. There is some indication that the ripening time for this cheese is shortened.

Conclusion

Thus Dairy Laboratory research has successfully demonstrated that a variety of low-lactose milk products can be readily produced with properties at least equal to those of untreated controls. Use of the lactase-treated products often affords possibilities for production efficiencies, may permit monetary savings as well as nutritional advantages by cutting down on sucrose and other high-calorie ingredients required for sweet foods; and most importantly, can produce dairy foods that can be more readily digested by that newly recognized and sizable segment of the population, the lactose-intolerant. These potential advantages should provide a strong stimulus to further research on more efficient and economical procedures for lactose hydrolysis.

References

1. Guy, E. J., A. Tamsma, A. Kontson, and V. H. Holsinger. 1974. Lactase-treated milk provides base to develop products for lactose-intolerant populations. Food. Prod. Develop. 8(8):50.
2. Tumerman, L., H. Fram, and K. W. Cornely. 1954. The effect of lactose crystallization on protein stability in frozen concentrated milk. J. Dairy Sci. 37:830.

Figure Legends

Figure 1. Flow diagram for preparation of lactase-treated milk products. Source: Guy et al., 1974 (1).

Figure 2. Sucrose equivalence of hydrolyzed lactose. Source: Guy et al., 1974 (1).

Figure 3. "Smiley" organoleptic rating sheet.

Figure 4. Effect of storage on viscosity of frozen 3:1 pasteurized whole milk concentrates. Source: Guy et al., 1974 (1).

TABLE 1

Dairy laboratory flavor score results from lactase treated pasteurized whole milk.

Sample	Flavor Score
Control	37.0
30% lactose hydrolyzed	37.0
60% lactose hydrolyzed	36.7
90% lactose hydrolyzed	36.2

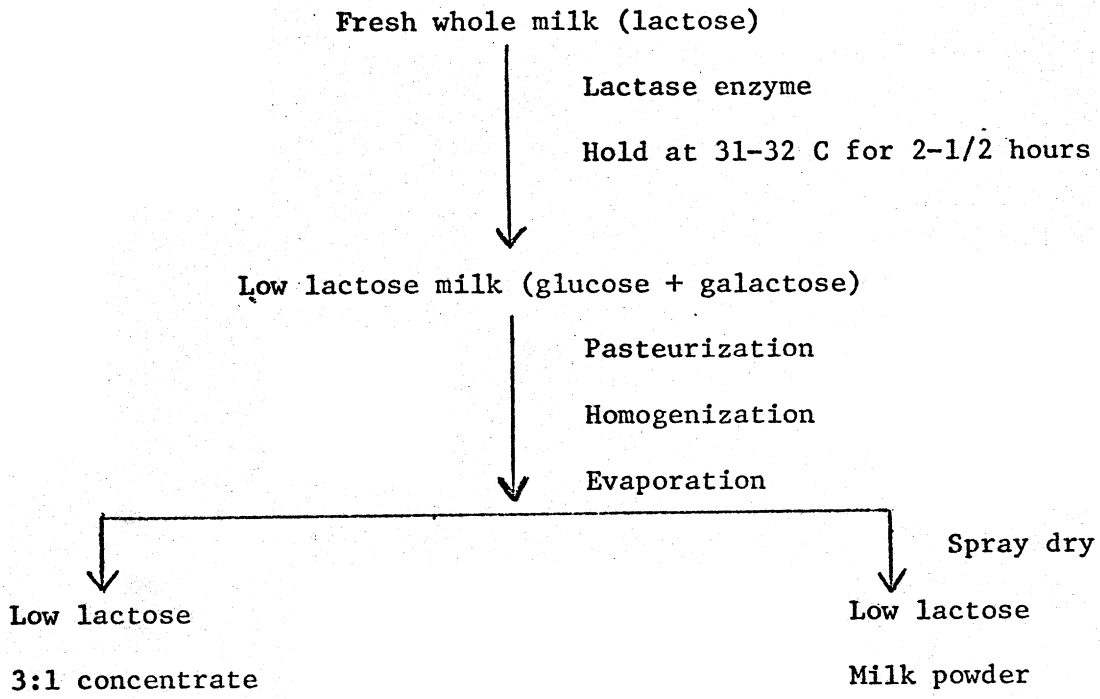
TABLE 2

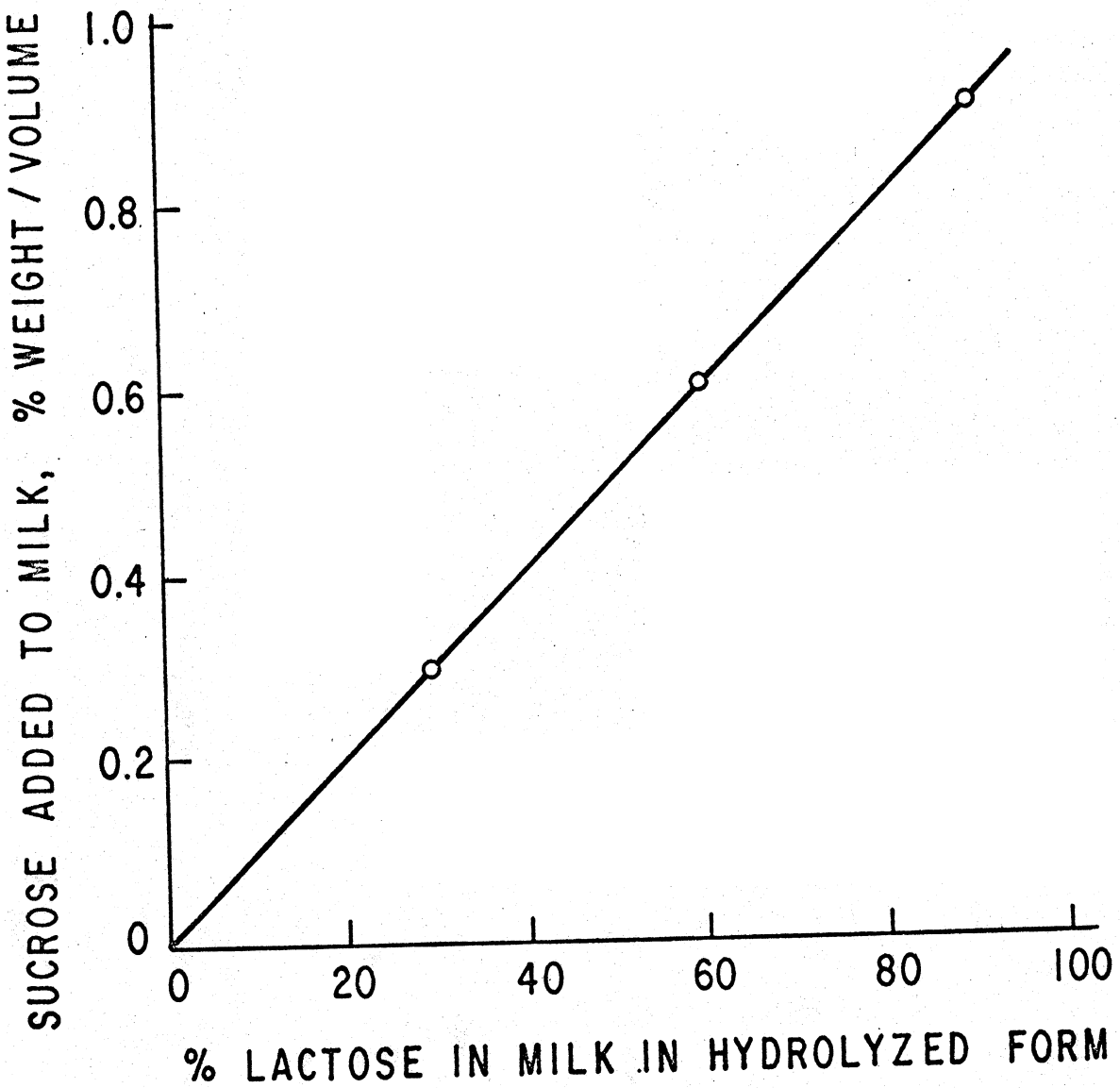
Hedonic flavor scores of lactase-treated whey-soy beverage powders stored at room temperature for various times.

	Initial	Storage time months 1	3	6
Control whey-soy (no treatment)	5.1	4.2	3.5	3.8
Lactase-treated whey plus soy flour	6.1	5.2[a]	4.6[a]	4.8[b]
Lactase-treated whey and soy flour	5.4	5.3[a]	4.6[a]	5.2[a]

[a]Significantly different from control at 1% level.

[b]Significantly different from control at 5% level.

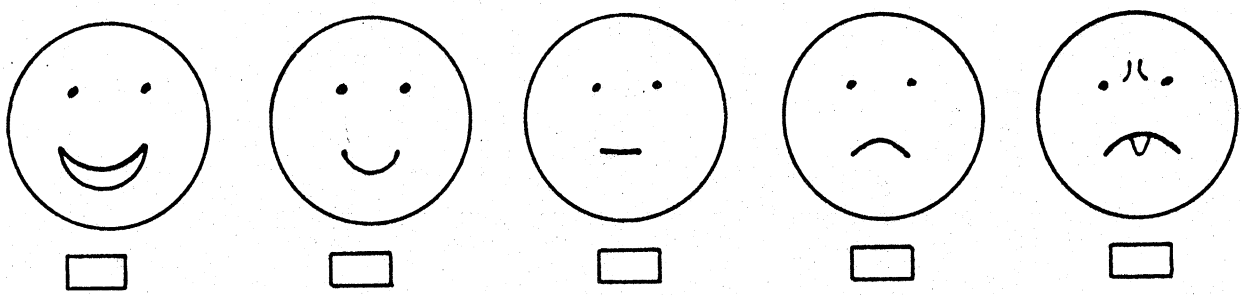

Fresh whole milk (lactose)
Lactase enzyme
Hold at 31-32 C for 2-1/2 hours
Low lactose milk (glucose + galactose)
Pasteurization
Homogenization
Evaporation
Spray dry
Low lactose
3:1 concentrate
Low lactose
Milk powder

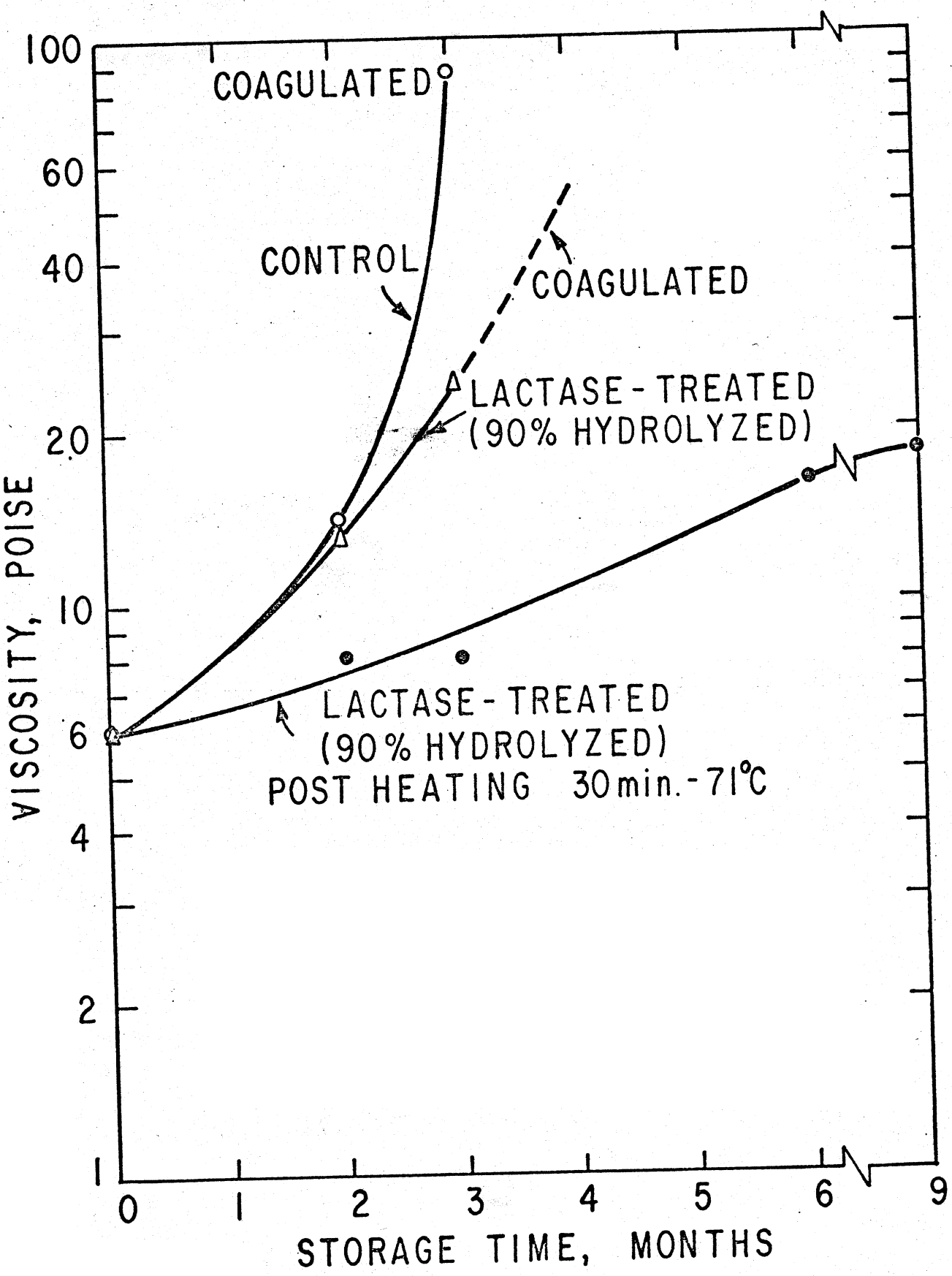

SUCROSE ADDED TO MILK, % WEIGHT / VOLUME
1.0
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
% LACTOSE IN MILK IN HYDROLYZED FORM

1. PLEASE CHECK ✓ THE STATEMENT WHICH BEST TELLS HOW YOU FEEL ABOUT THE GLASS OF MILK YOU JUST DRANK.

- ☐ I THINK THIS MILK IS FANTASTIC.
- ☐ I LIKE THIS MILK.
- ☐ THIS MILK IS JUST OK.
- ☐ I DO NOT LIKE THIS MILK.
- ☐ I DISLIKE THIS MILK VERY MUCH.

2. WHICH OF THESE FACES BEST DESCRIBES YOUR REACTION TO THE TASTE OF THIS GLASS OF MILK? PLEASE CHECK ✓ THE BOX.




100
60
40
20
10
6
4
2
1
VISCOSITY, POISE
COAGULATED
CONTROL
COAGULATED
LACTASE-TREATED
(90% HYDROLYZED)
LACTASE-TREATED
(90% HYDROLYZED)
POST HEATING 30 min.-71°C
0
1
2
3
4
5
6
9
STORAGE TIME, MONTHS