Hydrolyzed Lactose Cultured Dairy Products. I. Manufacture of Cheddar Cheese

Abstract

One of the principal cost factors in the manufacture of cheddar cheese is the time required for aging of the product. This cost is estimated (refrigeration expenses, capital investment, inventory) at 2.86¢/kg/mo. Using milk which has 65-80 percent of its lactose hydrolyzed by lactase, cheddar cheese has been manufactured which, at 3-4 months, has the flavor, body, and texture of 6-8 month-old cheese. The hydrolyzed lactose cheddar had better flavor than the control samples as well as improved body and texture when the latter were aged to their normal maturity. In addition to substantial savings by reduction of aging time, the whey (high in glucose) has potential value as a sweetening additive in ice cream and processed cheese.

Introduction

With the exceptions of improved starter cultures and more automated equipment, few modifications have been developed with the aim of improving the manufacturing and aging of cheddar cheese. As a new modification in the cheddar cheese process, we studied the effect of preliminary hydrolysis of lactose to its component sugars, glucose and galactose[4]. We have manufactured a total of 22 lots of hydrolyzed lactose cheddar cheeses (HLC) and controls, fifteen laboratory scale, five pilot plant, and four commercial. The purpose of this paper, however, is to report primarily on a method of manufacture citing only a few typical examples of the influence of lactose hydrolysis on the finished products. Subsequent papers will provide in-depth reports on the influence of lactose hydrolysis on flavor and rheology of cheeses so manufactured.

Milk Supply. Initial studies on HLC were performed on batches of milk ranging in butterfat content from 3.5-5.5 percent. Small lots of cheddar cheese were prepared from Jersey milk (22.7 kg) at 5.2-5.5 percent butterfat or Jersey milk which had been standardized to 3.5-3.7 percent butterfat. In subsequent studies, predominantly Holstein milk at 3.1-3.2 percent butterfat (standardized by partial separation) was used for the manufacture of HLC from 386 kg lots of milk. Commercial vats of 6,129 kg, 3.5-3.7 percent butterfat milk were also used for cheddar manufacture.

Lactose hydrolysis. The lactase isolated from *Saccharomyces lactis* was obtained from Enzyme Development Corporation, New York, N.Y.* The food grade enzyme was reported to have a specific activity of 40,000 Orthonitrophenyl Glucose units/gm.

Two schemes of adding the enzyme to milk were employed depending upon the volume of milk used:

1) Addition of lactase at 30 C. For small vats of milk it was convenient to add 0.3 gm lactase/l. milk 1 hour prior to the addition of starter, although scheme 2 (below) has also been used. This procedure gave enzyme action for about 2.5 hours prior to final cooking at 37.6 C, and resulted in at least 70 percent hydrolysis of lactose. To achieve 90 percent lactose hydrolysis in 2.5 hours, it was necessay to double the amount of enzyme added since it is product (galactose) inhibited. The enzyme is conveniently added to warm milk (30 C) and mixed until thoroughly dispersed before adding to the vat milk.

2) Addition of lactase at 4 C. When large amounts of milk (4,540 kg and above) were used in cheese manufacture it was necessary to react the milk for 16-18 hours with about 0.13 gm enzyme/l. to achieve 70 percent lactose hydrolysis. The lower amount of enzyme reduced the cost of cheese manufacture significantly. Addition of lactase to a storage tank must be done with care to insure proper mixing.

Measurement of degree of lactose hydrolysis. Measurements of the degree of lactose hydrolysis were made by analyzing for glucose liberated by lactase.[3] The total amount of lactose in milk was determined by measuring glucose after the sample was reacted for 2 hours at 30 C with a large excess (about 1 gm/100 ml) of lactase.

Pasteurization. Laboratory batches of milk were pasteurized at 61 C for 20 minutes, whereas all large scale batches of milk were pasteurized at 71 C for 15 seconds. "Raw milk" cheddar cheeses (New York State style) were prepared from milk heated to 65 C for 15 seconds.

Cheddar cheese cultures. All cheddar cheeses were prepared from frozen commercial cultures (Marschall Division Miles Laboratories). Single transfers from the frozen concentrate (1 ml/4 l.) were made to "Marstar" culture media which had been prepared according to the manufacturers' directions (heated to 95 C for 45 minutes) or by heating in an autoclave at 130 C, 15 lb p.s.i. for 1 minute. Either heating method produced a consistent culture for milk inoculation.

Pasteurized milk cheddar cheese was made by the addition of 1 percent active starter to the milk. In the late spring and early summer this was increased to 1.4 percent. A 2 percent inoculum was used in the manufacture of "raw milk" (65 C, 15 seconds) cheddar cheese.

Protocol for cheddar manufacture. Cheddar cheese was manufactured by the methods normally used at any one location. For example, if the cheese was manufactured in New York State, we did not modify such procedures as degree of ripening acidity before coagulant addition, stacking of curd during cheddaring, milling acid, etc. These procedures were modified only in the laboratory where varations in moisture, fat, and pH could be inexpensively controlled. However, each HLC manufactured always had a control vat for comparison. The object was to manufacture cheese, on locations, exactly as was routinely practiced except for the hydrolysis of milk sugar.

Results and Discussion

All hydrolyzed lactose cheddar

*Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

cheeses were prepared from milks whose lactose was at least 65 percent hydrolyzed. The presence of free glucose, as a readily available carbon source for *S. lactis,* modified the process of manufacture of cheddar cheese considerably. Firstly, the ripening period of milk before coagulant addition was reduced by 15-20 minutes from the normal 1 hour ripening period. Gilliland et al.[2] observed that streptococcal organisms were stimulated in their growth when lactose was converted to glucose and galactose by β-galactosidase. Secondly, not only is renneting time reduced, but the coagulum is much firmer than the control. Clearly, this is due in part to more rapid acid development during setting, but as will be discussed later, the state of water in the coagulum must be altered. Thirdly, during cooking of the curd, HLC tends to mat at 35 C requiring more vigorous agitation of the curd. The phenomenon of matting is also observed during the cooking of cottage cheese curd prepared from HL milks. Fourthly, HLC curd tends to cook-out in a shorter period of time at 37.8 C. Once again, this is due to more rapid acid development, causing curd syneresis, since the percent acid at the time of dipping and packing is usually 0.02-0.03 percent higher than the control. On occasion we have observed packing acids of 0.27 percent when more than 80 percent of the lactose was hydrolyzed. Fifthly, since acid development proceeds rapidly, cheddaring time is reduced by as much as 40 minutes from the usual 2-2.5 hours. The decrease in cheddaring time does not result in a significantly higher moisture cheese as might be expected. However, more moisture is expelled upon salting HLC than with the control vats. The condition of HLC curd at milling is smoother and more resilient than the control.

While the manufacture of cheddar cheese from hydrolyzed lactose milk does not improve greatly the yield of finished cheeses, we have observed higher percentages of fat in the product, and in some cases, higher moistures (for example, 39 percent HLC, vs. 38 percent control). We feel that the increase in moisture is not directly the result of cheddaring conditions, but rather that the replacement of lactose by the monosaccharides, glucose and galactose, decreases the nonsolvent water; that is, there is now more free water.[1] The increase in free water results from an increase in osmolarity due to the hydrolysis of lactose to the monosaccharides. This reasoning can be applied to the HLC pressed curd which is more close textured than the control, is not short bodied (but tends to be pasty if moisture is high) and which, upon heating, melts much more readily than the control. Further, this different body and texture persists throughout curing at either 4 C or 10 C although practically all free glucose has been utilized within a month in cure. However, some free galactose persists up to 6 months in cure.

HLC cheeses have flavor, body, and texture superior to the control cheeses with equivalent times in cure, including full term curing. Table 1 summarizes the results of two pilot plant and one commercial run of control and HL cheddars. The flavor scores of HL cheddars are higher than the controls for at least 6 months in cure. Since flavor scores reflect only defects (as do body and texture scores) it is important to point out that the development of cheddar flavor begins much earlier with HL cheeses than with the controls. For example, a 3-month HL cheddar may have the flavor of a 6-month-old cheese. A significant rapid development of body is also apparent; we have observed 2-month-old HL cheddars with body characteristic of a 6-month-old cheese. The advantage of these cheeses (and younger cheeses) in processed cheese manufacture is apparent since selection of young cheese is made on the basis of body. In subsequent publications we will detail the effects of prehydrolyzing lactose on the accelerated rate of cure of cheddar and mold ripened cheeses and the rheology of Italian varieties.

Finally, sweet whey containing glucose and galactose is a byproduct of HLC manufacture. New and extended used of this sweeter whey may partially offset the cost of enzyme required to produce HLC. However, because of the hygroscopic character of the monosaccharides produced, the whey may be difficult to spray dry.

REFERENCES

1. Geurts, T.J., P. Walstra, and H. Mulder. 1974. Water binding to milk protein, with particular reference to cheese. *Neth. Milk Dairy J.* 28:46-72.
2. Gilliland, S.E., M.L. Speck and J.R. Woodard, Jr. 1972. Stimulation of lactic streptococci in milk by β-galactosidase. *Applied Microbiology* 23:21-25.
3. Jasewicz, L., and A.E. Wasserman. 1961. Quantitative determination of lactase. *J. Dairy Sci.* 44:393-400.
4. Thompson, M.P. and D.P. Brower. 1974. Manufacture of cheddar cheese from hydrolyzed lactose milks. *J. Dairy Sci.* 57:598.

Table 1. Flavor, body and texture scores[1] on typical control and hydrolyzed lactose (HL) cheddar cheeses

Cheese	Description	Age (mo)	Scores: Flavor	Scores: Body and Texture
1	Pasteurized milk (pilot plant lots, cured 10 °C)			
Control		3	38.0 (acid, sl. bitter)	28.0 (short, open)
HL		3	39.0 (acid)	29.0 (short)
Control		6	36.5 (acid, bitter)	27.0 (short, open)
HL		6	39.0 (sl. acid)	29.0 (short)
2	Raw milk (commercial lots, cured 5 ° C)			
Control		2	38.5 (acid)	28.0 (short, open)
HL		2	39.0 (acid)	29.5 (short)
Control		4	38.5 (acid)	28.0 (short, open)
HL		4	39.0 (acid)	29.5 (short)
Control		6	38.5 (acid)	28.0 (short, open)
HL		6	39.0 (acid)	29.0 (short)
Control		9	38.5 (acid)	28.0 (short, open)
HL		9	39.5 (sl. acid)	29.0 (short)
3	Pasteurized milk (pilot plant lots, cured 10 ° C)			
Control		3	38.0 (acid)	27.0 (crumbly)
HL		3	38.5 (acid)	29.0 (short)
Control		6	36.0 (bitter)	27.5 (crumbly)
HL		6	39.0 (acid)	29.0 (short)
Control		9	36.0 (bitter)	27.5 (crumbly)
HL		9	36.0 (bitter)	28.5 (short)

[1]*Determined by commercial graders.*