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치즈의 숙성과정중 치즈조직의 변화연구

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Understanding of Development of Cheese Texture during Ripening

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ABSTRACT

During cheese ripening, the textural properties of cheese undergo significant changes from short, grainy, irregular to smooth, homogeneous and connected (well-net) structure. To make this change, many biochemical reactions occur during ripening and there have been tremendous researches in this topic for decades. In this review, several key parameters, such as cheese composition (especially cheese moisture and cheese pH), proteolytic activity and changes in Ca equilibrium will be discussed to understand the development of cheese texture during ripening.

Keywords : cheese texture, ripening, proteolysis, Ca equilibrium

INTRODUCTION

Cheese making is considered as a mass dehydration process since the solid content of milk (such as protein and fat) is concentrated up to 10 fold. During cheese making and ripening, there are several biochemical reactions including changes of cheese pH, proteolysis, reduction of insoluble calcium (INSOL Ca) and etc. (Hassan *et al.*, 2004; Lucey *et al.*, 2005; Lee *et al.*, 2005). The textural properties of cheese also changes during ripening and there have been many researches on this topic (Lawrence and Gilles, 1982; Creamer *et al.*, 1988; Lawrence *et al.*, 1987; Lucey and Fox, 1993; Watkinson *et al.*, 2001; Guinee *et al.*, 2002; Pastorino *et al.*, 2003; Lucey *et al.*, 2003; Joshi *et al.*, 2003; Sheehan and Guinee, 2004; Lee *et al.*, 2005; O'Mahony *et al.*, 2005; O'Mahony *et al.*, 2006). In this review, general aspects of textural changes of cheese during ripening will be elucidated.

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TEXTURAL PROPERTIES OF CHEESE

Texture of cheese is important as each cheese has its own unique mouthfeel so that consumers can easily tell the differences of specific varieties of cheeses (Lawrence *et al.*, 1987). Usually, a young cheese (1 day) has very grainy, curdy texture, which changes into smooth and soft during maturing (Lucey *et al.*, 2003). These textural changes of cheeses during ripening are influenced by many factors, such as cheese composition (Ca, salt and moisture), cheese pH, cheese making procedure, interactions between casein micelles and biochemical reactions (e.g., proteolysis) during ripening (Lucey *et al.*, 2003). Here are important key parameters in development of cheese texture during ripening.

1. Effect of Cheese Moisture on Cheese Texture

It is easily assumed that cheese with high moisture can give softer matrix compared to cheese with low moisture. Table 1

Table 1. Classification of cheese according to moisture content (Adapted from Fox *et al.*, 2000)

Soft cheese (50~80% moisture)	Semi-soft cheese (39~50% moisture)	Hard cheese (Max. 39% moisture)	Very hard cheese (Max. 34% moisture)
Cottage	Blue	Cheddar	Asiago Old
Cream	Limburger	Colby	Parmersan
Mozzarella	Gorgonzola	Swiss	Romano
Camembert	Brick	Gouda	Parmigiano
Feta	Pasta Filata	Edam	Grana
Brie	Provolone	Stilton	Sardo

shows the classification of cheese by its moisture content. We all know that Romano cheese (~30% moisture) is much harder than Mozzarella cheese (~55% moisture) but moisture content can not be the only parameter that distinguishes the textural differences of cheese. For example, Cottage cheese has completely different textural properties from that of cream cheese (Table 1).

2. Effect of Cheese pH on Cheese Texture

Cheese pH is one of the critical parameters that determine the textural properties of cheese (Lawrence *et al.*, 1987). At the early period of ripening (~2 wks) there is a very active lactic acid formed from fermentation, then cheese pH drops (Fig. 1). But as cheese ripens, there are other chemical reactions, such as solubilization of colloidal Ca phosphate (CCP) and proteolysis, which buffers in cheese (Fig. 1).

Springy and elastic (cheese pH ~5.5) texture of Cheddar

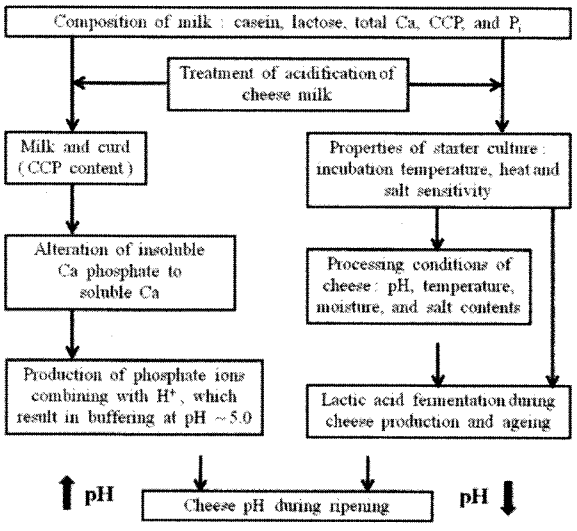

Fig. 1. Relationships between the solubilization of colloidal calcium phosphate, catabolism of lactose and pH changes during Cheddar cheese ripening (adapted from Hassan *et al.*, 2004).

cheeses changes to brittle and short (cheese pH ~4.8) over various pH ranges (Lawrence *et al.*, 1987; Pastorino *et al.*, 2003). Increased fracture strain and fracture stress was observed when the pH of Cheddar cheeses was intentionally increased from 5.2 to 6.2 (Watkinson *et al.*, 2001). At the same ripening point, low pH Cheddar cheese showed more fracture compared to high pH cheese in large deformation test (Lee *et al.*, 2005). Lower values of TPA hardness were observed in Mozzarella cheeses during ripening when the draining pH decreased from 6.40 to 6.15 during cheese making (Yun *et al.*, 1995). Much greater flowability, stretchability, and fluidity were observed when pH of Mozzarella cheeses was reduced from 5.95 to 5.58 (Guinee *et al.*, 2002). In the other hand, reducing curd pH from 5.1 to 4.6 by injecting a 20% glucono-delta-lactone solution resulted in less melt during heating (i.e., decreased flow rate) (Pastorino *et al.*, 2003).

3. Effect of Proteolysis on Cheese Texture

Proteolysis is considered as one of the major contributing factors to textural changes of cheese during ripening. As protein breaks down with cheese-aging the "green" rubbery young cheese turns into smooth, soft matured cheese. 〈Fig. 2〉 shows general proteolytic agents in cheese. The proteolytic activity can be distinguished into two steps, which explained in 〈Table 2〉.

4. Effect of Changes in Ca Equilibrium on Cheese Texture

It is very common that cheese with lower total Ca content can be softer and more meltable compared to cheese with higher total Ca content (Lucey *et al.*, 1993). Generally, decreasing the total Ca levels of cheese results in increased melt and softer cheeses, i.e., more flexible structure (Lucey and Fox, 1993; Yun *et al.*, 1995). The stretchability and flowability of Mozzarella cheese increased with a reduction in the total Ca concentration of cheese (Guinee *et al.*, 2002; Joshi *et al.*, 2003; Sheehan and

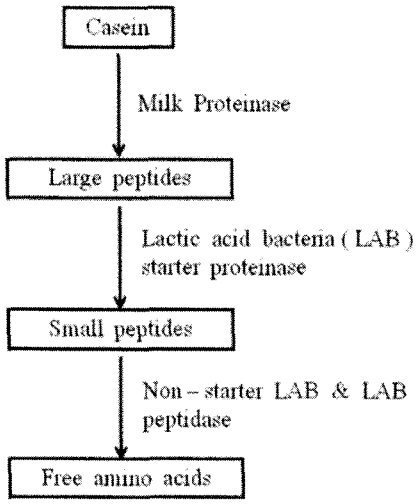

Fig. 2. General cheese proteolytic agents (adapted from Sousa *et al.*, 2001).

Table 2. Changes of cheese texture during ripening periods (Adapted from Lawrence *et al.*, 1987)

Step 1	During first 7 and 14 days, rapid textural changes in cheese occur. Casein networks become weak as the coagulant hydrolyzes a single bond in α_{s1} casein (~20%).
Step 2	More gradual textural changes in cheese occur in months, which determined by extent of proteolysis and pH changes.

Guinee, 2004). There is an increase in the hardness and a decrease in cohesiveness and melting in part-skim Mozzarella cheeses after multiple injections of a $CaCl_2$ solution to cheese, presumably forming more cross-linking in cheese matrix (Pastorino *et al.*, 2003).

Generally, it is believed that decreasing the total Ca levels of cheese results in increased melt and softer cheeses (Lucey and Fox, 1993). The melting properties of Mozzarella cheeses, such as stretchability and flowability, increased with a reduction in the total Ca concentration of cheese (Guinee *et al.*, 2002; Joshi *et al.*, 2003; Sheehan and Guinee, 2004). It has also been reported that there is an increase in the hardness and a decrease in cohesiveness and melting in part-skim Mozzarella cheeses after multiple injections of a $CaCl_2$ solution, presumably forming more cross-linking in cheese system (Pastorino *et al.*, 2003).

It does not seem that the total Ca concentration in cheese is the best indicator (predictor) in determining the textural and melting properties of cheese as cheeses with similar total Ca content may behave in very different way. Due to recent intensive researches it is now well-known that there is a considerable proportion of the Ca (i.e., Ca is not in soluble form, INSOL Ca) still attached to casein after cheese making and that the reduction in INSOL Ca content in cheese during ripening can be responsible for the changes in textural and melting properties of cheeses along with proteolysis (Lucey and Fox, 1993; Lucey *et al.*, 1993; Hassan *et al.*, 2004; Lucey *et al.*, 2005; Lee *et al.*, 2005; O'Mahony *et al.*, 2005; O'Mahony *et al.*, 2006).

Lucey and Fox (1993) first proposed that the proportion of Ca and phosphate attached to casein after cheese making may play a critical role in determining the changes in the structure, texture and functionality of cheese during maturation. During 9 mo Cheddar cheese ripening, the INSOL Ca content of cheese were more highly correlated with various rheological parameters, such as storage modulus (G') and maximum loss tangent (LT_{max}) from heating profile of cheese than the level of pH 4.6-soluble nitrogen (extent of primary proteolysis) (Lucey *et al.*, 2005). The hardness of Cheddar cheese in TPA profile significantly ($P<0.05$) decreased during the first 21 d of ripening even when hydrolysis of α_{s1}-casein at Phe_{23}-Phe_{24} was blocked by the addition of pepstatin, which is a potent inhibitor of chymosin, during cheese making (O'Mahony *et al.*, 2005).

O'Mahony *et al.* (2006) also investigated the effects of INSOL Ca concentration on the rheological properties of cheese that had similar extent of primary proteolysis. The concentration of INSOL Ca in cheese was varied from 1.36 to 2.36 g calcium/ 100 g of protein in cheese by incubating Cheddar cheese slices (from a single cheese block) in synthetic Cheddar cheese aqueous phase solutions containing various levels of Ca. After increasing the INSOL Ca in cheese, there was a significant decrease in the LT_{max} value ($P<0.05$) and an increase in the hardness of cheese.

CONCLUSION

As discussed above, it is very clear that there is a no single parameter that determines the textural properties of cheese during ripening. Several biochemical reactions (including proteolysis and reduction of INSOL Ca) undergo during cheese ripening and these reactions are interrelated to give specific textural properties of a variety of cheese. Cheese making procedure can also determine the textural properties of cheese during ripening. Recent challenged investigation on the changes of Ca equilibrium in cheese gives more detailed information on the exact mechanism of textural changes of cheese during ripening along with proteolysis.

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