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Nutritional and Organoleptical Aspects of UHT Treated Milk

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UHT처리된 우유의 영양 및 미각적 분석

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Abstract

The UHT treatment and consequent storage effect on nutritional value of milk are discussed. Compared with the conventional sterilization the UHT treatment of milk represents a relatively small thermal stress. During UHT processing, nutritive value of protein, fat, carbohydrates, fat-soluble vitamins and minerals are generally unaffected. Nutritive value of some water-soluble vitamins and protein are adversely affected in a small degree during storage. It has been recommended that UHT milk has best nutritional and organoleptic qualities on storage under refrigeration. Some unsolved future problems are also suggested.

UHT processing

To achieve prolonged storage and safe distritution of high quality milk products, heat sterilization is generally advocated. A recent method of producing sterile milk called Ultra-High-Temperature(UHT) treatment came into commercial use around the year 1960.

The International Dairy Federation(IDF) has suggested that UHT milk should be defined as "a milk which has been subjected to a continuous flow heating process at high temperature for a short time and which afterwards, has been aseptically packaged"[1].

There are many different aspects of difinition, heating temperature, holding time and the sell-by date in several countries as indicated in Tbale 1.

Table 1. Legislative regulations of UHT treatment and sell-by date of milk

Nation	Temperature	Holding time	Sell-by date
Ausralia	133°C	*	*
Denmark	135°C	1 sec	*
Finland	135°C	2-3sec	90 days
France	140-150°C	1 sec	*
Germany(F.R.)	135-150°C	short time	6 weeks
Israel	130°C	1 sec	*
Switzerland	130-150°C	few sec	30days
United Kingdom	132.2°C	1 sec	use by date
U.S.A.	138°C	2 sec	*
USSR	140-142°C	2-4 sec	10 days

* infinite or no dating requirement

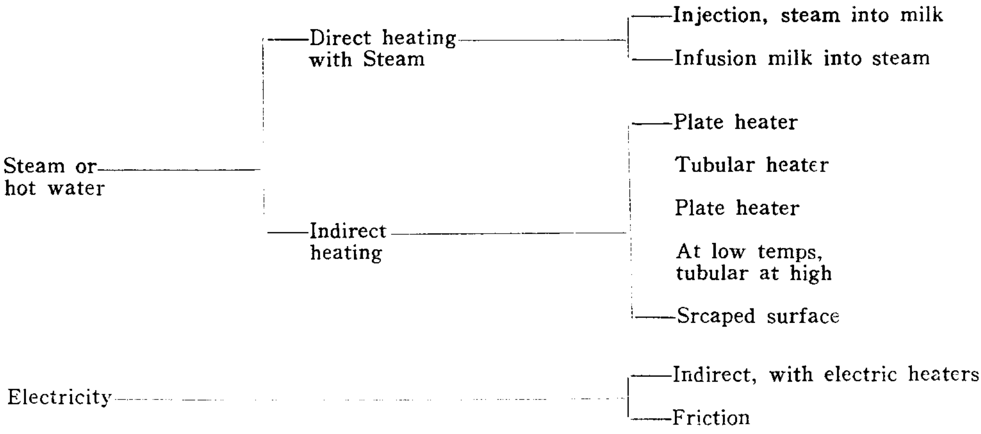

Fig. 1. Types of UHT sterilization processes

As a general rule, heating can be carried out by direct and indirect heat exchange, electrical methods and mechanical heat of friction[2~6] as shown in Figure 1.

In many western European countries, Australia and Canada, the proportion of UHT milk of total liquid milk market has continued to rise rapidly since 1970. In Federal Republic of Germany, the UHT milk is produced in higher proportion than pasteurized milk, while the price of UHT milk is lower than that of pasteurized milk.

Nutritive value of UHT milk

As a component of mixed diet, milk is most unique balanced food as a source of high quality protein, calcium and vitamins. For example, 0.5 liter of good quality milk supplies some 25% of calories some 40% of protein, some 70% of the calcium and riboflavin and about one third of the vitamin A, thiamine and folic acid, which are required daily for a five year old child[7,8].

Heat treatment not only destroys microorganisms and inactivates enzymes in milk, but also has an adverse effect on milk nutrients.

In UHT milk, nutritional changes should be evaluated at two stages: during heat treatment of the milk and during storage.

1. Protein

UHT processing causes some changes in milk protein system. Severe heat treatment may cause considerable denaturation of the milk serum protein i.e. the immunglobulins are the most sensitive to heating followed by serum albumin, β-lactoglobulin and α-lactalbumin[9].

The direct UHT process generally causes less denaturation(60~70%) than the indirect UHT process (75~80%)[7,10,11]. The thermosensitivity of whey proteins is attributed to the absence of phosphorus, to the low content of prolin and to the high level of S-containing amino acids. On the contrary to the serum protein, the caseins are not denatured due to hydrophobic characteristic, low amount of tertiary structures and high content of prolin[12~15].

The UHT treatment and homogenization cause the increase of the casein submicelles and the building of large micelles[16~19].

During UHT treatment of milk, an interaction occurs between casein and whey protein, leading to the formation of the SH groupings free from globulin[20,21,22]. The stability of the casein-whey protein complex differs for different heating and storage conditions[23,24].

Although the UHT treatment of milk does denature milk proteins to some extent, but in general the biological value, PER (protein efficiency ratio) are not adversely affected[11,25].

Recent studies have indicated that the denaturation may render the milk more easily digestible because proteins in heated milk release amino groups more quickly under the influence of digestive enzymes[26~29].

A small loss of available lysine was observed during the UHT processing as shown in Table 2.

Table 2. Lysine losses in milk by different heating procedures

Autors	Lysine losses in %			
	Pasteurization	UHT direct	UHT indirect	Sterilization
Blanc (27)	0.7-1.1	1.1	1.7	6.2
Mottar & Naudts(46)	2.0	4.3	6.5	9.9
Renner(29)	1-2	3	4	6-10

Maillard reaction, which causes a connection between ε-amino groups of lysine and aldehyde groups of carbohydrates or other organic substances, results in decrease of lysine due to enzyme resistant bonds, thereby preventing lysine utilization[30].

The Table 2 shows that the UHT treatment causes lysine losses of about 1.1 to 6.5% with small differences between direct and indirect procedure, while 0.7~2.0% in pasteurized milk. In UHF milk the greatest part of lysine remains in available and reactive form[7,31].

The sulfur containing essential amino acids, cystine, cysteine and methionine, can be affected by UHT processing, as sulfhydryl groups are liberated from these amino acids by heating. This indicates the degradation of the S-containing amino acids[12].

β-Lactoglobulin undergoes important changes on heating and different sulfur compounds are formed i.e. hydrogen sulfide, mercaptons, sulfides and disulfide[32~35]. These compounds have a very pronounced flavor and are responsidble for the cooked flavor in UHT mlik. The degree of cooked flavor, protein denaturation and the concentration of reactive SH groups show a similar dependence upon the severity of heat treatment[26,36]. However, the losses of the essential sulfur containing amino acids and other essential amino acids are not significant [26,37].

Andrews[38] and Möller et al.[30] found that the milk proteins undergo chemical change during storage, mainly by the Maillard type reaction between lactose and lysine residues and their nutritional quality is slowly degraded. This reaction can lead to a browning reaction.

The non-casein nitrogen (NCN) content is decreased after-UHT treatment while it's increased during storage of milk[23~26].

The increase in NPN (non protein nitrogen) content during storage indicates proteolysis[23~24,39~42].

Under normal conditions of storage, there is little change in the biological value and the digestibility of milk proteins resulting from Maillard reactions [11,27]. It was concluded that the Maillard reaction compounds in milk have no injurious and toxic effect[43].

On the view point of nutrition, it is suggested that UHT milk can be estimated as valuable as pasteurized milk and its protein efficiency is significantly better than sterilized milk[2,7,29,37].

2. Lipids

Although it has been reported that there may be some loss of polyunsatured fatty acid in UHT milk [44], untritive value of fat is unaffected[15,45~47]. Only very slight lipolysis occurs during storage. This lipolysis occurs mainly because of residual lipase of pschrotropic microorganisms, which are not completely inactivated under the condition of UHT treatment[45~50]. The release of free fatty acids depends on the storage temperature i.e. the higher the temperature, the more free fatty acids. In the refrigerated milk (4°C) the fatty acids content are little changed[51].

An increase in the content of methyl ketones and aldehydes, results in the off-flavor of stored UHT milk depending upon storage temperature and oxygen content[26,52].

3. Lactose

Lactose can be decomposed to some small degree to organic acid and furfural and takes part in the Maillard. But, there are no changes of important nutients[44].

4. Vitamins

The fat-soluble vitamins, vitamin A, D and E, are not destroyed significantly during UHT treatment[16,44].

Vitamin B complex, riboflavin, pantothenic acid, biotin and nicotinic acid are very little affected by UHT processing. The effects of different heating processes on the vitamin composition are presented in table3. There are somewhat higher losses of vitamins B_1, B_2, B_6, B_{12}, folic acid and vitamin C in milk. The losses of these vitamins are increased

Table 3. Losses (in %) of vitamins in milk by different heating procedure

Vitamin	Pasteuri-zation	UHT-processing	Sterili-zation
Vitamin A		2.8	
β-carotine		6.1	
Pantotheinic acid	minimal	<4	
Nicotinic acid	minimal	<4	
Biotin	minimal	minimal	
Vitamin B_1	<10	5-20	30-50
Vitamin B_2		<10	30-50
Vitamin B_5	0-5	<10	10-20
Vitamin B_{12}	<10	10-20	30-100
Folic acid	5	10-20	40-50
Vitamin C	5-15	10-30	30-100

pararelly to the thermal processing intensity[26,29,46].

From the nutritive point of view, freshly-processed UHT milk is little different in vitamin content from pasteurized milk[53].

Some vitamins of milk are sensitive to light, oxygen and temperature. The fat-soluble vitamins are stable in absence of light during storage[54]. It has been found that there occurs no loss of vitamin A after 14 days of storage at 20°C in darkness, but a 45% loss after storage in diffuse daylight[55].

Vitamin B_6, B_{12}, folic acid and vitamin C are also sensitive to light and oxygen. On storage of UHT milk in clear glass bottles exposed to light for 3 hours resulted in a complete loss of ascorbic acid higher amount of riboflavin, folic acid and vitamin B_{12}[7].

High initial content of oxygen caused rapid loss (about 20%) of vitamin C and folic acid during storage[56].

5. Minerals

The free calcium content decreases during UHT-treatment due to building of casein-whey complex and calcium phosphate[32]. Calcium ions and other minerals move from milk serum into the casein. This reaction is reversible[45]. The calcium content and the availability of calcium are not influenced byUHT processing of milk[16,32,57].

Gelation

One of the serious problems of UHT treated milk is socalled "gelation", "age thickening" or "coagulation" during prolonged storage.

The shelf-life of UHT milk at ambient temperatures can be limited as a consequence of this phenomenon and nutritional quality can be also reduced due to proteolysis. Gelation depends generally on the methods of heat treatment, the storage temperature and characteristics of the milk[26,58,59].

There are many theories of the gelation procedure, however, its mechanism is not still fully explained [27,45,60,61,62]. Some researchers postulated that the gelation could be caused by purely physico-chemical processes[63,64]. Andrews and Cheeseman[65] suggested that the gelation were due to the action of carbonyl compounds by a Maillard type of reaction and crosslinking between protein chains.

Reactive sulfhydryl groups may contribute to instability of milk protein leading to gelation or deposit formation[64,66]. On the other hand, it had been demonstrated that the gelation of UHT treated milk caused by not only native but also heat resistant bacterial proteases[16,50,67~73]. The native milk proteinase shows minimal affinity towards kcasein, while bacterial proteinase predominantly attacks k-casein[49,70].

Andrews *et al.*[74], Swaisgood[75] and Blanc *et al.*[27] suggested that the gelation is generally caused by a combination of biochemicaland physico-chemical processes.

Harwalkar and Vreeman reported that proteolysis did not appear to be a predominant factor in gelation and some type of surface phenomenon would be responsible[76].

Flavour deteriorations

The final limitation to the life of a UHT product is flavour change[16]. Uncooled storage of UHT milk exceeding 6 weeks[77] or 8 weeks[42] causes highly noticeable deviations taste.

In UHT milk, the cooked flavour is mainly due to presence of hydrogen sulphide[78]. Methyl sulfide and methyl disulphide also take part in this taste[79]. This cooked flavour appears during storage due to decrease of sulfur compounds[36,80]. Naudts[81] supposed that the decrease of the SH groups of the UHT milk during storage can be related to the effects of a sulfhydryl oxidase enzyme.

Some investigations suggested that the cooked flavour could be eliminated with either immobilized enzyme or with L-cystsne addition[36,82].

HMF (Hydroxymethylfurfural), which is one of the intermediate products of the Maillard reaction, may cause bitter taste of UHT milk[78,80].

Its formation depends on both heating and storage temperature[42,51,80,83].

The off-flavour are related to lipolysis, and proteolysis and caused due to residual enzyme after UHT treatment[42,50]. Mckellar[84] reported that proteolysis is necessary for significant off-flavour development in UHT milk ranged from 0, 289 to 0, 554 μmol per milliliter.

The organoleptic defects may also be related to chemical reactions between the milk constituents[26].

The volatile aromatic compounds, methyl ketones, 2-hepatone, hexanal, octanal, nonanal, propanal and lactones are involved in the flavour deteriorations of UHT milk during storage[52,78,85].

The flavour of milkis largely affected by temperature, light, time, oxygen, packaging material and nature of milk. Mehta and Bassette[85] noted that milk in aluminium foil-lined cartons retained desirable flavour characteristics longer than did that stored in polyethylene-lined cartons, which is permeable to light.

Further research needed

The UHT processing technology has been much progressed, however, there are some problems to be solved.

As it was already mentioned above, the limitation of shelf-life and nutrition deterioration due to gelation should be intensively and systematically studied.

More sensible assay methods to detect small amount of protease activity in the UHT milk is needed.

A cooked flavour, which is caused during UHT processing, off-flavour due to oxidation of fat, lipolysis or proteolysis and stale flavour should be exactly determined and minimized.

An effective method for distinguishing between UHT milk and conventionally sterilized milk should be improved.

More studies of nutritional and physiological effects of UHT milk on human nutrition and infant feeding on the view of point of public health and preventional medicine are necessary.

Much attention also should be given to ensure better quality of raw milk, which is very important starting material for the nutritional value and shelf-life of UHT milk.

요 약

초고온 살균(UHT) 처리와 이에 따른 저장이 우유의 영양가에 미치는 효과에 대하여 토론되었다.

초고온 처리된 우유는 재래의 멸균우유와 비교해 상당히 적은 열 부담을 받는다.

일반적으로 초고온 살균처리 공정중에는 단백질, 지방, 유당, 지용성 비타민과 무기물들의 영양가들은 거의 영향을 받지 않는다.

작은 정도의 수용성 비타민들과 약간의 단백질의 영양가치가 저장중에 손실된다. 우유의 향미와 영양가를 최대한으로 유지하기 위해서는 초고온 살균우유는 냉장온도에 저장되어야 한다고 권장되고 있다.

해결되어야 할 문제점들도 간략히 기술되었다.

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