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CHEESE YIELD AS AFFECTED BY SOME PARAMETERS REVIEW

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Summary. Cheese yield is defined as the amount of cheese, expressed in kilograms, obtained from 100 kg of milk. It is a very important parameter: the higher the recovered percentage of solids, the greater is the amount of cheese obtained and therefore gains in economic terms. The definition of cheese yield, or how to express yield, is important in two main applications: 1. Economic control of cheesemaking; 2. Expressing the results of cheesemaking experiments. Cheese yield is affected by many factors including milk composition, amount and genetic variants of casein, milk quality, somatic cell count (SCC) in milk, milk pasteurization, coagulant type, vat design, curd firmness at cutting, and manufacturing parameters.

Key words: dairy products, cheesemaking, manufacturing, parameters, quality

INTRODUCTION

Cheesemaking is a process concentrating milk components, in particular fat and protein contents which are determinant factors of cheese yield [Banks et al. 1981]. Cheese yield is vital in an economic sense for cheese makers since small differences in yield translate into big differences in profits. A difference of 1% in the moisture of Cheddar cheese is equivalent to a difference in yield of 1.8%. Measurement of yield should become a tool not only of cheesemaking but also of management [Emmons 1993 b, Lacroix et al. 1993].

Cheese yield is defined as the amount of cheese, expressed in kilograms, obtained from 100 kg of milk. It is a very important parameter: the higher the recovered percentage of solids, the greater is the amount of cheese obtained and therefore gains in economic terms. It is, therefore, obvious how to elaborate a rapid method that allows for an estimate, before transformation, of the final cheese yield on the basis of the composition

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of the raw material. In order to make a comparison between the forecast yield and the actual one: this would allow the cheesemaker to have a constant check on the efficiency of operations, and to estimate the influence that some technological strategies can exercise on the entire process of cheesemaking. Equally important is the calculation of the effects that each milk component, and in particular, fat and casein, can have on cheese yield, in order to adopt a milk quality payment system that could remunerate each parameter for its actual value [Paolo et al. 2008].

Lucey and Kelly [1994] describes different aspects related to cheese yield: characteristics of the milk (contents of protein and fat, genetic variants of proteins, somatic cells), cheesemaking conditions (incorporation of whey proteins in the curd, homogenization of the fat, type of coagulant, use of different starters, curd firmness, type of vat, treatment of the curd). The same authors also consider different predictive formulas for determine cheese yield and strategies in order to minimize cheesemaking losses.

Van den Berg et al. [1996] analyse some aspects of the review of Van Boekel [1993], about the transfer of the various components from milk to cheese, focusing mainly on cheesemaking technology and the treatments which milk undergoes, such as bactofugation, pasteurization, enzyme addition, denaturation of the whey proteins, addition calcium chloride, and the influence that all these aspects have on the transfer of substances in the curd.

Utilization of reconstituted skim milk and cow milk cream in Domiati cheese manufacture was found to increase the fresh and pickled cheese yield throughout the storage time, which may be attributed to increased moisture retention [Abd El-Kader 2003, Ismail 2005].

The aim of this review article was to discusses and expresse cheese yield; many factors that influence cheese yield during processing over which the cheesemaker has control. Predictive formulas are given for estimating the cheese yield.

DEFINITION AND EXPRESSION OF CHEESE YIELD

The expression of cheese yield is important in the economic control of cheesemaking and in expressing results of cheesemaking experiments. The usual way is as "kg of cheese per 100 kg of milk". It is important that the composition of milk and cheese (and whey) be given because they markedly affect yield. It is recommended that actual yield be compared with the theoretical yield to estimate yield efficiency (actual yield as percentage of theoretical yield). The definition of cheese yield, or how to express yield, is important in two main applications: 1. Economic control of cheesemaking; 2. Expressing the results of cheesemaking experiments [Emmons 1993 c].

EXPRESSION OF YIELD AS PERCENTAGE OF THE THEORETICAL YIELD

Expression of actual yield can be rather meaningless because yield of cheese varies enormously for a number of reasons: variety of cheese and its typical composition; composition of milk (fat and casein/protein); composition of cheese (moisture, salt); losses of fat and curd during cheesemaking. It is usually useful to know what the yield of cheese of a typical constant composition should be from a lot or vat of milk.

For purposes of comparing the theoretical and actual yields. This theoretical yield is calculated from the composition of the milk by means of a yield formula. Yield can then be expressed as a percentage of theoretical yields. In some applications this can be termed cheese yield efficiency [Barbano and Sherbon 1984].

FACTORS AFFECTING CHEESE YIELD

Cheese yield is affected by many factors including milk composition, amount and genetic variants of casein, milk quality, somatic cell count (SCC) in milk, milk pasteurization, coagulant type, vat design, curd firmness at cutting, and manufacturing parameters [Banks et al. 1981, Fenelon and Guinee 1999, Lawrence 1993 b, Lucey and Kelly 1994, Walsh et al. 1998].

Milk composition

Cheese yield potential of milk is largely dependent on milk composition, particularly fat and protein [Barbano and Sherbon 1984, Gilles and Lawrence 1985, Banks et al. 1986, Lawrence 1993 a, Lou and Ng-Kwai-Hang 1992, Lucey and Kelly 1994, Van den Berg 1994, Brito et al. 2002, Guo et al. 2004].

Van Boekel [1993] regards the transfer of the components from milk to cheese: the author considers mainly the protein, estimating the amount of each single protein fraction that is retained in the curd and that is lost in the whey and suggests more accurate methods for the determination of the paracasein.

Research on both commercial and laboratory scales have established relationships between milk components (fat and casein) or cheese composition (moisture, fat, protein) and yield for a variety of cheeses, such as Cheddar and Gouda [Lolkema 1993, Brito et al. 2002]. Variation in cheese yield due to differences in moisture content of cow cheese can be minimized [Emmons et al. 1990], if actual cheese yield is adjusted to the standard moisture content for the cheese variety (e.g., 38% for Cheddar cheese, when developing the predictive formulae).

Of the various yield-influencing factors under the control of the cheesemaker, moisture is probably the most important. Increasing (decreasing) moisture has a magnifying effect on yield, more so at higher levels of moisture. For example, an increase of 0.01 in the moisture fraction in cheese from 0.32, 0.37, 0.47 or 0.57 was estimated to result in an increased yield of 1.67, 1.82, 2.23 or 2.87% respectively [Emmons 1993 a].

The casein fraction of milk protein is the dominant factor affecting curd firmness, syneresis rate, moisture retention, and ultimately affecting cheese quality and yield [Lawrence 1993 c]. Therefore, casein content, along with that of fat, is included in all current formulae for cow cheese.

Data relative to the production of Cheddar cheese from milk with a fat to casein ratio of 1.46 clearly show the close relationship between casein content and industrial milk yield [Custer 1979].

Thus, the quantity of cheese varies in direct relationship to milk casein content, and is related to fat to casein ratio of vat milk. This second factor can clearly be seen in the production of Parmigiano-Reggiano, and is even more marked in the production of Grana Padano cheese, both of which are made using partially skimmed milk [Aleandri et al. 1989].

Yield of cottage and other cheeses is dependent upon casein content of milk [Kosikowski 1977]. The degrading effect of psychrotrophic proteases is much greater on casein than on whey proteins [DeBeukelar et al. 1977]. Any factor affecting the casein content of raw milk has a potentially great impact on yield of cottage cheese. Manufacturer's profits depend on yield; thus, factors that decrease casein are costly [Custer 1977].

Ibrahim et al. [1974] showed that buffalo milk gave a higher yield than cow milk cheese. Fat and moisture contents were also, higher in the former than in the latter kind of Domiati cheese.

Increasing the protein-to-fat ratio (PFR) led to a significant decrease in the actual yield of cheese per 100 kg of milk but a significant increase occurred in the normalized yield of cheese per 100 kg of milk with reference values of fat plus protein (3.4 and 3.3%, wt/wt, respectively). The results demonstrate that alteration of the PFR of cheese milk in the range 0.70 to 1.15 has marked effects on cheese composition, component recoveries and cheese yield [Guinee et al. 2007 a].

Callanan [1993] describes in detail the recovery of milk substances, focusing his study particularly on protein, fat, "particles of curd", and dry matter of whey, starter and minerals. Furthermore, on the influence of the cheesemaking process towards the recovery of the specific constituents. He also describes the strategies to carry out in order to optimize cheese yields.

Verdier-Metz et al. [2001] study the relationships between the contents of fat and protein of milk and the cheese yield in the production of Saint-Nectaire cheese; its cheesemaking is carried out standardizing the fat/casein ratio of the vat milk. The same authors observe a linear correlation between the increase of yield and the increase of the sum of the contents of fat and casein; this sum explains 77% of the fresh yield.

Genetic variants of milk protiens

Aleandri et al. [1989] observe that curd firmness is the only coagulation parameter correlated with cheese yield; it is one of the main factors that can significantly affect yield. The two parameters, curd firmness and cheese yield, are related by a non linear relationship. In particular, the influence of the curd firmness on cheese yield is more marked if the fat content is low. It is known, in fact, that some genotypes, such as, for example, the κ-casein B are related to a greater κ-casein and total casein content. The content of casein is directly related to the cheese yield, while the κ-casein content has repercussions on the size of the casein micelles, which results smaller, and therefore on the rennet-coagulation properties, that manifest a significant improvement. The curd is firmer and able to retain a greater amount of substances, thus increasing cheese yield.

There is considerable interest in using milk protein genes as markers for improving the overall efficiency in different sectors of the dairy industry because some genetic variants are associated with: higher milk yield, better milk composition, improved physicochemical properties of milk and dairy products, and better cheesemaking qualities [Ng-Kwai-Hang 2006].

The first indication of the effects of genetic variants on coagulation properties and cheesemaking [Sherbon et al. 1967] was through the following observations: ß-lactoglobulin B milk gave a firmer curd than milk containing the A variant; κ-casein AA milk took longer to coagulate and produced a softer curd than either AB or BB milk;

milk containing αs1-casein BC was different from BB milk in terms of clotting time and consistency of the gel.

The differences in cheesemaking are due to the associations between certain genetic variants and milk composition. For example, κ-casein B and ß-lactoglobulin B milks have been found to have higher concentrations of casein and fat than the A variant milks [Ng-Kwai-Hang and Grosclaude 2003].

Lawrence [1993 c] reported that the concentration of total casein and fat was found to increase as the A-variant of ß-lg was replaced by the B-gene. The relationship between ß-lg and the casein fractions presumably occur because these proteins are synthesized and secreted into the alveolar lumen in a similar manner.

The use of milk containing the BB genotype of κ-casein result in higher cheese yields than the used of milk without this variant higher cheese yields were obtained with milk containing the genetic variants κ-casein B and ß-lg B than with milk containing other phenotypes of the respective protein [Lawrence 1993 c].

In general the yield and quality of most of the varieties of cheeses depend, to a large extent, on the fat and casein contents of the milks from which they are derived. The B genotype of ß-lg and the caseins are associated with high total casein and fat concentrations in milk and that the suitability of milk for cheesemaking would be improved by deliberately selecting such genetic variants as ß-lg BB or κ-casein BB, or a combination of the two [Ng-Kwai-Hang 2006].

Casein fractions analysis indicated a wide variability of αs1-CN with a nearly three-fold increase in Anglo-Nubian milk compared to Saanen milk, which could explain the higher cheese yield and its better performance for cheesemaking. Saanen milk had a lower αs1-CN content, which suggests advantages of this breed for fluid milk sale [Damián et al. 2008].

Good quality milk, giving an optimal cheese yield and cheese quality, originate from healthy animals, has good flavour, has been cold stored for a limited amount of time and has a high protein content with the BB genotypes of s-lactoglobuline and κ-casein (bovine milk). The milk should be low in somatic cell count, as proteases from somatic cells attacks αS2- and scaseins and reduce the cheese yield. The content of free fatty acids should be low, as free fatty acids bind Ca^{2+} and thereby reduce the coagulation properties of the milk, in addition free fatty acids contribute to the development of rancid flavour in cheese. Milk used for cheesemaking must be of good microbiological quality, pathogenic bacteria should be absent, psychotropic bacteria have heat resistant lipases and proteases which may reduce yield, but may also cause undesirable flavours in the ripened cheese. Clostridia spores cause late blowing in cheeses with eyes, but also to cheeses with closed texture these bacteria induce inedible flavours. Antimicrobial agents as antibiotics, detergents etc. must be absent, as the acidification by lactic acid bacteria will be strongly influenced [Skeie 2007].

The yield of the processed cheese and the Sudanese white cheese made out of it from 4.4% fat milk after 15 and 30 days ripening were 2.850 kg and 1.75 kg and 2.750 kg and 1.50 kg respectively. While that made from 2.2 fat % yielded 2.0 kg and 1.25 kg and 2.0 kg and 1.2 kg, respectively. There is possibility of using the Sudanese white cheese as a raw material for preparation of the processed cheese. Moreover, it yielded more quantity that will increase the incomes, in addition to the high prices of the processed cheeses [Nour El Diam and El Zubeir Ibtisam 2007].

Nowadays, polymorphisms of milk proteins can be determined at protein level and DNA level. Some of these polymorphisms in milk proteins are known to affect milk yield, milk composition, micelle organization, coagulation characteristics and cheese yield [Yardibi et al. 2009].

Cheese making trials were arranged to investigate the effect of κ-casein genotypes on milk renneting properties, fresh cheese yield and composition κ-casein BB in significantly higher fat and protein recoveries into cheese yields. Cheese produced from κ-casein BB variant milk had higher concentrations of protein and lower fat levels than that produced from the AA variant. The higher fat and protein recovery with the κ-casein BB milk resulted in cheese with higher fat and protein levels. The is increases in the yield of cheese solids per kg of milk associated with the κ-casein BB variants. This is due to suggest that selective breeding to increase the proportion of the BB variant may prove advantageous to the dairy industry [Alipanah and Kalashnikova 2007].

Early studies on the impact of genetic variants of κ-casein on cheese yield indicated as much as a 10% increase in cheese yield with the BB variant of κ-casein [Aleandri et al. 1990, Marziali and Ng-Kwai-Hang 1986, Buchberger and Dovc 2000]. Initial reports credited the increase in cheese yield to an increase in protein in the BB milk. More recent studies have shown only small yield differences between the AA and BB variants [Bremel et al. 1998, Stasio et al. 2000].

Physiological factors

Lawrence [1993 a] characterizes and analyses the factors that can mainly affect the composition of the milk and, consequently, the cheese yield: breed, variability between individuals, stage of lactation, seasonal variations, feeding factors, age of the cow, mastitis, etc.

Lactation stage

According to Sapru et al. [1997] in Cheddar cheese, the relative losses in fat and protein during cheesemaking are greater for cow milk produced at the end of lactation with respect to milk produced at the beginning of lactation, with consequent minor recovery of substances in the curd. However, since the late lactation milk has a higher content of casein and fat, the higher losses do not markedly affect and the cheese yield of late lactation milk is higher than the cheese yield of early lactation milk.

Guinee et al. [2007 a] showed that the protein content of the milk increased during lactation and that the cheese yield increased similarly to the protein content. At very late lactation the protein content and the cheese yield dropped, however, when the yield were normalized per 100 kg of milk with reference levels of fat and protein, the yield did not decrease to the same extent during very late lactation.

Somatic cell count (SCC)

Milk coming from mastitis has higher somatic cell counts, indicating an increase in plasmin activity. Numerous papers demonstrate that milk with high contents of somatic cells leads to a greater loss of protein in the cheesemaking and therefore to a lessening of cheese yield; these losses are probably due to the greater proteolytic activity of plasmin on caseins, which characterize such milk [Barbano et al. 1991, Klei et al. 1998].

Changes in milk composition and increases in SCC at late lactation milk have resulted in lower levels of casein and decreased cheese yield [Gilles and Lawrence 1985, Sapru et al. 1997].

Milk with a high SCC (> 500 000 cells per ml milk) reduces cheese yield [Auldist et al. 1996], as this milk is associated with higher proteolytic activity, lower concentration of fat and casein and a higher content of whey proteins especially serum albumin and immunoglobulin. Barbano et al. [1991] suggested that the upper limit for SCC for cheese milk should be 100 000 per ml milk. This was based on results showing a marked decrease in cheese yield at SCC > 100 000 per ml milk. Skeie [2007] reported that the milk should be low in SCC, as proteases from somatic cells attacks α_{S2}- and β-casein and reduce the cheese yield.

Othmane et al. [2002] mentioned that a high SCC was accompanied by an increase in serum protein content and involved a loss in milk yield.

Mistry and Kosikowski [1988] mentioned that the direct UF of high SCC milk to 1.84:1 total protein improved cheese quality and increased yield over control milk cheeses but not to the same high level attained with retentate supplementation. They also show that normal cheese yields and excellent quality are possible despite the presence of high SCC in the retentate supplemented milk. This observation raises questions concerning the major cause of poor cheese yield and quality from high SCC milk.

Seasonal variations of milk characteristics

Seasonal variations of the composition of milk, in particular those regarding the protein or casein content, markedly affect the cheese yield of most cheese productions [Barbano and Sherbon 1984, Gilles and Lawrence 1985, Paolo et al. 2008].

Bynum and Olson [1982], Barbano and Sherbon [1984] and Ozimek and Kennelly [1993] have underlined an analogous trend for the yield in Cheddar cheese, with minimum values in the months of June, July and August and the maximum ones in correspondence with the autumnal months.

Banks and Tamime [1987] find for the content of fat the maximum values in the month of May and minimum values in December and January and for the casein maximum values in May and minimum values in January and November. Consequently, the yield of milk in Cheddar cheese, manifests minimum values in January and maximum in September and October. From these data it clearly emerges that the climatic conditions and the physiological state of the cows exercise a determining role on the contents of fat and casein and on the coagulation properties, factors that, conversely, markedly affect the cheese yield.

Type of milk

The cheese yield was the highest for buffalo milk cheese and the lowest for goat milk cheese. The yield of all the cheeses was influenced by the type of milk used and loss of moisture during the storage period [Abd El-Rafee and Abd El-Gawad 2002]. The yield and the recovery of cheese milk constituents recorded highest values in buffaloe milk and the lowest in cow milk [Abdou et al. 2002]. Mozzarella cheese supplemented with caseinate gave the highest yield and gained highest score for flavour, body and texture compared to control and cheese supplemented with other concentrates [Hassan and Abd El-Gawad 2000]. The yield of Mozzarella cheese from goat milk was more affected by addition of glucono-δ-lactone, (GDL) than, that of buffaloe and cow milk cheese. As it is expected and because milk used in cheese manufacture is not standardized, the yield values of buffaloe milk cheese were higher than that of cow or goat milk cheese [Ismail et al. 2007]. The yield of mixture of buffalo and soy milk in the ratio of 4:1. The yield of cheese from buffalo and soy milk mixture was slightly lees, and weight losses during pickling were slightly higher than cheese from buffalo milk [Hofi et al. 1976].

Processing conditions

A wide range of processing conditions affect cheese yield and loss of potential cheese constituents can occur at any stage after milking. Some of the factors involved may have only a relatively small effect on yield individually but, when extrapolated to large scale cheese production, the effect on cost benefits may be very significant [Lawrence 1993 b].

Storage of milk

It has become an increasingly common practice in many countries for milk to be cooled rapidly to 7°C or less on the farms after milking. At the same time there has been a decrease in the frequency of pick-up of milk from farms and an increasing tendency for plants to manufacture cheese for only 6 or even 5 days a week. These have led to the storage of milk for longer periods. Storage of cold milk leads to solubilization of casein from the micelles, which will tend to increase the possibility of proteolysis by enzymes derived from psychrotrophic bacteria, somatic cells or the blood. Milk stored at temperatures of less than 7°C for 48 h contained a high proportion of soluble casein and clotted slowly. The use of such cold milk resulted in a weaker curd, lower curd yield and greater losses of fat and curd fines into the whey than the use of unsorted milk or milk stored at 10-20°C. In most cases, however, the cold milk is heat treated before processing. This results in the re-incorporation of the soluble casein into the curd matrix with no significant loss in cheese yield [Grandison 1986].

An investigation in Northern Ireland Weatherup et al. [1988] found significant decreases in yield when cheese was made from milk stored at both 3 and 7°C. Yield of cottage cheese decreased with an increase in time that raw milk was stored. Yield decreases were 2.5 to 3% per day of low temperature storage after the bacterial count of raw milk attained 106/ml [Aylward et al. 1980].

Domiati cheese from frozen milk had slightly less total solid and fat content compared to fresh milk cheese, whereas, cold and frozen storage remarkably increased cheese yield [Ammar 1999].

The yield and weight of ripend cheese made from heated goat's milk with or without cold storage were relatively higher than cow milk or unheated goat milk [Okasha 2001, El-Demerdash 1996].

Standardization of milk

Milk standardization gives the producer the ability to manipulate the composition of the final cheese by controlling the composition of the starting milk in order to meet the legal definition of the specific variety and to improve yields. In addition, however, the use of standardized milk avoids the manufacture of cheese containing excess fat and minimizes fat and casein losses into the whey [Lucey and Kelly 1994, Scott 1998].

Chapman [1981] has outlined the three main methods for standardizing milk for cheesemaking: the addition of skimmed milk powder, the addition of liquid skim milk and the removal of cream. In the first two cases the quality and temperature history of the skimmed milk powder or liquid are important, particularly in the manufacture of high quality Cheddar cheese. When Cheddar cheese was made from milk showing the normal seasonal trends in composition and from milk that had been standardized to a crude protein-to-fat ratio of 0.9 (by the addition of skimmed milk), standardization resulted in a small loss of yield from a standard volume of milk (averaged over a complete year). This loss was compensated for by an almost equal gain in the efficiency of fat retention [Banks et al. 1984 a].

Types of starter culture used

The cheese yield has a major importance on quality of final product. Among the different factors, the role of starter culture and renneting pH is of an importance in making of Iranian brine cheese. Thus, the effects of commercially available starter culture which is a mixture of mesophilic (*Streptococcus lactis. Lactis* and *Str. Lactis. ceremuris*) and thermophilic (*Str. Thermophilus* and *Lactobacillus bulgaricus*) bacteria and renting pH on the physico-chemical changes of Iranian brine cheese was investigated throughout ripening and storage up to 5 week [Najaf et al. 2008].

Theoretically the use of proteinase-negative starter strains would be expected to result in the least loss of casein. This was found to be true in the manufacture of Cottage cheese, as the highest yields were obtained with the exclusive use of proteinase-negative strains. Their use in long maturing cheese varieties, however, may lead to a lack of typical flavour formation [Lawrence 1993 b].

Kareish cheese could be manufactured from reconstituted skim milk (–20% total solids) using a culture of *L. bulgaricus* at the rate of 5% and 3 ml rennet per 100 kg. The resulting cheese was higher in yield, total solids, total nitrogen, titretable acidity and lactose; and longer in shelf life (20 days) than control (12 days) made from fresh cow skim milk (–9% total solids) [Abou Dawood and Comai 1977].

El-Abd et al. [2003] studied effect of some lactic acid bacteria on the properties of low salt Domiati cheese. Addition of starter cultures reduced the coagulation time, yield and moisture content of fresh cheese which being more pronounced in containing 3% salt.

Heat treatments of milk

Heat treatment of milk at 64-68°C/10 s, indirectly influences cheese yield by preventing losses of milk solids during storage. Thermization leads to an immediate reduction in the numbers of proteolytic bacteria and the storage life of the milk is not as dependent on the microbiological quality of the raw milk as it is with low temperature storage.

Cheddar cheese was made from pasteurized (63°C for 30 min) and raw milk to determine the influence of pasteurization on cheese yield and on fat and nitrogen (i.e., protein) recovery in cheese. Pasteurization had no effect on fat recovery in cheese, but nitrogen recovery was higher for cheese made from pasteurized milk. Composition-adjusted cheese yield was higher in cheese made from pasteurized milk. Based on casein measurement by the International Dairy Federation method, it appeared that approximately 5% of the whey proteins originally present in the milk, presumably ß-lactoglobulin, was associated with casein micelles after milk pasteurization. It was concluded that heat denaturation of whey protein caused by HTST pasteurization of milk prior to cheese making results in a theoretical cheese yield increase of about 0.01 to 0.04 kg for milk with a theoretical Cheddar cheese yield of 10 kg/100 kg of milk. Higher pasteurization temperatures or longer holding times would cause more heat-induced interactions of casein and whey proteins [Lau et al. 1990].

High heat treatment (> 90°C) of cheese milk denatures more whey proteins and results in a greater increase in cottage cheese yield [Vakaleris 1962] in comparison with milk subjected to only minimum legal pasteurization (72°C/15 s). Therefore, it was unexpected that milk subjected to a relatively mild heat treatment (74°C/10 s), stored for 7 days, and then subjected to normal pasteurization would give higher yields of satisfactory cottage cheese. An increased yield of approximately 5% was obtained in cottage cheese production by heating the cheese milk to 74°C for 10 s and storing at 3 ±1°C/7 days [Emmons and Tuckey 1967, Kosikowski 1977].

The yield percentage was higher in heated milk cheese than unheated milk cheese. Heating the skim milk improved the quality of the Kariesh cheese especially its body and texture [Abdou and Abou Dawood 1977]. Camembert-type cheese was manufactured from pasteurized milk (72°C, 15 s) or milk heated to 80°C for 3 min or from a 30:70 mixture of high heated milk (90°C, 6 min) and raw milk. A significant increase in yield, moisture retention, solids and protein recovery was observed in the cheeses produced from the heated and mixed milk both with a total denaturation degree of 30% of whey proteins [Ghosh et al. 1999].

Homogenization of milk

Homogenization, leads to increased retention of fat and moisture, probably by altering the coagulum structure and modifying the smaller fat globules within the coagulum. The retardation of syneresis, however, means that homogenization can be used only in the manufacture of high moisture cheeses such as Blue cheese varieties and UF Cast Feta and is not suitable for the manufacture of relatively low moisture cheeses such as [Cheddar Lawrence 1993 b].

A specific use of homogenization to increase yield occurs in the manufacture of Cottage cheese. Lawrence [1993 b] has shown that up to 8% of the casein originally present in the milk may be present as sludge. This sludge, which is probably caused by agglutinins in the skim milk, is largely lost into the whey. Homogenization of the skim milk before cheesemaking at least partially destroys the agglutinins and is found to improve yields by up to 5%.

Everett and Auty [2008] reported that homogenization of milk prior to the manufacture of cream cheese allows the fat globules to interact with the casein matrix and produce a more elastic cheese with less free oil formation. In addition, use of homogenized milk for cheese-making will produce higher yields since more moisture will ultimately be retained in the protein network.

The yield and the moisture content of the fresh cheese increased with increasing homogenization pressure. Renneting time and fat percentage of cheese decreased with increasing homogenization pressure. The maximum cheese yield was obtained at homogenization pressure of 3000 Ib/sq. inch [Farag and Moneb 1977].

Camembert cheese manufactured from homogenized milk (35 bar, 55°C) prior to pasteurization or high heat treatment 80°C, 3 min). Higher yields, better moisture retention, higher solids and protein recovery were observed in the cheese from homogenised milk (pasteurized, high heated) compared with cheese from unhomogenised pasteurized milk [Ghosh et al. 1999].

Types of coagulant used

Several studies demonstrated the lack of significant differences in yield when enzymes from *Mucor* species and *Endothia parasitica* were compared with rennet extract or blends of rennet and porcine pepsin. A critical the literature indicates that review of most milk-clotting enzymes is likely to affect yield of many varieties of cheese relative to calf rennet. Based on protein losses in whey, relative losses for Cheddar were, compared with calf rennet: bovine pepsin, –0.14%; chicken pepsin, –0.44%; *Mucor miehei*, –0.63 to –0.68%; *Mucor pusillus*, –0.49; *Endothia parasitica*, –1.24; these data are qualified by milk fat and assuming an equal value for cheese [Emmons and Binns 1990].

A longer rennet coagulation time (firmer coagulum at cutting) resulted in an increase in cheese moisture, as well as an increase in cheese yield [Johnson et al. 2001].

Amount of rennet and temperature increasing the amount of rennet speed up milk coagulation. The yield of Domiati cheese and its moisture content was lower, while, fat/solids content was higher than cheese at lower levels of rennet. Although as the renneting temperature increased milk coagulation time decreased, cheese yield increase and fat/solids ratio decreased [Fahmi et al. 1973].

The yield of Mozzarella cheese made using Mucor miehei rennet, was the lowest compared with using the other type of coagulants [Abd El-Rafee et al. 1998].

Adding of glucono-δ-lactone, (GDL) alone to Mozzarella cheese milk decrease both actual and moisture and salt adjusted cheese yields more than using GDL with yoghurt starter as acidulate. The progressive reduction in moisture and salt adjusted cheese yield with increasing preacidification was caused by a substantial reduction in calcium recovery in the cheese and a tendency for decreased protein recovery in the cheese. This would decrease moisture and salt adjusted yield [Ismail et al. 2007, Mtzger et al. 2000].

In the production of soft cheese, Colin and Laurent [1991] and Colinet al. [1992] underline that milk coagulation properties, in particular curd firming time, can have a marked influence on the cheese yield. These authors assert, in fact, that the simultaneous use of the chemical parameters and the coagulation parameters improves remarkably predictions of the fresh yield, while the ripened cheese yield would not be related to the coagulation parameters. The authors found that the curd firming time explains 74% of the variation of the fresh yield.

Van Boekel and Crijns [1994] found that, in the acid coagulation at pH 4.6 all proteose-peptones (pp) are lost in the whey, in the rennet coagulation three quarters of them, that are pp5 and pp8 are retained in the curd, contributing to increase the cheese yield.

Curd firmness

Reports on the influence of curd firmness at cutting on cheese yield are inconsistent, probably because it is difficult to assess the firmness of rennet gels objectively. In addition, the factors that influence the extent of loss of fat and casein fines into the whey are complex. The type of cheese vat, the construction of the knives, the way in which the rennet coagulum is formed, the cutting regime and the properties of the curd in relation to the cheese variety being manufactured are all important [Lawrence 1993 b].

If the curd is cut when it is very soft, the network will shatter and fat will be lost, decreasing yields, and altering. Conversely, if the curd is too firm when cut, the protein network will break and there will be high loss of casein, again, altering texture. Presumably, the change in the moisture content is a reflection of the extent of bonding between and within casein particles, which increases with time texture [Johnson and Law 1999, Johnson et al. 2001].

After cutting, the curd is left alone for a short period known as a healing period. During the healing period, a "skin" forms on the outside of the curd, which prevents further losses of fat and moisture. The curds are then stirred and cooked in order to expel moisture and to promote shrinkage of the protein network [Brown 2002].

Bynum and Olson [1982] have observed, in Cheddar cheesemaking, a significant effect of the curd firmness on the yield: an increase in firmness leads to a lowering of the losses of fat and casein, and, therefore, to an increase of the cheese yield.

Mayes and Sutherland [1989] found an increased recovery of milk solids with a prolonged renneting time. However, a 16% increase in the normal renneting time increased the moisture content and decreased the quality of the cheese especially after long ripening. It was concluded that a 10% deviation from the optimum renneting time could be tolerated. A second conclusion was that deviations below the optimum renneting time were more critical with respect to the overall performance of the process (yield and quality) than deviations above the optimum.

Curd handling systems

The greater part of the fat and protein losses during cheesemaking occur at the vat stage. Further losses depend on the way in which the curd is handled. As a general principle, the curd should be handled as gently as possible vat for all cheese varieties. This is of course particularly true for the higher moisture cheeses. Special equipment has been specifically designed for such cheeses as Camembert and modern dosing systems keep losses for the Gouda-type cheeses down to a minimum [Lawrence 1993 b].

Most Cheddar cheese plants use mechanized belt systems and mechanical damage to the curd can occur as the curd is stirred during draining and salting. Salting the curd at temperatures above 32°C and pressing warm curd also lead to higher than average fat losses [Chapman 1981]. Care must be taken when blowing curd from the vat to the cheddaring belt and also from the salter to the press. Rapid application of air pressure should be avoided and the air pressure should be the minimum required. Right angle bends in the air pipes must also be avoided.

Curd washing

The quantity of wash water used in the manufacture of Gouda-type cheeses affects the solids-not-fat (SNF) content in the moisture (diluted whey) phase of the cheese. An increase in the quantity of added water from 30 to 40% (expressed per mass of curd after part of the whey has been removed) reduces the yield by 0.5-1%. There is an almost linear relationship between the decrease in yield of Gouda, measured 12 days after manufacture, and the quantity of water added to the curd [Lawrence 1993 b].

Removing whey and wash water from the curds without taking advantage of the filtration effect of the curd mass seriously reduces the yield of Cottage cheese. Many plants increase the retention of "fines" by removing whey and wash water from the top and bottom at the same time. In addition, less solids are removed from the curd if the chill water is recycled from vat to vat [Lawrence 1993 b].

Salt and loss of moisture during ripening

A factor affecting the cheese yield of surface-waxed cheeses at the time of consumption, as distinct from curd or green cheese yield, is loss of moisture by evaporation. The rate of evaporation might be expected to vary with the relative humidity and especially with the temperature of the ripening room. In the absence of air conditioning, hot dry summers will be conducive to low yields in matured cheese irrespective of the fat plus casein value of the milk [Lawrence 1993 b].

Yield and moisture content of fresh cheese made from buffaloes milk containing 2% cheese hydrolyzate increased with increasing the amount of salt added, as well as, to the formation of softer curd retaining higher moisture. As ripening progressed, cheese yield, moisture and salt content gradually decreased [El-Sissi and NeamatAllah 1996].

Utilization of reconstituted skim milk and cow milk cream in Domiati cheese manufacture was found to increase the fresh and pickled cheese yield throughout the storage time, which may be attributed to increased moisture retention. The yield of control and experimental cheeses decreased gradually as storage period progressed [Abd El-Kader 2003, Ismail 2005].

The yield of Labneh manufactured from buffalo milk was higher than that of cow or recombined milk. Raising the amount of salt added to Labneh's milk led to increase the yield and total solids of the product to some extent [Ammar et al. 1999].

Edam cheese salted by adding 2% dry salt showed higher yield (%), moisture (%) and titratable acidity than other treatments either in fresh or during the ripening. The yield and moisture content of all treatment decreased gradually with the increase of ripening period up to 90 days [Duzrec and Zall 1982, El-Demerdash 1996, El-Sisey 2002, El-Batawy et al. 2004].

Cheese stored in salted whey showed the lowest yield followed by that stored in deproteinized salted whey. While cheese stored in brine solution showed the highest yield. Also, the same trend was found in cheese stored at room temperature for two weeks followed by refrigerator. However, cheese stored all through pickling at room temperature showed lower yield than the corresponding samples stored at low temperature. [Abou Zeid et al. 2007]. This may be due to the high acidity development in cheese stored at room temperature which would inherence curd contraction. Also, the high cheese yield at low temperature may result from the high ability of cheese proteins to absorb moisture at low temperature [Abdel-Kader 2003, Ismail 2005].

Incorporation of whey proteins in cheese

There is an increasing interest in incorporating whey proteins in cheese. The main reason is economics; whey contains approximately 0.6% protein. Incorporating whey proteins in cheese will increase the cheese yield and thereby the profit in cheesemaking – if the process can be adapted without proportional expenses, e.g. expensive equipment or inferior cheese quality – and will reduce the expenditure on wastewater treatment [Jensen and Stapelfeldt 1993].

There is a nutritional interest in incorporating whey proteins in cheese. The protein contained in the whey is of high biological value. In fact, the whey proteins are higher nutritional value than the caseins because of their higher content of essential amino acids (especially Ile, Lys, Thr and Trp) [Hambraeus 1982].

In principle, whey proteins can be incorporated in cheese in two ways:

a) directly: addition of whey proteins to the cheese milk;

b) indirectly: incorporation of the whey proteins naturally present in the cheese milk.

Addition of heat-denaturated whey proteins to cheese milk

Addition of heat-denatured whey proteins to the cheese milk is a more controlled way of obtaining the quantity and composition of whey proteins that are desired in the cheese [Jensen and Stapelfeldt 1993].

A novel process has been developed [Reflection... 1985] for increasing the yield of Cheddar cheese by the incorporation of heat-denatured whey protein in curd.

Domiati cheese was made from pasteurized milk containing whey proteins precipitated from salted rennet whey by heat treatment. The yield of cheese containing whey proteins was higher than cheese without added whey proteins and the weight losses during storage were much less in former cheese [El-Shibiny et al. 1973].

Heat treatment of cheese milk

Heat treatment of the cheese milk may be a competitive alternative to the use of ultrafiltration as a means of incorporating whey proteins into cheese. Heat treatment is less costly than ultrafiltration and will improve the bacteriological status of the milk. If UHT treatment can be used, then the number of spores and therefore the addition of KNO_3 can be reduced.

It is well known that high heat treatment of milk increases the rennet clotting time. This increase is caused by a change in the equilibrium between dissolved and colloidal calcium phosphate and the formation of a complex between κ-casein and β-lactoglobulin. The effects of high heat treatments cause some practical difficulties in obtaining a cheese with a quality equal to that of a cheese made from raw or high temperature short time (HTST) – pasteurized milk [Emmons 1993 b].

Marshall et al. [1978] found that the increased yield (not given) of Cheddar cheese manufactured with replacement of one-third or one-half of the pasteurized milk (72°C/15 s) with milk heated at 87.8°C/17 s was due entirely to greater moisture retention.

Marshall [1986] manufactured Cheshire cheese from milk heated at 97°C/15 s, and obtained an increase in the cheese yield on a dry matter basis of 4.5% – mainly additional protein, but also fat. In an attempt to optimize the quality of the cheeses, it was necessary to add $CaCl_2$, increase the scalding temperature, and cheddar the curds. The experimental cheeses had higher levels of moisture and milk non-fat solids (MNFS) and tended to have a flavour of a slightly lower quality and a softer, more crumbly structure than the controls.

Heat treatment greater than pasteurization (i.e. 72°C/16 s) has not been favoured for the production of Cheddar because of the slower coagulation, weaker curd and impaired syneresis it produces Beeby et al. [1971]. Such milk has, however, been used to increase yields in other varieties of cheese, e.g. Cottage cheese and acid set Mozzarella [Kannan and Jenness 1956, Buchanan et al. 1965].

Use of co-precipitate technology

Co-precipitation of casein and whey proteins is performed by heating milk to – as an example – 90°C/15 s and then adding $CaCl_2$. The milk with the Ca-casein-whey protein complex can then be used for cheese manufacture.

Poznański et al. [1974] manufactured Grana, Gruyere, Cheddar, Blue, Stilton, Munster and Limburger cheeses, with an increase in cheese yield of over 30% and with flavour and consistency comparable with those of the controls.

Use of ultrafiltrated milk

The use of ultrafiltration (UF) in cheesemaking has developed since the technique was introduced by Maubois and Mocquot [1971].

In the last two decades the UF process has proven to be successful in the dairy industry and particularly in cheesemaking. Ultrafiltration allows the concentration, separation and recovery of individual milk components. The application of UF process accounts for about 3% of total world cheese production and it is postulated that this process contributes to higher cheese yield. An accurate assessment of the cheese yield produced by the additional method as compared to the UF method in cream cheese making: is crucial in the evaluation of milk component utilization and cheese production costs [Salhab 1998].

The bakery and confectionery industries are creating a steadily increasing demand for soft cream cheese. UF technology has proven its success in concentrating milk proteins for cheese making especially for soft type cheeses such as cream cheese. Thus UF will lead to an increase in cheese yield as compared to cream cheese manufactured in the traditional manner. It has been reported that up to a 20% increase in cheese yield might be expected due to the application of membrane processing [Dejmek 1986]. The main factor that contributes to cheese yield increase is the whey protein recovery.

By increasing the concentration ratio of UF retentates the quarg cheese yield was increased. Retentate enriched with calcium resulted in a higher ratio of these yield than in the control one [Omar et al. 1998].

Brown and Ernstrom [1982] reported that the whey was concentrated by ultrafiltration to between 9.8 and 20.3% solids (4.3 to 7.1% protein) and then heated at 75°C/30 min. Return of this concentrate to cheese milk increased average yield 4.0% at constant cheese moisture.

UF Edam cheese from retentate enriched with 2% sodium caseinate gave higher cheese yield, highest gross yield in fat and protein recoveries, ripening indices and organoleptic properties [El-Shibiny et al. 1998].

UF Edam cheese from retentate supplemented with 50% low whey proteins milk retentate showed the best yield and organoleptic quality. This ingredient can be successful used in the manufacture of UF Edam cheese [El-Sheikh et al. 1999].

The use of membrane filtration to concentrate milk by between 20 and 50% appears to offer the most attractive means of increasing the protein concentration of milk at the present time. This use of low concentrated retentates is common practice in Europe, particularly for the manufacture of Camembert-type cheese. This is equivalent to standardizing the protein level of the milk to about 4%. The proportion of whey proteins retained by these procedures, and therefore the increase in yields, is very small. However, the increased proportions of casein and associated minerals in UF milk increase its buffering capacity and thus allow greater control over both the rate of pH decrease during manufacture and the final pH of the cheese. This control of pH results in greater uniformity in cheese quality [Lawrence 1993 b].

FORMULAS OF MEASUREMENT AND PREDICTION OF CHEESE YIELD

Various formulas of measurement and formulas of prediction of the cheese yield have been proposed; the first are based on the weight of the cheese or of some of its components (e.g. dry not-fat extract), the second may be applied also without cheesemaking and base their calculations on the chemical characteristics of milk or on statistical formulas with coefficients calculated from an elevated number of cheesemaking trials [Paolo et al. 2008]. For the measurement of cheese yields various formulas have been elaborated which consider different parameters.

Predictive formulas

The predictive formulas serve in order to estimate the obtainable maximum cheese yields for a particular type of cheese and, therefore, in order to calibrate the transformation process according to the actual cheese yields obtained in the cheese factory for that type of cheese; practically they concur to give indications as to the goodness of the technological process of cheesemaking.

Formulas based on the statistical analysis of a high number of trials

Formulas of van Slyke

The formula of van Slyke [1984] is valid for Cheddar, but it is the basis for formulas elaborated successively for different cheese varieties. According to this formula, the cheese yield, expressed in kg of cheese for 100 kg of milk, can be calculated by the following equation:

$$\text{Cheese yield} = [(0.93\ G + C - 0.1) \cdot 1.09 \cdot 100] / (100 - U)$$

where G is the milk fat (%), C is casein (%), U is the moisture of cheese (%), 1.09 is a constant that considers the effect of salt and other solids and 0.1 represents the presumed loss of casein. Varying the constants, the same formula can be applied to the calculation of the cheese yields of other cheeses.

Formulas of multiple regressions beginning from fat and protein (casein)

One of the more important formulas, probably the one mainly used Tavola Rotonda [1981] is the following: $a \cdot G + b \cdot P$, where G and P are respectively the fat and the protein of the milk, while 'a' and 'b' are two coefficients which take into account the recovery of these two components, that is the contribution with which each of them participates in the curd formation. The two coefficients vary depending on the type of cheese and manufacture and are the average values resulting from a high number of trials. The variant that uses the casein content instead of the total protein has been shown as mainly able to forecast cheese yield. These predictive formulas tend to give results that differ in excess or defect with respect to the effective cheese yields of a cheese factory; they serve however to orient the technician and can constitute a basis of evaluation of the technological results.

Formulas of Colin, Laurent and Vignon

Colin and Laurent [1991], Colin et al. [1992] in the elaboration of formulas of cheese yield for soft cheese, draw attention, in particular, to the coagulation properties; they develop, in fact, multiple regressions that take into account numerous parameters that can be related to cheese yield: besides TP, TB (taux butyreux) and Tcas, respectively the content of protein, fat and casein, they take into consideration also MAC (curd nitrogen substance), the proportions of α_{s1}-casein and β-casein and, in particular, the curd firming time k_{20}. Several predictive formulas, obtained from several combinations of the parameters cited above, are considered, with relative coefficients calculated by multiple regressions. The formula that, according to the authors, results as more suitable in order to forecast the cheese yield for soft cheese is the one that considers protein content and k_{20}:

$$Y\ (\text{soft cheese}) = 9.75 - 0.021 \cdot k_{20} + 0.211 \cdot TP$$

Formulas based on theoretical considerations relative to the distribution of the solids and the moisture between the different phases

The second typology of formulas, based on theoretical considerations relative to the distribution of the solids and the moisture between the different phases, proposed by Emmons et al. [1990] is based on the principle that the cheese is constituted by three phases: fat matter, paracasein "tissue" and watery phase, which consists of water and the substances dissolved in it. The different ways to distribute the soluble substances in water and the same water in the other constituents give rise to four different types of formulas:

– Type A formulas in which the solid particles of the whey, the salt and the water amount are distributed proportionally to the fat and to the paracasein.
– Type B formulas in which the solid particles of the whey and the salt are included in the paracasein so as to form the "dry not-fat cheese", and the water content is distributed proportionally to fat and dry not-fat substance.
– Type C formulas in which solid particles of the whey, salt and moisture are distributed in proportion to the paracasein only.
– Type D formulas in which solid particles of the whey, salt and moisture are considered together as the "watery phase" and where all the phases are confronted on the base of their volumes.

The choice of determined formula typology depends on the type of cheese, for example if cheese is fat, soft, or hard.

CONCLUSION

Further research will include validation of the yield predictive formulae for hard and semi-hard cheeses of milk using larger data sets over several lactations, because of variation in relationships between milk components due to breed, stage of lactation, season, feeding regime, somatic cell count and differences in casein variants. Standardization of UF cheese yield assessment and cheese yield equations are needed. It should be appreciated that a good degree of agreement of formula to a particular type of cheesemaking situation does not mean that the formula will be universally applicable to other types of cheese or indeed to other factories making similar cheese, or that it represents a true index of the yield potential of the milk.

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CZYNNIKI WPŁYWAJĄCE NA WYDAJNOŚĆ PRODUKCJI SEROWARSKIEJ

Streszczenie. Wydajność produkcji serowarskiej („wydatek serów") jest określana ilością kilogramów sera uzyskanych z przerobu 100 kg mleka. Jest to istotny parametr świadczący o odzyskaniu w jak największym stopniu składników suchej substancji mleka przerobowego, co z kolei wpływa na ekonomikę produkcji. Właściwe i szybkie określenie wydajności produkcji serowarskiej ma dwojakie znaczenie: pierwsze dotyczy ekonomiki procesu produkcji serów, drugie pozwala na wdrożenie wyników prowadzonych doświadczeń. Wydajność produkcji serowarskiej zależy od wielu czynników, w tym od składu mleka przerobowego, ilości i genetycznych wariantów frakcji kazeiny w mleku, jakości mleka, zawartości w mleku komórek somatycznych (LKS), pasteryzacji mleka, typu użytych preparatów koagulujących mleko, kształtu i wyposażenia wanny serowarskiej, zwięzłości skrzepu, sposobu cięcia skrzepu oraz parametrów procesu wytwórczego.

Słowa kluczowe: mleczarstwo, sery, produkcja, parametry, jakość

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