Iranian Food Science and Technology Research Journal
Vol. 12, No. 3, Aug. Sep. 2016, p. 371-381

نشریه پژوهشهای علوم و صنایع غذایی ایران
جلد ۱۲، شماره ۳، مرداد - شهریور ۱۳۹۵، ص. ۳۸۱-۳۷۱

Effects of Different Manufacturing Methods on Yield, Physicochemical and Sensory Properties of Mozzarella Cheese

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Received: 2016.04.18
Accepted: 2016.08.23

Abstract

The effect of different mozzarella cheese manufacturing methods, i.e. direct acidification (DA), starter culture (SC) and their combination method (CM) on physicochemical, yield, texture, color and sensory properties of the product were compared. Chemical analyses of samples revealed that the SC cheese had higher fat, moisture, ash, titratable acidity, actual and adjusted yields and fat recovery than DA cheese. DA cheese showed higher springiness, cohesiveness, and hardness than CM and SC cheeses, due to denser and elastic protein network, whereas meltability and adhesiveness of DA cheese was lower than CM and SC samples. SC cheese had significantly higher b-value than DA sample. The sensory evaluation revealed that the SC cheese had higher sensory quality than other cheeses in fresh state and during 45 days of storage. In general, sensory scores of all mozzarella cheeses were acceptable up to 15th day of storage and thereafter decreased progressively till the end of storage period.

Keywords: Different manufacturing methods; Mozzarella cheese; Physicochemical; Textural properties; Sensory attribute.

Introduction

Mozzarella cheese belongs to the family of 'Pasta Filata' cheeses and has a specific manufacturing method which the curd is immersed and kneaded in hot water and then stretched several times to the desirable smooth texture (Abd El-Gawad *et al.,* 2012). Because the main application of mozzarella cheese is used as a topping on pizza, therefore the texture and particularly melting characteristics of cheese has significant effect on consumer acceptance. Mozzarella has a several desirable properties, such as medium firmness, appropriate melting and stretchability, and easy shredding (Jana and Mandal, 2011). These properties can be affected by different parameters such as moisture, pH and salt content of the cheese.

The variation of pH at different steps of manufacturing can affect the water holding capacity, composition and in addition promote the functional properties of the cheese (Guinee *et al.,* 2002). It also can affect the meltability and distribution of calcium in the cheese (Kindstedt *et al.,* 2001). Proteolysis which occurs in most varieties of rennet-curd cheeses has a significant effect on development of texture and flavor of the product. The proteolysis of casein is affected by calcium content and pH in diluted systems (Feeney *et al.,* 2002). The pH of 5.3 is a critical point in related to the yield and calcium contents of obtained cheese and by controlling/decreasing the calcium content of the cheese through lactic acid addition (e.g. with increasing the acidity of the curd from 0.5 to 0.8%), the meltability (Kiely *et al.,* 1992) and sensory scores (Jana and Mandal, 2011) of the final mozzarella cheese can be improved.

Milk pre-acidification with food grade acids before adding rennet causes the casein destabilization and removing the large amounts of calcium in casein micelles. This reduces the extent of calcium bonded between casein polymers and therefore the softer cheese with better and higher flow ability and stretching can be produced (Feeney *et al.,* 2002; Zisu and Shah, 2005).

Acid production rate is a critical issue that

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determines the cheese quality. Starter cultures used for promotion of acid production during curd manufacturing have also significant effects on flavor characteristics and textural properties of final cheese. A various variety of starter cultures such as, *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* or *Lactobacillus helveticus* can be used alone or in combination for obtaining the appropriate properties of mozzarella cheese (Sameen *et al.,* 2010). Although the cheeses obtained by starter cultures may have more yield and flavors, but direct acidification method of cheese manufacturing can be a good choice for mechanization and continuous manufacturing of mozzarella cheese (Ernstrom, 1965).

Different manufacturing methods of mozzarella cheese can alter the quality and the quantity of the product. Though the effect of pre-acidification or addition of starter culture on the textural properties, sensory attributes, and quantity of the mozzarella cheese have been extensively investigated by many researchers (Dave *et al.,* 2003; Kiely *et al.,* 1992; McMahon *et al.,* 2005; Oommen *et al.,* 2002; Zisu and Shah, 2007), but comparison between these procedures along with their combination method (pre-acidifiacation and starter culture) have not yet been studied. Therefore, in the current research, effect of different methods of mozzarella cheese making, i.e. direct acidification, starter culture and their combination methods on physicochemical, yield, and sensory of the obtained cheeses were investigated.

Materials and Methods

Cheese Manufacture

The whole milk (3.2% fat) was pasteurized (72 °C for 15 s), cooled to 37 °C and divided into 10-litre quantities for each manufacturing method. Manufacturing methods of mozzarella cheese were done according to Dave *et al.* (2003) and Guinee *et al.* (2002) with some modifications. In direct acidification (DA) method, citric acid (10% solution) was used before and after curd formation. Before coagulation, pH of milk was reduced to 6.1 with using citric acid solution. Then commercial powdered microbial rennet (Rennilase, Meito Sangyo Co., Nagoya, Japan) at a level of 1.5 g per 100 kg of milk was added and after incubation at 37 °C for 30 min, curd was cut. At that time curd was maintained for about 10 min without stirring and then was gently stirred for further 10 min to facilitate whey expulsion and avoid fusion of freshly cut curd cubes. Then the half of whey was removed and temperature of remained whey was gradually raised up to 40 °C over 20 min. Afterward, another fourth of remained whey volume was removed and citric acid was added gradually and temperature was raised with time up to 43–44°C in at least 1h until the pH of whey and curd was reached approximately to 4.4 and 5.3, respectively. For starter culture (SC) method, about one percent starter culture (mixture of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* at a ratio 1:1) was added to the milk at 42 °C and milk was incubated at 42 °C for 45 min. At the end of this incubation period, the pH of the milk was approximately reached to 6.3. Then, milk temperature was adjusted to 37 °C and rennet was added. After 30 min, the pH was reached to 6.1 and the curd was cut and further manufacturing method was sustained same as DA method. In combination method (CM), starter culture was added but milk pre-acidification was done using 10% citric acid solution and milk pH was adjusted to 6.3 before curdling. After curd formation, the reduction of pH was continued with starter culture and no citric acid solution was used.

In all three procedures, after attainment to final pH of curd, i.e. 5.3, whole amount of whey was drained and the curd was wrapped within a cheese-cloth for one hour. Afterward, the curd was stretched by hand in brine (2%) at 75 °C and after subsequent molding, the curd was immersed in cold brine (20% salt) for 1 h. Then brined curd was vacuum packed, stored at 4 °C and chemical composition, textural and sensory properties of cheeses were measured. All manufacturing methods were done at tree times.

Chemical Analysis

All cheese samples were analyzed for determination of pH at 20 °C (Metrohm, 827 pH lab, Swiss made), moisture content (102 °C for 4 h), acidity (NaOH 0.1 N), ash content (540 °C for 5h), protein content (Kjeldahl method, by multiplying the total nitrogen by 6.38) according to AOAC methods (2000). Fat content was measured through Gerber method according to the technique reported by Marshall (1993) with some modifications. For fat measurement, 10 ml of sulphuric acid was added to butyrometer, followed by adding the 3 ml of hot distilled water (60°C), 3 g of each cheese sample, 5 ml of distilled water (60°C) and 1ml amyl alcohol. In order to complete dissolving cheese particles, the butyrometer and its content were shacked extremely and then the butyrometer was centrifuged at 1300 rpm for 5 min. The fat content of each cheese sample was expressed as percentage by measuring the fat column.

Actual and Adjusted Yields of Cheese

Yield is an amount of cheese which is obtained from a known amount of milk and measured by weighing the obtained cheese before brining. The yield (%) can be expressed as (a) based on actual moisture (actual yield) which calculated by dividing the obtained cheese before brining on the weight of milk and (b) based on 55% moisture content according to following equations (Robinson and Tamime, 1996):

$$W_{55} = [(W \times TS)/0.45] \times 100 \qquad (1)$$

Where W_{55} is a weight of cheese (kg) at 55% moisture; W is weight of cheese (kg); and TS is a weight of total solids in one kg of cheese.

$$Y_{55} = [W_{55}/Wm] \times 100 \qquad (2)$$

Where Y_{55} is adjusted yield (%) at 55% moisture of cheese; W_{55} is a calculated amount in previous equation; W_m is weight of milk.

Fat and Protein Recoveries

Fat and protein recoveries (%) of cheese were calculated by dividing the total amount of fat or protein in obtained cheese on total amount of fat or protein in milk, respectively (Jooyandeh and Minhas, 2009):

Fat or protein recovery =((weight of cheese × fat or protein content of cheese)/(weight of milk × fat or protein content of milk)× 100) (3)

Meltability

Meltability of all cheese samples was measured according to the method of Madadlou *et al.* (2005).

Color Evaluation

Color evaluation of cheese samples were done by using Chroma meter (Chroma Meter CR-400, Konica Minolta, Japan made). The L, a and b-values are correspond to whiteness /darkness, redness/greenness and yellowness /blueness, respectively.

Texture Profile Analysis (TPA)

The texture evaluation of cheese was measured by using Texture Analyzer (TA-XT plus Texture Analyzer [Stable Micro System, Godalming, UK]). Testing conditions were set up according to method of Jooyandeh (2009) with some modifications. A aluminum cylindrical probe (5-mm diameter), 2 mm/s pre-test speed, 1 mm/s test speed, 1 mm/s post-test speed, rest time of 5 s, trigger force of 3 g, data acquisition 200 pps and 50% strain were used.

Sensory Evaluation

All cheese samples were encoded randomly and then evaluated by ten well trained panelists who were faculty members and students of food science and technology department of Ramin Agriculture and Natural Resources University. All cheese samples were evaluated for taste, odor, texture, color and appearance, and overall acceptability according to the nine-point hedonic scale test (1= dislike extremely to 9= like extremely (Lawless and Hymann, 1998)) after 0, 15, 30, and 45 days of storage. Samples were cut in pieces with a similar size (2 cm× 2 cm× 2 cm) and then obtained pieces were placed into airtight plastic container and maintained at ambient temperature for 20 min before evaluation. The panelists used water for washing their mouth between testing each samples.

Statistical Analysis

All experiments were done at least in triplicate. The results obtained were subjected to statistical analysis to determine significant differences between three different cheese making procedures. The SAS software (version 9.1) were used for data analysis and differences between means were determined by Duncan's test at $P<0.05$.

Results and Discussion

Chemical Analysis

The chemical composition of mozzarella cheeses are shown in Table 1. Moisture is essential component of cheese which has a plasticizer effect in the protein matrix and therefore making it less elastic and more susceptible to fracture upon compression (Fox *et al.,* 2000). The moisture content of SC cheese was significantly ($P<0.05$) higher than DA cheese. These results are in agreement with those of Sheehan *et al.* (2005) and Zisu and Shah (2007), who reported the lower moisture in mozzarella cheeses produced with direct acidification. Katsiari *et al.* (2002) found that when adjunct cultures used for cheese manufacturing, the moisture content and hardness of cheese increased and decreased, respectively.

The SC cheese had lower protein content than DA and CM cheeses but showed higher fat content. The lower fat content in DA cheese is due likely to more and rapid interactions between proteins in this cheese sample (McMahon *et al.,* 2005) which causes the more compact protein network and therefore the lower moisture and fat content retained in final curd. These results are in agreement with those of Guinee *et al.* (2000), who reported that increased the volume fraction of the casein matrix is due to reduced fat content. The SC and CM cheeses had higher ash content due to their higher moisture content which may increase the amounts of soluble minerals including ionic K, Na, and Ca (McMahon *et al.,* 1999). The similar results were reported by Dave *et al.* (2003) and Sameen *et al.* (2008). The higher titratable acidity of SC and CM than DA cheese samples is likely due to the higher biochemical reactions and production of organic acids, particularly lactic acid by starter cultures which is in accordance with the results of Sameen *et al.* (2008).

Yield, Fat and Protein Recovery

Cheese yield is a one kg of obtained cheese from a one kg of milk, which is a very important parameter in cheese making. The higher recovery of solid material causes the higher cheese yield (El-Gawad and Ahmed, 2011). According to our results (Table 2), though SC cheese had higher actual yield than other mozzarella cheeses, their differences were not significant. However, for adjusted yield, magnitude variations were recognized and SC and CM samples had significantly higher adjusted yield than DA cheese. The higher yields of SC and CM cheeses were likely due to their higher moisture and fat contents. The proteolysis development which occurs during curd formation by starter culture may increase the water holding capacity of casein network and therefore causes the increase in weight/yield of cheese. Hence, CM and SC cheeses had the higher yield in compare with DA sample. These results are in agreement with those of Metzger *et al.* (2000), who reported that pre-acidification of milk before mozzarella making causes the decrease in cheese yield from 2.5 to 5.8% depend on pH of milk and type of used acid. Pre-acidification of milk and subsequent reduction of calcium, fat and protein recovery in cheese leads to lower actual and adjusted yields.

Fat and protein recoveries in cheese are very important parameters in cheese making industry, because their lessening result in cheese yields reduction. These parameters are significantly affected by the type of cheese making procedure/acidification. Different cheese making procedures had significant effect ($P<0.05$) on fat and protein recoveries.

SC cheese had higher fat and protein recoveries than DA cheese, but showed the lower protein recovery than CM cheese. The higher protein recovery and protein content of CM than SC cheese is likely due to the effect of partial acidification which causes more interactions between proteins (McMahon *et al.,* 2005). Increasing the acidity by direct acidification in DA cheese causes the decrease in cheese calcium and this has bilateral impact, lower the protein interactions between proteins and reduces the entrapped fat in casein matrix (Zisu and Shah, 2005). In agreement with our results, Metzger *et al.* (2000) observed that mozzarella cheeses produced by direct acidification of milk had lower fat and protein recoveries.

Table 1. The chemical composition of mozzarella cheeses.

Cheese sample	Protein content (%)	Fat content (%)	Moisture content (%)	Ash content (%)	Titratable Acidity (%)
SC	19.29±0.35^{b}	24.94±1.16^{a}	51.85±0.61^{a}	4.19±0.08^{a}	0.50±0.04^{a}
DA	23.05±0.27^{a}	21.95±0.84^{b}	47.83±1.14^{b}	3.18±0.06^{b}	0.35±0.01^{b}
CM	22.38±0.58^{a}	23.04±0.11^{ab}	49.94±0.30^{ab}	3.32±0.15^{b}	0.44±0.06^{a}

Means within the same column with different superscripts differ significantly (*P*<0.05); SC, Starter Culture; DA, Direct Acidification; and CM, their Combination Methods.

Table 2. Effect of different manufacturing methods on yield, fat and protein recoveries of cheese samples.

Mozzarella cheese	Actual Yield (%)	Adjusted Yield (%)	Protein recovery (%)	Fat recovery (%)
SC	10.85±0.63^{ns}	11.60±0.01^{a}	62.12±1.15^{ab}	72.12±2.51^{a}
DA	8.81±0.96	10.22±0.41^{b}	55.51±6.06^{b}	47.46±2.86^{c}
CM	10.07±0.86	11.21±0.14^{a}	65.12±4.38^{a}	59.80±2.00^{b}

Means within the same column with different superscripts differ significantly (*P*<0.05); SC, Starter Culture; DA, Direct Acidification; and CM, their Combination Method.

Color Evaluation

Food appearance is one of the most important properties of foods which are directly related to product quality and customer acceptance, and affected by its reflection, absorption or transmittance of light and these states are related to the physical structure and chemical nature of food (Rudan *et al.,* 1998). Results (Table 3) showed relatively higher but non-significant L value for SC cheese likely due to its higher fat globules content which increases the light scattering and therefore enhances whiteness of cheese (Rudan *et al.,* 1998). Rudan *et al.* (1999) also showed that by reducing the fat content, the amount of whiteness and opacity of cheese critically decreases. The b value of the SC cheese was significantly higher than other samples because of higher fat content. As well, SC and CM cheeses had higher moisture content and therefore the amount of serum in these cheese samples were higher than DA sample, resulted in greater greenish color (greater negative a value).

Table 3. The L, a, and b-values of cheese samples from different cheese samples from different manufacturing methods.

Cheese sample	L-value	a-value	b-value
SC	69.20±0.61^{ns}	-4.59±0.13^{b}	13.24±0.77^{a}
DA	67.28±1.91	-4.13±0.02^{a}	10.08±0.44^{b}
CM	67.01±1.54	-4.55±0.05^{b}	11.43±0.80^{b}

Cheese Texture Characterization

Meltability is a key functional property of mozzarella cheese (Sameen *et al.,* 2008) which defined as flowability and spreadability of cheese particles upon heating (Ma *et al.,* 2011). Fat amount and protein-protein interactions with water are two most important parameters which determine the meltability of mozzarella cheese (McMahon *et al.,* 1999). Meltability of cheese samples are reported in Table. 4. The higher meltability of SC and CM samples is because of their higher fat content, which is in agreement with the results of Abd El-Gawad *et al.* (2012) and Ma *et al.* (2013). Khosrowshahi *et al.* (2006) reported that when fat content in cheese decreased, the obtained product has a compact texture, lower meltability, and undesirable sensory properties. The texture and functionality of mozzarella cheese also can be affected by its moisture contents. As, cheeses with higher moisture retention causes the softer and more pliable product with improved melting properties (Zisu and Shah, 2005).

Among the milk proteins, casein is the main factor which can affect the curd firmness, syneresis rate, moisture retention and finally cheese quality (Lawrence, 1993). Fat reduction in cheese causes the more elastic and dense protein network (Tunick *et al.,* 1995). According to our results (Table 4), hardness, cohesiveness and springiness of DA sample were higher than SC and CM samples, which are agreed with the results of Rudan *et al.* (1999), Sheehan and Guinee (2004) and Fife *et al*. (1996) who reported higher hardness, cohesiveness, elasticity, and springiness as a result of lower fat or moisture contents. Furthermore, the higher hardness and chewiness of DA cheese than other cheese samples (P<0.05) is likely due to its higher protein content and more compact texture.

The starter culture cheese had softer texture which could not completely restore its primary shape after 50% compression and showed lower springiness, cohesiveness, and hardness. Oommen *et al.* (2002) also reported that starter culture cheeses have a lower cohesiveness. The SC cheese had significantly higher adhesiveness than DA and CM samples, which is agreed with results of Zisu and Shah (2006), who observed that obtained cheese without pre-acidification has higher adhesiveness. Higher moisture content causes weakening of protein matrix and when this state is concomitant with proteolysis, the higher adhesiveness values can be obtained (McMahon *et al.,* 2005). Proteolysis rate in cheese is directly depends on concentration of starters and bacterial population in cheese. Hence, the lower hardness, chewiness, and cohesiveness of SC and CM cheeses are likely due to the higher proteolysis rate of added starter cultures (Jooyandeh, 2009). Firmness is inversely correlated with proteolysis, as decrease the firmness is concomitant with higher primary proteolysis (Sheehan and Guinee, 2004). The gumminess is result of hardness and cohesiveness of cheese (Tunick, 2000) and when cohesiveness or/and hardness of product decreases, its gumminess also reduces. The gumminess of SC cheese was significantly lower than DA cheese, because of probably the higher proteolysis.

Sensory Evaluation

Cheese body is gradually softened during proteolysis and produced water-soluble nitrogenous compounds which have a significant effect on cheese flavor. Cheese flavor, which numerous amounts of volatile and nonvolatile compounds contribute it, is very complex and result of lipolysis, proteolysis and glycolysis (Albenzio *et al.,* 2013).

Effect of storage times on color and appearance of the cheese samples are shown in Fig. 1A. Results revealed that SC sample had higher color and appearance scores than CM and DA samples at fresh state. Color and appearance of SC sample was intensely reduced over times of storage, because of probably its higher microbial activity due to starter cultures (Sameen *et al.,* 2008).

Proteolytic and peptidolytic activities in mozzarella cheese are due to residual coagulant, plasmin, or starter culture enzymes (Yazici *et al.,* 2010; Oommen *et al.,* 2002). As shown in Fig. 1B., SC and CM samples had higher odor scores than DA sample at 0 and 15 days of storage, probably due to their starter cultures activity which produces higher aromatic compounds.

But odor scores of all samples reduced over times, because of extreme and uncontrolled metabolic processes. Starter cultures have direct and indirect contribution to sensory properties such as aroma, taste, texture, and flavor in cheese (Losito *et al.,* 2014). In terms of texture, results revealed significant differences (P<0.05) between texture of mozzarella cheeses while storage time had not momentous effect on this respect (Fig. 1C). Among cheeses, SC sample at 15th day of storage had higher score than the other cheeses during storage period. As it shown in Fig. 1D., there were no differences between taste of various cheeses at different storage period. However, SC cheeses had slightly better taste than DA and CM cheeses during all the storage period. With respect to overall accetability, results showed that the various mozzarella cheese making procedures had significant (P<0.05) effect on overal acceptability while storage time had no effect (Fig. 2). In general, SC cheese had higher overall acceptability than other cheeses at the beginning till the end of storage period.

Table 4. Texture profile analysis and meltability of various mozzarella cheeses.

Texture parameters	SC	DA	CM
Hardness (N)	3.83±0.44^{b}	5.25±0.24^{a}	4.25±0.04^{b}
Cohesiveness	0.58±0.04^{b}	0.64±0.02^{a}	0.55±0.00^{b}
Adhesiveness (J)	2.89±0.40^{a}	1.14±0.09^{c}	2.59±0.21^{b}
Springiness (mm)	6.48±0.61^{ns}	7.07±0.38	6.92±0.20
Gumminess (N)	2.22±0.19^{b}	2.88±0.15^{a}	2.74±0.11^{a}
Chewiness (J)	14.35±0.27^{b}	20.41±0.69^{a}	18.96±1.45^{a}
Meltability(mm)	75.50±2.08^{a}	64.75±2.71^{b}	67.25±3.02^{b}

Means within the same row with different superscripts differ significantly (P<0.05); SC, Starter Culture; DA, Direct Acidification; and CM, their Combination Method.

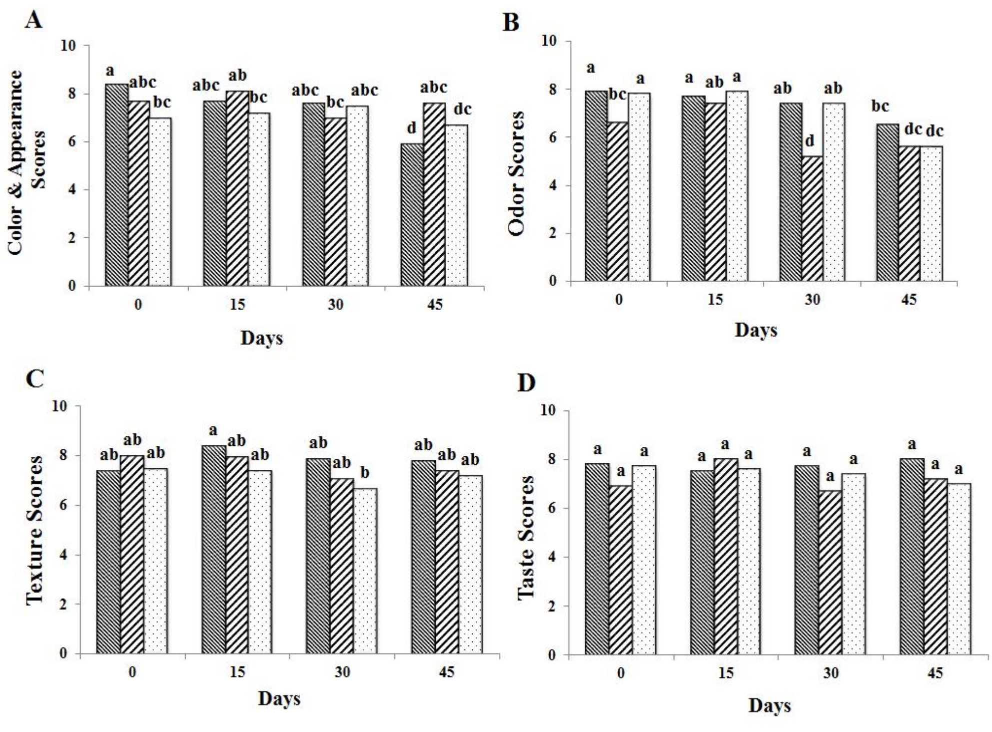

Fig. 1 Effect of different cheese making procedures and storage times on color and appearance (A), odor (B), texture (C) and taste (D) of mozzarella cheeses (SC ; DA ; CM).

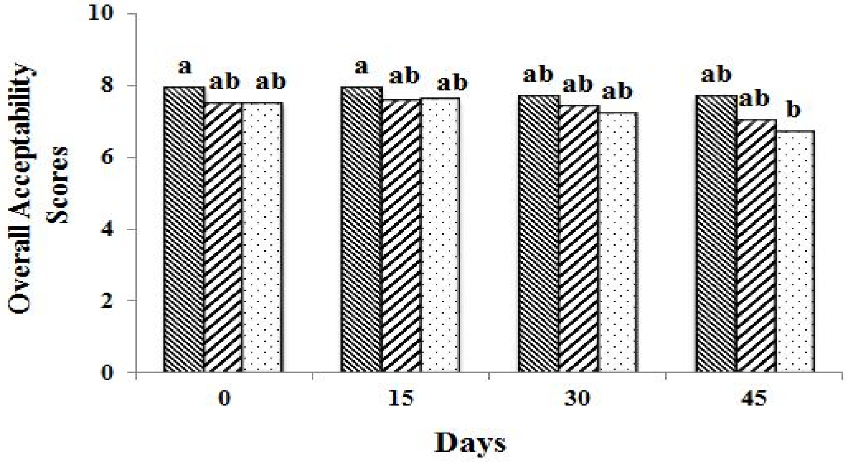

Fig. 2 Effect of different cheese making procedures and atorage times on overall acceptability of mozzarella cheeses (SC ; DA ; CM)

Mostly, sensory attributes (odor, taste, texture, color, and overall acceptability) of all mozzarella cheeses were higher at the beginning and 15th day of storage period. This is due to the fact that mozzarella cheese unlike many other cheeses is a un-ripened or non-aged cheese (Moneim and Sulieman, 2013; Yazici *et al.,* 2010) and therefore its sensory properties diminish over the storage period. However, fresh mozzarella cheese has an inappropriate meltability and is better to consume it after 1-3 weeks of storage (Rowney *et al.,* 1999). Whey protein films are excellent moisture, oxygen, aroma and oil barriers and may be used as a layer of protection to mozzarella cheese to protect its sensory characteristics during storage period (Jooyandeh, 2011).

Conclusions

The three different methods were used for mozzarella manufacturing and the starter culture method increased the fat, moisture, ash and titratable acidity of the cheese. The cheese making methods also affect the yield, fat and protein recoveries and SC method showed the higher actual yield and fat recovery. Color evaluation of cheese samples revealed that SC cheese had higher b- value than DA cheese probably due to its higher fat content. The texture of cheese samples was also influenced by cheese making methods. DA cheese had higher cohesiveness, hardness and springiness and lower meltability than other cheeses.

All mozzarella cheeses had almost higher sensory scores at 15th day of storage period. However, due to water movement from surface of all mozzarella cheeses during storage, the cheese color and appearance was diminished. Therefore, cheese coating with whey protein films could be suggested as a best solution, since these films are only moderate barriers to moisture.

Acknowledgement

The authors wish to express their gratitude to the research council of Ramin Agriculture and Natural Resources University of Khuzestan for financial support of this work which was performed as a student project.

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Iranian Food Science and Technology Research Journal
Vol. 12, No. 3, Aug. Sep. 2016, p. 371-381

نشریه پژوهشهای علوم و صنایع غذایی ایران
جلد ۱۲، شماره ۳، مرداد - شهریور ۱۳۹۵، ص. ۳۸۱-۳۷۱

تأثیر روش‌های مختلف تولید بر میزان راندمان و ویژگی‌های فیزیکوشیمیایی و حسی پنیر موزارلا

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تاریخ دریافت ۱۳۹۵/۰۱/۳۰
تاریخ پذیرش: ۱۳۹۵/۰۶/۰۲

چکیده

تأثیر روش‌های مختلف تولید پنیر موزارلا، یعنی روش اسیدی کردن مستقیم (DA)، استفاده از کشت آغازگر (SC) و تلفیقی از این دو روش (CM) بر میزان راندمان پنیرسازی و ویژگی‌های فیزیکوشیمیایی، بافت، رنگ و حسی محصول بررسی گردید. آنالیز شیمیایی نمونه‌های پنیر نشان داد که پنیر SC دارای مقادیر چربی، رطوبت، خاکستر، اسیدیته قابل تیتر، راندمان واقعی و تعدیل‌شده و همچنین بازیافت چربی بالاتری نسبت به پنیر DA می‌باشد. پنیر DA مقدار کشش‌پذیری، پیوستگی و سفتی بالاتری نسبت به نمونه‌های CM و SC به دلیل شبکه پروتئینی متراکم و الاستیک تر نشان داد، درحالی‌که قابلیت ذوب شدن و چسبندگی نمونه DA کمتر از نمونه‌های CM و SC بود. پنیر SC به طور معنی‌داری مقدار b-value بالاتری نسبت به نمونه DA داشت. ارزیابی حسی نمونه‌ها نشان داد که پنیر SC دارای کیفیت حسی بالاتری نسبت به سایر نمونه‌های پنیر در حالت تازه و طی ۴۵ روز نگهداری بود. به‌طورکلی، امتیازات حسی تمام پنیرهای موزارلای تولیدی تا ۱۵ روز اول نگهداری قابل قبول بود و سپس تا پایان دوره نگهداری به تدریج کاهش یافت.

واژه‌های کلیدی: روش‌های مختلف تولید، پنیر موزارلا، فیزیکوشیمیایی، خواص بافت، ویژگی‌های حسی

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