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EFFECT OF POTASSIUM CHLORIDE AS A SALT REPLACED ON THE QUALITY OF BUFFALO'S MOZZARELLA CHEESE

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ABSTRACT

Low-moisture Mozzarella cheese (LMMC) was manufactured from cow milk (control) and from standardized buffalo milk (SBM, 3 % fat) by partial substitution of NaCl with KCl. LMMC was made and salted with 4 salt mixtures: NaCl only, 3 NaCl: 1 KCl, 1 NaCl: 1 KCl and 1 NaCl: 3 KCl. The effect of substitution NaCl with KCl on the meltability and texture properties of Mozzarella cheese from different treatments was investigated. The resultant cheeses were analyzed when fresh and after 1,2,3 and 4 weeks of storage at $\simeq$ 5 ^{o}C for chemical and organoleptic properties, whereas, fresh and 4 weeks for physical and reheological properties. Mozzarella cheese manufactured from SBM salted with substitution 1 NaCl: 3 KCl had the lower moisture content. Mozzarella cheese made from SBM had total protein (TP), fat and ash contents higher than the control. Soluble nitrogen (SN), tyrosine, tryptophan and total volatile fatty acids (TVFA) increased in all treatments after storage period ($P < 0.05$). Mozzarella cheese made from SBM salted with NaCl only had the highest yield. Acidity development of Mozzarella cheese made from SBM with substitution 1 NaCl:3 KCl was higher than all other treatments and increased during storage period in all treatments. Using substitution NaCl with KCl increased the meltability of buffalo Mozzarella cheese and cheese manufactured by partial substitution 1 NaCl: 1 KCl had meltability closed to the control. Traditional Mozzarella cheese showed high oiling off. The oiling off increased in all treatments after storage. Also, rehelogical properties (hardness, cohesiveness, springniess, gumminess and chewiness) of Mozzarella cheese improved by substitution of NaCl with KCl. Mozzarella cheese made by partial replacement of NaCl with KCl (1:1) had the highest scores for flavour and acceptability. Whey and kneading water of Mozzarella cheese made from SBM were higher in total solids, protein, ash and some of minerals (Ca, K and P) than that made from cow milk.

Keywords: Mozzarella cheese, cow" milk, buffaloes" milk, NaCl, KCl- meltability, fat leakage, oiling off- textural properties.

INTRODUCTION

Mozzarella cheese is a prominent member of pasta filata, or stretched curd, cheeses that originated in Italy. Pasta filata cheeses are distinguished by a unique plasticizing and kneading treatment of the fresh curd in hot water, which imparts to the finished cheese its characteristic fibrous structure, melting and stretching properties. Low moisture Mozzarella cheese (LMMC) is one of the most popular cheeses in the world used for pizza manufacturing. Mozzarella cheese is an unripened, soft and white cheese whose melting and stretching properties are highly suitable for Pizza making (Kindstedt, *et al.* 1995). Production of LMMC has been increasing rapidly over the last 2 decades (Kindstedt, 2002; Kindstedt, *et al*. 2004).

Tradition and habits of buffalo milk consumption are quite diverse in different parts of the world. Buffalo's milk is ranked second in the world after cow's milk being more than 12% of the world, milk production (Ahmed *et al.*, 2008). There is an increasing demand for buffalo milk and buffalo milk products.

Conventionally, Mozzarella cheese made from buffalo milk. Recently, it is being made all over Italy, in other European countries and USA from cow milk with certain modifications (Ghosh, *et al*., 1990). Buffalo milk is reported to be more suitable more than cow milk for Mozzarella cheese due to high yield, its characteristic aroma and physical attributes. In addition, it has a potential market in industry, such as pizza. A limited number of studies exist on buffalo milk Mozzarella cheeses (Mauriello *et al*., 2003). On the contrary, Abdou *et al*., 2008 reported that Mozzarella cheese made from buffalo milk is too hard and non-meltable enough compared with that made from bovine milk.

Several studies have assessed the potential of potassium as a sodium substitute on cheese processing and storage quality, including Feta (Katsiari, *et al.,* 2000), white pickled cheese (Karagözlu, *et al.,* 2008), Halloumi cheese (Kamleh, *et al*., 2012). According, substitution of NaCl by other salts has been considered as an alternative technique to improve meltability of low moisture Mozzarella cheese made from bovine milk (Ayyash and Shah, 2011). Therefore, studies have focused on replacing NaCl by KCl, which is the most successful candidate to be used as NaCl replacer (Guinee, 2004 a,b). The objective of the present study was to examine the effect of NaCl substitution by KCl on physical and reheological properties of Mozzarella cheese made from buffalo's milk.

MATERIALS AND METHODS

Fresh buffalo and cow milk were obtained from the herd of El-Gemeaza station, Gharbia Governorate, Animal Production Research Institute. Thermophilic cheese culture consisting of *Streptococcus salvarius ssp. thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus* (TCC-4, DVS) and calf rennet powder (HA-LA) were obtained from CHR-Hansen's Denmark. Dry salt was obtained from El-Nasr Company at Alexandria, Egypt. Potassium chloride was obtained from El-Nasr Company at Abu Zaabal, Kalubia Governorate, Egypt. The composition of fresh cow milk and standardized buffalo's milk (SBM) is shown in Table (1).

Table (1).Chemical composition of fresh cow's and standardized fresh buffalo's milks (SBM).

Milk	Components %										
	TS	Fat	Protein	Ash	Lactose	Na	K	Ca	P	acidity	pH values
Cow	11.45	3.0	3.16	0.63	4.66	0.179	0.141	0.162	0.167	0.15	6.68
SBM	13.52	3.0	4.82	0.97	4.73	0.184	0.147	0.175	0.169	0.16	6.75

Cheese manufacture:

Buffalo's milk was standardized to 3 % fat. Low-moisture buffalo' Mozzarella cheese was manufactured according to Ayyash and Shah (2011) with some modifications. The milled curd was dry-salted at 46 g/ kg using four mixtures of NaCl and KCl: NaCl only (A), 3 NaCl : 1 KCl (B), 1 NaCl : 1 KCl (C) and 1 NaCl : 3 KCl (D). Control Mozzarella cheese manufactured from cow milk, and salted with NaCl only. The curd from all treatments allowed mellowing for 20 min. then the salted curd was plasticized in 4 % brine solutions at 80 ^{o}C for 5 min and then manually kneaded. All experimental cheese were made in triplicates and analyzed for chemical and organoleptic properties when fresh, 1, 2, 3 and 4 weeks at cold storage (4^{o}C). The textural and physical properties determined when fresh and at the end of storage period only.

Methods of analysis:

Chemical analysis:

Total solids, fat , total protein, ash contents, titratable acidity and minerals (Na, Ca, K, P) for cheese, milk, whey and kneading water were estimated according to AOAC (2007). Lactose content of milk was calculated by difference. Soluble nitrogen (SN) was determined by the micro-kjeldahl method according to (Kosikowski and Mistry, 1997). Salt content was determined according to (Richardson, 1985). Total volatile fatty acids (TVFA) were estimated according to (Kosikowski, 1982). Tyrosine and tryptophan contents were determined according to Vakaleris and Price (1959). pH values were measured using JENWAY digital pH meter, Model 3310. The cheese yield and recovery were calculated according to Vandeweghe and Maubois (1987); adjusted yield increase was calculated according to Metzger, *et al*. (2000).

Physical and Textural properties:

Meltability (tube) test was determined as described by Muthukumarappan *et al.* (1999), meltability (disc) and fat leakage test were determined according to Guinee *et al.* (1999). Free oil was measured according to Kindstedt and Fox (1991). Textural properties such as hardness, cohesiveness, springniess, gumminess and chewiness of Mozzarella cheeses were measured using Instron Universal Testing Machine (Model 4302, Instron Corporation, Canton M.A) according to the procedure of Bourne (1978). The Instron with a load cell of 100 N and strip chart recorder were employed for various tests under the following operating conditions:

- Load range:	20 %
- Cross-head speed:	25 mm/min.
- Chart recorder speed:	50 mm/min.
- Cross-head speed: Chart recorder speed:	1:2
- Depth:	10 mm
- Test temperature:	15 ^{o}C ± 1 ^{o}C.

The textural variables were calculated as follows:

Hardness = Maximum force recorded during the first compression cycle (N).

Cohesiveness = The area under curve / Area under curve.

Springiness = Width of the down strake in curve $_{(mm)}$.

Gumminess = Hardness x Cohesiveness. (N).

Chewiness = Gumminess x Springiness (n. mm).

Sensory evaluation: All experimental cheeses were graded when fresh and after 1, 2, 3 and 4 weeks of cold storage (4^oC) by the staff of the Dairy Technology Department, Animal Prod. Res. Ins. according to Land and Shepherd (1988).

Statistical analysis:

The general liner models procedure of Statistical Analysis System (SAS) was used to analyze the data. Analysis of variance for all cheese samples were performed to determined differences between samples. One–way randomized complete block design and least significant differences (L.S.D) were adopted in the resultant (SAS 1990).

RESULTS AND DISCUSSION

Chemical composition of Mozzarella cheese:

The effect of substitution of NaCl with KCl at different levels on chemical composition of Mozzarella cheese produced from cow' milk and SBM (3 %) fat are presented in Table (2). The results indicated that the type of milk had significant effect on moisture, protein and ash. The highest value of protein and ash were recorded with buffalo' Mozzarella cheese. This variation could be attributed to high total solids, protein and ash in buffalo milk. Moreover, cow' Mozzarella cheese contained the highest moisture content than buffalo' Mozzarella cheese treatments. This may be due to the ability of cow milk casein to bind more water than buffalo milk casein which attributed to the properties of casein micelles and mineral salts of buffalo milk. This is in agreement with the results given by Abdou, *et al.* (2008). The values of moisture content that found by Banville, *et al.* (2013) and Ganesan, *et al.* (2014) were lower than our values.

The results indicated that fat content significant increased during storage period ($P < 0.05$). The total protein and ash contents were lower in cow' Mozzarella cheese when fresh and during storage period than buffalo' Mozzarella cheese ($P < 0.5$). These results are in line with those reported by Geurts *et al*., 1980, Abdou *et al*., 2008 and El-Batawy *et al.*, 2004. Moreover, ash and protein values are close to that found by Gernigon, *et al*. (2009).

It could be noticed that substitution of NaCl with KCl had significant effect on moisture, protein, fat and ash between treatments at the same storage time and during storage. Moisture content for Mozzarella cheese salted with substitution of NaCl with KCl (Treatment, B, C and D) were significantly ($P < 0.05$) lower than that salted with NaCl only (control and treatment A). on the other hand, fat, protein and ash contents of Mozzarella cheese salted with substitution of NaCl with KCl were significantly ($P < 0.05$) higher than that salted with NaCl only with LSD = 0.2954, 0.2507, 0.2162 and 0.1515 for moisture, fat, protein and ash respectively.

Table (2). Effect of NaCl substitution with KCl on chemical composition of Mozzarella cheese.

Components %	Storage period weeks	Treatments					LSD
		Control	A	B	C	D	
Moisture	Fresh	54.61	52.80	52.52	51.14	50.90	
	1	53.86	52.09	51.74	50.32	49.36	
	2	52.90	51.11	50.94	49.64	48.82	
	3	51.63	50.94	50.72	49.31	48.56	
	4	50.40	50.03	49.61	48.87	47.90	
	Mean	52.61^{a}	51.39^{b}	51.11^{b}	49.86^{c}	49.11^{d}	0.2954
Fat	Fresh	20.2	20.6	21.1	21.4	21.9	
	1	20.3	20.8	21.3	21.5	22.1	
	2	21.1	21.4	21.8	21.9	22.4	
	3	21.8	21.9	22.3	22.5	22.9	
	4	22.2	22.5	22.9	23.2	23.5	
	Mean	21.1^{d}	21.4^{c}	21.9^{b}	22.1^{b}	22.6^{a}	0.2507
Protein	Fresh	22.32	23.15	23.91	25.62	26.13	
	1	22.94	23.80	24.67	26.24	26.91	
	2	23.45	24.27	25.23	26.74	27.40	
	3	24.85	25.40	26.14	27.21	27.92	
	4	25.14	25.95	26.83	27.34	28.37	
	Mean	23.74^{e}	24.51^{d}	25.36^{c}	26.63^{b}	27.35^{a}	0.2162
Ash	Fresh	2.61	2.80	2.71	2.95	2.98	
	1	2.74	2.95	3.08	3.41	3.52	
	2	2.90	3.13	3.32	3.60	3.71	
	3	3.15	3.40	3.51	3.82	3.85	
	4	3.40	3.52	3.77	3.91	3.94	
	Mean	2.96^{c}	3.16^{b}	3.28^{b}	3.54^{a}	3.60^{a}	0.1515
Salt	Fresh	1.60	1.67	1.70	1.78	1.84	
	1	1.63	1.72	1.77	1.85	1.93	
	2	1.71	1.76	1.83	1.89	1.99	
	3	1.76	1.81	1.88	1.96	2.15	
	4	1.78	1.83	1.92	2.03	2.23	
	Mean	1.70^{e}	1.76^{d}	1.82^{c}	1.90^{b}	2.03^{a}	0.0225
Yield %		10.82^{d}	15.76^{a}	15.58^{b}	15.54^{bc}	15.42^{c}	0.1598
Adjusted yield increase %			16.97^{a}	16.86^{a}	17.23^{a}	17.32^{a}	1.0293

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

The changes in salt content of Mozzarella cheese cleared that the salt content increased during storage period in all treatments. There was a significant variation between treatments in salt content. The obtained results are within the range given by Nilson and LaClair (1976) who observed a wide range of salt content from 1.0 to 4.5 % in Mozzarella cheese.

Data in Table (2) showed that, the type of milk had significant effect on the yield of Mozzarella cheese. All Mozzarella cheese treatments made from SBM had a higher yield than the control. The increase in yield % in buffalo'

Mozzarella cheese was due to the buffalo milk is richer in fat and protein especially casein. Since, casein is the major constituent that influences the cheese yield and chemical composition. These results are in agreement with those reported by Abd El- Gawad (1998). Furthermore, the adjusted yield increase range was from 16.86 to 17.32 % compared with the control.

Recovery of milk total solids, fat, protein and ash contents is presented in Table (3). The obtained data showed that, the recovery of all components of Mozzarella cheese made from SBM was higher than the control one. This may be due to the buffalo milk which is richer in fat, protein and ash content. Ahmed, *et al*., (2008) they indicated that buffalo milk is rich in fat and protein especially casein. The casein is the major constituent that influences the cheese yield and chemical composition. Our findings are in line with the results obtained by Ahmed, *et al*., (2011). On the other hand, substitution NaCl with KCl had remarkable effect on recovery of TS, fat, protein and ash between treatments (A, B, C and D). The highest values were recorded with treatment A and B than treatments C and D.

Table (3). Recovery % of milk components of Mozzarella cheese.

Components %	**Treatments**				
	control	**A**	**B**	**C**	**D**
Total solids	57.42	62.53	62.10	59.86	58.92
Fat	90.14	93.75	93.23	92.58	92.42
Protein	91.05	94.08	93.30	93.18	93.07
Ash	86.71	91.32	90.17	89.64	88.24

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

The titratable acidity and pH values of Mozzarella cheese are shown in Table (4). The titratable acidity is increased significantly ($P < 0.05$) during storage. The trend of the change in pH values of all treatments was opposite to acidity. In addition, pH values of cheese in treatments C and D were lower than those in A, B and control. This may be due to the activity of starter culture. The treatment A had a significantly lower titratable acidity compared with the other treatments.

Moreover, the proportions of NaCl : KCl were effective on pH decline values, this may suggest that when KCl increased and NaCl decreased in salt treatment, the production of organic acid increased. The pH values were lower than found by Banville, *et al.* (2013) and Ganesan, *et al.* (2014). Our findings were in accordance to the results of Karagözlu *et al.* (2008), in which cheeses with more KCl content showed lower pH values. It could be understood that starter culture bacteria maintained their activity more adequately in the presence of greater amounts of KCl compared with NaCl which led to a higher acidification rate during the ripening period. This fact makes it clear why the treatments of A and C, respectively, possessed the lowest final pH levels at the end of storage.

Table (4). Ripening indices of Mozzarella cheese as affected by different substitution of NaCl with KCl.

Components	Storage period weeks	Treatments					LSD
		Control	A	B	C	D	
Titratable acidity %	Fresh	0.69	0.67	0.71	0.74	0.77	
	1	0.71	0.70	0.75	0.76	0.79	
	2	0.80	0.78	0.81	0.83	0.85	
	3	0.83	0.81	0.85	0.85	0.87	
	4	0.85	0.85	0.88	0.89	0.92	
	Mean	0.78 [bc]	0.76 [c]	0.80 [bc]	0.81 [ab]	0.84 [a]	0.0397
pH values	Fresh	5.26	5.24	5.23	5.19	5.16	
	1	5.19	5.18	5.18	5.15	5.14	
	2	5.15	5.15	5.14	5.13	5.10	
	3	5.13	5.14	5.11	5.11	5.08	
	4	5.03	5.06	5.07	5.02	5.02	
	Mean	5.15 [a]	5.15 [a]	5.14 [a]	5.12 [b]	5.10 [b]	0.025
Soluble nitrogen %	Fresh	0.154	0.152	0.134	0.162	0.169	
	1	0.182	0.168	0.152	0.189	0.197	
	2	0.208	0.196	0.243	0.245	0.248	
	3	0.230	0.226	0.274	0.265	0.267	
	4	0.251	0.237	0.284	0.272	0.264	
	Mean	0.205 [c]	0.196 [d]	0.217 [b]	0.227 [a]	0.229 [a]	0.0064
TVFA	Fresh	3.14	3.18	3.58	3.88	4.62	
	1	5.67	5.90	6.15	6.15	6.28	
	2	8.17	8.22	8.71	8.73	8.68	
	3	12.24	12.64	13.15	13.25	13.52	
	4	15.16	14.91	16.50	17.17	18.15	
	Mean	8.88 [d]	8.97 [d]	9.62 [c]	9.84 [b]	10.12 [a]	0.1951
Soluble tyrosine (mg/100g cheese)	Fresh	3.65	3.74	3.78	4.24	4.94	
	1	6.15	6.32	6.81	7.23	7.30	
	2	10.24	12.14	12.54	13.01	13.35	
	3	22.50	24.43	24.88	26.10	27.30	
	4	41.15	44.34	46.20	47.50	50.40	
	Mean	16.74 [e]	18.19 [d]	18.84 [c]	19.62 [b]	20.66 [a]	0.4309
Soluble tryptophan (mg/100g cheese)	Fresh	2.24	2.30	2.86	3.14	3.25	
	1	5.34	5.80	5.98	6.12	6.34	
	2	13.20	15.22	17.30	18.40	18.43	
	3	20.04	22.41	24.20	28.06	30.30	
	4	34.40	36.81	40.15	43.11	47.22	
	Mean	15.04 [e]	16.51 [d]	18.09 [c]	19.77 [b]	21.11 [a]	0.446

T.V.F.A (ml 0.1 N NaOH/100 gm cheese
Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

Mozzarella cheese with higher content of KCl had a higher SN %. The level of SN in Mozzarella cheese with addition of 25 % of NaCl and 75 % of KCl treatment (D) were significantly higher than other treatments when fresh and during the storage period. The SN % in buffalo' Mozzarella cheese made from 100 % NaCl treatment (A) was at the lowest value. Therefore, the inhibitory effect of KCl on proteolytic enzymes must have been weaker than NaCl. This result agreed with those of other investigators for Feta, Cheddar and white cheese salted with NaCl : KCl (Rasmussen and Barbano, 1987; Aly, 1995; Güven and Karaca; 2001 and Katsiari *et al*., 2001).

Mozzarella cheese made with high level of KCl had the highest TVFA than that the other treatments. The TVFA content of all cheese treatments significantly ($P < 0.05$) increased during storage which may be due to the growth of starter culture. This agree with Hassan and Abd El-Kader, (2000) and Badawi *et al*. (2004).

Soluble tyrosine and tryptophan expressed as mg/ 100 g cheese are mentioned in Table (4). Soluble tyrosine and tryptophan considered good indicators for cheese ripening during the storage period. Tyrosine and tryptophan contents in cheese showed the same trend during the storage period. Tyrosine and tryptophan contents in Mozzarella cheese made with KCl had higher contents than that cheese made with NaCl only. This may be due to high activity of starter culture which, increased protein hydrolysis and produced amino acids. Moreover, the tyrosine and tryptophan contents increased with increasing the level of KCl- in the same storage period.

Tyrosine and tryptophan contents significantly ($P < 0.05$) increased in all treatments at the end of storage period at $\simeq 5\ ^{o}C$. These results are in agreement with those found by Hassan and Abd El-Kader (2000); Badawi *et al*. (2004) and Abdou, *et al*. (2008).

From the data in Table (5), it could be noticed that buffalo' Mozzarella cheese salted with NaCl only (treatment A) had the highest values of Ca, Na and P. Whereas buffalo' Mozzarella cheese salted with substitution NaCl with KCl (1:3) (treatment D) had the highest value of K and the lowest values of Ca, P and Na. Moreover, minerals contents of Mozzarella cheese had significantly differences between all treatments ($P < 0.05$). Furthermore, buffalo' Mozzarella cheese had the highest contents of minerals (Ca, Na, K and P) compared to cow' Mozzarella cheese (control).

Table (5). Effect of NaCl substitution with KCl on minerals content of Mozzarella cheese.

Components %	Treatments					LSD
	Control	A	B	C	D	
Ca	0.75 ^{c}	0.86 ^{a}	0.82 ^{b}	0.77 ^{c}	0.71 ^{d}	0.027
Na	0.74 ^{ab}	0.76 ^{a}	0.70 ^{b}	0.64 ^{c}	0.52 ^{d}	0.0495
K	0.41 ^{e}	0.45 ^{d}	0.55 ^{c}	0.74 ^{b}	0.88 ^{a}	0.0304
P	0.71 ^{c}	0.80 ^{a}	0.77 ^{ab}	0.74 ^{bc}	0.74 ^{bc}	0.0304

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

Physical properties of Mozzarella cheese:

Meltability of Mozzarella cheese is one of the important functional properties. The term meltability has been used to indicate the extent to which cheese flows and spreads upon heating. Meltabilty of different treatments is presented in Table (6). The results indicated that meltability was significantly affected by different treatments during storage period. The meltability of Mozzarella cheese either by disc or by tube methods increased with increasing the storage period. At the end of storage period, buffalo' Mozzarella cheese (treatment, A) showed lower meltability compared with buffalo' Mozzarella cheese (treatments B, C and D) and cow' Mozzarella cheese (control). Moreover, meltability of cheese made from cow milk (control) was higher than that of standardized buffalo milk (A, B, C and D treatments). Meltability increased significantly ($p < 0.05$) during storage period. This increase may be attributed to either an increase in proteolysis during storage (Kindstedt *et al*. 2004 and Upadhyay *et al*., 2004) or an increasing in the conversion of insoluble Ca to soluble Ca, which in turn reduced the strength between casein networks (Feeney, *et al*., 2002 and Guinee *et al*., 2002). Statistical analysis of variance revealed that there are significantly differences of meltability either by tube or disc methods during storage periods with LSD = 0.1841 and 0.2332 respectively

Concerning to the fat leakage and oiling off (table 6), it was noticed that fat leakage and oiling off of all treatments increased after storage period. This increase may be partly related to the increase in meltability and to the changes in the polymorphic structure of milk fat in Mozzarella cheese during storage, (Rowney *et al*., 1999). The results are in line with those reported by Fox (1993) who mentioned that, free oil formation showed characteristic patter of change during aging. In addition, direct relation between both fat leakage and oiling off of cheese and fat content of cheese. Fox (1993) reported that, fat content was a strong determinant of oiling off, as indicated from surveys of commercial Mozzarella cheese.

Table (6). Effect of NaCl substitution with KCl on Physical properties of Mozzarella cheese.

Physical properties	Storage period weeks	Treatments					LSD
		Control	A	B	C	D	
Meltability (tube mm)	Fresh	15.82	10.21	11.18	15.04	13.23	
	4	48.43	28.62	38.15	48.32	42.27	
	Mean	32.13 [a]	19.42 [e]	24.67 [d]	31.68 [b]	27.75 [c]	0.1841
Meltability (disc cm2)	Fresh	47.26	37.15	39.00	46.84	43.52	
	4	146.6	86.40	100.60	142.50	124.35	
	Mean	96.93 [a]	61.78 [e]	69.80 [d]	94.67 [b]	83.94 [c]	0.2332
Fat leakage/ cm2	Fresh	63.36	64.68	66.14	68.24	69.45	
	4	86.37	89.23	91.41	95.15	98.54	
	Mean	74.87 [e]	76.96 [d]	78.78 [c]	81.69 [b]	83.99 [a]	0.0873
Oiling off %	Fresh	4.7	3.3	3.5	3.2	3.5	
	4	9.4	7.5	8.1	7.4	7.6	
	Mean	7.05 [a]	5.40 [d]	5.80 [b]	5.30 [d]	5.55 [c]	0.1234

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

The statistical analysis showed that, both fat leakage and oiling off of Mozzarella cheese were high significantly ($P < 0.05$). Also, the storage period showed high significantly on the fat leakage and oiling off of Mozzarella cheese (LSD= 0.0873 and 0.1234 respectively).

Texture properties of Mozzarella cheese:

Hardness is described to the panelist as the force required to enetrate the sample with the molar teeth (from soft to firm) (Lee *et al*., 1978). From the obtained results (Table 7), it could be noticed that the substitution of NaCl with KCl had considerable effect on hardness. Buffalo' Mozzarella cheese salted with substitution NaCl with KCl (1:3) (treatment D) had the highest hardness. This may be due to its high content of dry matter compared with the other treatments. Abdel-Hamid *et al*., (2001) mentioned that Mozzarella cheese hardness increased with lower moisture content. Moreover, the hardness of Mozzarella cheese increased significantly ($P < 0.05$) during storage period for all treatments

Springiness is described to the panelists as bouncing property of the sample through several consecutive bites (from plastic to elastic). The springiness depends on fat content of Mozzarella cheese. It is obvious that substitution NaCl with KCl had significant effect on springiness. Moreover, springiness decreased with the level of KCl increasing. Thus buffalo' Mozzarella cheese salted with substitution NaCl with KCl (1:3) (treatment D) had the lowest springiness. This may be due to it high fat content in this treatment. Bhaskaracharya and Shah (1999) mentioned that, the fat content of Mozzarella cheese affected the springiness significantly ($P < 0.05$).

Cohesiveness known as the degree to which the cheese samples deform before rupturing, therefore, cohesiveness value is a direct function of the work needed to overcome the internal bonds of the material. It was clear that cohesiveness took the same trend of hardness being higher in buffalo' Mozzarella cheese salted with substitution NaCl with KCl (1:3). This may be due to it high protein content. These results in agreement with the finding of Bhaskaracharya and Shah (1999) who mentioned that, the cheese with higher protein content showed higher cohesiveness.

Gumminess is expressed as the product of hardness and cohesiveness. Chewiness is described to be the number of chews required to swallow a certain amount of sample (from tender to tough).

The data in table (7) showed that, gumminess and chewiness affected with level of KCl. Treatment (D) had the highest gumminess and chewiness compared with the other treatments, this may due to the high protein content in Mozzarella cheese. These results were in agreement with Abdou, *et al*. (2008). While, they are not in agreement with Moustafa, *et al*. 2007. Analysis of variance revealed that there were significantly differences of springiness, cohesiveness, gumminess and chewiness of all treatments during storage period ($P < 0.05$).

Table (7). Effect of NaCl substitution with KCl on texture properties of Mozzarella cheese.

Texture properties	Storage period weeks	Treatments					LSD
		Control	A	B	C	D	
Hardness (N)	Fresh	6.86	8.61	8.82	8.89	8.96	
	4	8.41	9.84	9.95	10.21	10.32	
	Mean	7.61 [b]	9.23 [a]	9.39 [a]	9.55 [a]	9.64 [a]	0.4797
Springiness (mm)	Fresh	12.60	12.40	12.00	11.25	10.75	
	4	14.25	14.20	13.70	13.50	12.00	
	Mean	13.43 [a]	13.30 [a]	12.85 [b]	12.38 [c]	11.38 [d]	0.248
Cohesiveness (cm)	Fresh	0.445	0.443	0.500	0.512	0.578	
	4	0.465	0.460	0.510	0.531	0.594	
	Mean	0.455 [d]	0.456 [d]	0.505 [c]	0.522 [b]	0.586 [a]	0.0077
Gumminess (N)	Fresh	3.05	3.81	4.41	4.55	5.18	
	4	3.91	4.53	5.07	5.42	6.13	
	Mean	3.48 [e]	4.17 [d]	4.74 [c]	4.99 [b]	5.66 [a]	0.0646
Chewiness (n-mm)	Fresh	38.43	47.24	52.92	51.19	55.69	
	4	55.72	64.33	69.46	73.17	73.56	
	Mean	47.08 [e]	55.79 [d]	61.19 [c]	62.18 [b]	64.63 [a]	0.0991

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

Chemical composition of Mozzarella cheese whey and kneading water:

A summary of the chemical composition of Mozzarella cheese whey and kneading water is shown in tables (8 & 9). The data revealed that total solids, protein and ash contents of Mozzarella cheese whey and kneading water made from SBM were higher than of control treatment. While, the fat content of both of them nearly the same of all treatments. Similar results were obtained by Abdou *et al*. (2008). Total solids of either whey or kneading water in this study was lower than those reported by Gernigon, *et al*. (2009), they found the total solids values of 6.06 and 6.62% respectively. Regarding to some of minerals such as (Ca, Na, K and P) in whey and kneading water took the same trend of total solids except Na. These results may be attributed to increase of these components of mozzarella cheese made from standardized buffalo milk. These results were in accordance with Abdou *et al*. (2008), and they lower than that found by Gernigon, *et al*. (2009). Increasing of K content and decreasing of Na contents in Mozzarella cheese whey and kneading water of (B, C and D) treatments may be attributed to substitution of NaCl with KCl.

Table (8). Effect of NaCl substitution with KCl on chemical composition of Mozzarella cheese whey.

Components %	Treatments				
	Control	A	B	C	D
Total solids (TS)	5.38	5.74	5.82	5.40	6.12
Fat	0.3	0.4	0.3	0.3	0.3
Protein	0.32	0.56	0.52	0.49	0.42
Ash	0.54	0.68	0.67	0.66	0.71
Ca	0.048	0.051	0.058	0.064	0.072
Na	0.051	0.056	0.048	0.044	0.041
K	0.015	0.019	0.024	0.027	0.031
P	0.032	0.036	0.045	0.052	0.046

Table (9). Effect of NaCl substitution with KCl on chemical composition of cheese kneading water.

Components %	Treatments				
	Control	A	B	C	D
Total solids (TS)	4.25	4.86	4.32	4.51	4.70
Fat	0.3	0.2	0.2	0.3	0.3
Protein	0.063	0.082	0.079	0.078	0.075
Ash	3.80	4.36	3.92	4.02	4.28
Ca	0.067	0.072	0.075	0.084	0.089
Na	0.036	0.041	0.032	0.024	0.019
K	0.022	0.023	0.028	0.034	0.038
P	0.032	0.036	0.040	0.043	0.045

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

Sensory evaluation:

As can seen from Table (10) results of organoleptic properties revealed that the substitution of NaCl with KCl had considerable effect on flavour, appearance and body & texture and total score. As the level of KCl increased in Mozzarella cheese the score of flavour and total score was increased. In general, all Mozzarella cheese made with different level of KCl had acceptable flavour, body & texture and appearance during storage period. Furthermore treatment C had the highest scores for flavour and general acceptance followed by control and treatment D during the storage period.

Table (10). Effect of NaCl substitution with KCl on Sensory evaluation of Mozzarella cheese.

Sensory evaluation	Storage period weeks	Treatments				
		Control	A	B	C	D
Falvour (50)	Fresh	38	36	37	41	40
Body & texture (35)		28	28	28	33	33
Appearance (15)		12	10	12	13	12
Total (100)		78	74	77	87	85
Falvour (50)	1	40	38	40	43	41
Body & texture (35)		29	30	30	33	33
Appearance (15)		13	11	13	14	12
Total (100)		82	79	83	90	86
Falvour (50)	2	42	40.5	41	45	43
Body & texture (35)		31	31	31	34	33.5
Appearance (15)		13.5	11.5	13.5	14	12.5
Total (100)		86.5	83	85.5	93	89
Falvour (50)	3	42.5	41	42.5	46	43.5
Body & texture (35)		32.5	32	32	35	34
Appearance (15)		14	12	14	15	13.5
Total (100)		89	85	88.5	96	91
Falvour (50)	4	45	41.5	43.5	47	44.5
Body & texture (35)		34	32.5	32.5	35	34.5
Appearance (15)		14	13	15	15	14
Total (100)		93^{b}	87^{d}	91^{c}	97^{a}	93^{b}

Control: Mozzarella cheese from cow's milk
A: Mozzarella cheese from SBM with NaCl only
B: Mozzarella cheese from SBM with 3NaCl:1 KCl
C: Mozzarella cheese from SBM with 1NaCl:1 KCl
D: Mozzarella cheese from SBM with 1NaCl:3 KCl

While, treatment A had the lowest score for flavour and general acceptance when fresh and through the storage period. With regard to body and texture of Mozzarella cheese ,it tended to be improved significantly (P<0.05) with increasing the storage period.

It could be concluded that Mozzarella cheese can be made successfully from buffalo's milk salted with substitution NaCl with KCl at level (1:1) to improve flavour, body & texture and total score.

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تأثير كلوريد البوتاسيوم كبديل للملح على جودة الجبن الموزاريللا المصنع من اللبن الجاموسى

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أجريت هذه الدراسة لدراسة إمكانية تحسين الخواص الطبيعية والريولوجية للجبن الموزاريللا المصنع من اللبن الجاموسى. وفى هذه الدراسة تم استبدال كلوريد الصوديوم بكلوريد البوتاسيوم. وقد تم تصنيع الجبن الموزاريللا من اللبن البقرى كمعاملة مقارنة (كنترول). كما تم صناعتها من اللبن الجاموسى المعدل (٣% دهن) مع استخدام ٤ مخاليط مختلفة من الملح كما يلى:-

كلوريد الصوديوم فقط، ٣ كلوريد الصوديوم: ١ كلوريد البوتاسيوم، ١كلوريد الصوديوم: ١ كلوريد البوتاسيوم، ١ كلوريد الصوديوم: ٣ كلوريد البوتاسيوم. تم اختبار وتحليل الجبن الناتج طازجا وخلال ١، ٢، ٣، ٤ أسابيع من التخزين على درجة حرارة ٥ °م من حيث الخواص الحسية والتركيب الكيماوى. أما بالنسبة للخواص الطبيعية والريولوجية فقد تم تقديرها للجبن طازجا وبعد٤ أسابيع من التخزين. وكان من أهم النتائج المتحصل عليها مايلى:-

- احتوت الجبن الموزاريللا المصنع من اللبن الجاموسى المعدل مع استبدال للملح بنسبة ١ كلوريد الصوديوم: ٣ كلوريد البوتاسيوم على أقل نسبة رطوبة بالنسبة لبقية المعاملات فى حين احتوت جبن المعاملة على أعلى نسبة رطوبة.
- نسبة البروتين الكلى –الدهن- الرماد- الملح كانت أعلى فى الجبن الموزاريللا المصنع من اللبن الجاموسى المعدل عن جبن المقارنة.
- زيادة كل من النيتروجين الذائب، التيروسين، التربتوفان، الأحماض الدهنية الطيارة فى جميع المعاملات خلال مدة التخزين للجبن الناتج.
- زيادة الحموضة فى الجبن الموزاريللا المصنع من اللبن الجاموسى المعدل مع استبدال للملح بنسبة ١ كلوريد الصوديوم: ٣ كلوريد البوتاسيوم عن بقية المعاملات.
- استبدال كلوريد الصوديوم بكلوريد البوتاسيوم بنسبة (١:١) أدى إلى تحسن خاصية الانصهار لدرجة تقارب جبن الكنترول. كما أدى ذلك إلى تحسين الخواص الريولوجية للجبن الناتج.
- زيادة الجوامد والبروتين والرماد فى الشرش وماء العجن للجبن الموزاريللا المصنع من اللبن الجاموسى المعدل عن جبن المقارنة.

ومن ثم فإنه يمكن استبدال كلوريد الصوديوم بكلوريد البوتاسيوم بنسبة لاتزيد عن ٥٠% وذلك لإنتاج جبن موزاريللا من اللبن الجاموسى ذات خواص طبيعية وريولوجية وحسية جيدة.