Using Ultrafiltered (Uf) Retentate in Mozzarella Cheese Making

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ABSRACT

Mozzarella cheese was made using UF- retentates TS ~20g100^{-1} from cows and buffaloes milks. It was also made from difiltered and direct acidified retentates to reduce the calcium content in the retentate to achieve objective the firmness of the curd. The fresh cheeses were analyzed when fresh and after storage for one month at ~5°C for chemical, physical, rheological and organoleptic properties. The obtained results revealed that Mozzarella made from cow milk and its retentates exhibited much better ripening indices and rehological properties cheeses. The UF- technique lowered the moisture content, lactose, ripening indices, meltability and oilling off in the resultant cheese, while it elevated protein content and yield. Diafiltration processe decreased Ca^{++}, P^{++}, lactose, ripening indices, while its effect on rehological properties was low. Acidification process either to the normal milk or to the retentats decreased Ca^{++}, P^{++}, lactose, ripening indices and meltabilty of the produced cheese. Storage increased all constituents in all treatments except lactose and improved the meltability and oilling off. Sensory evaluation revealed that the Mozzarella cheese from UF-cows' retentate was the best treatment and similar to that from traditional one, while the cheese made from buffaloes' milk had some defects.

Keywords: ultrafilitration, meltability, buffaloes, Mozzarella, cheese, retentate, diafilitration.

INTRODUCTION

Due to economic advantages, ultrafilitration has become an increasingly common processing step in the manufacture of cheeses. Mozzarella cheese composition and physical characteristics are influenced by a number of variables, and rate of acid production by lactic starter cultures which considered to be one of the most important factors. However, because of minerals in milk are more soluble at low pH, high buffer capacity of UF-retentate can be overcomed by reducing its minerals content (especially calcium) by acidification of milk coupled with diafiltration to maintain stretching and care must be taken to minimize residual of lactose in the cheese that may contribute to brown discoularation when heated.

Rheology is important to study the physical properties such as body and texture of cheese which affected by the chemical composition of the products, like its protein content and state of hydrolysis and the lipid make-up.

Mozzarella cheese differs from most of cheeses whereas, it is usually consumed in the melted state on some foods, *e.g.*, Pizza and related foods, this means that rheological properties are a critical to that type of cheese quality and its acceptability. Meltability is the most important rheological property of Mozzarella cheese.

So, the objective of this work was to evaluate Mozzarella cheese made from different UF-retentate and to study the effect of acidification and diafiltration treatments on the quality of the resultant cheese.

MATERIALS AND METHODS

Materials

Fresh Buffaloes' and cows' milk were obtained from EL-Gemmeza Animal Production Research Station herd (Gharbiea Governorate), Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt., Starter culture containing *Streptococcus salivarius* sub spp *thermophilus* and *Lactobacillus delbreuckii* sub spp *bulgaricus* was obtained from Chr. Hansen's Lab., Copenhagen, Denmark. Animal rennet powder (HA-LA) was obtained from Chr. Hansen's Lab., Copenhagen, Denmark, and used at a rate of 4g/100 liter retentate, however, it was 20g/100 liter milk. Commercial grade fine salt was purchased from the local market, produced by El- Nasr Company, Alexandria, Egypt.

Methods:

Cheese milk concentration for Mozzarella cheese making

Raw buffaloes' or cows' milk were standardized to ~3 % fat, heated up to 50ºC and ultrafiltrated directly until the total solids reached ~ 20 %, using Carbo- sep, The Tech. Sep UF was fitted with 2s 151 (Model Tubular), membrane type: mineral (Zerconium Oxid), support: with a membrane surface area of 6.8 m^2. The UF unit was operated with an inlet pressure of ~5 bars and outlet pressure of ~3 bars. This unit belong to Food Sci., Department, Moshtohor, Faculty of Agriculture, Benha Univ.,. The concentration factor (CF) was 1.75:1 according to that given by Fernandez & Kosikowski (1986b). Chemical composition of cows' and buffaloes' milk and their UF-Retentates and permeates used in making Mozzarella cheese are shown in Tables (1) and (2).

Mozzarella cheese manufacture

Mozzarella cheese was made as described by Kosikowski (1982). Therefore, ten treatments were employed:

T1- Cows' milk (control).
T2- UF-Cows' retentate (control–UF).
T3- UF- Cows' retentate with direct acidification (DAC).
T4- Diafiltration of Cows' retentate with water (DFWC).
T5- Diafiltration of Cows' retentate with 1 % salt solution (DFSC).
T6- Standaredized Buffaloes' milk, 3 % fat (control).
T7- UF- Buffaloes' retentate (control–UF).
T8- UF- Buffaloes' retentate with direct acidification (DAB).
T9- Diafiltration of Buffaloes' retentate with water (DFWB).
T10- Diafiltration of Buffaloes' retentate with 1% salt solution, (DFSB).

The produced fresh cheeses were analyzed when fresh and after storage for one month in a polyethylen bags at ~5°C, for chemical, physical, rheological and organoleptical properties. Yield percent as well as recovery of milk constituents and their losses in whey and stretch water were calculated. Also, the whey and stretching water were analysed.

Chemical Analysis

Moisture content and moisture on-a-fat-free basis (MFFB) of milk, UF-retentate, RO-retentate, whey, permeate, stretching water, and cheese were determined according to the method described by AOAC (1990) and Codex Standard (1978). Fat content, titratable acidity and ash content were determined according to the method described by International Dairy Federation (IDF) (1991a) and AOAC (1990). pH values were measured using Jenway digital pH meter model 3310. Salt content

Table 1: Chemical composition and pH values of cows' and buffaloes' milk and their retentates used in making Mozzarella cheese

Constituents	Raw milk		Retentate		Diafiltered Retentate by			
					Water		1% salt solution	
	Cows	Buffaloes	Cows	Buffaloes	Cows	Buffalos	Cows	Buffalos
Total solids %	11.92	12.64	20.13	20.21	19.99	20.04	20.16	20.12
Fat %	3.00	3.05	6.10	6.10	6.10	6.10	6.20	6.15
lactose**	4. 72	4.80	4.24	4.22	3.79	3.89	3.76	3.83
Ash %	0.65	0.78	0.98	0.955	0.93	0.808	0.97	0.853
Total protein %	3.55	4.01	8.81	8.93	9.17	9.24	9.23	9.29
Casein %	2.85	3.13	7.22	7.17	7.83	7.80	7.77	7.81
Whey proteins%	0.57	0.60	1.35	1.37	1.06	1.13	1.16	1.15
Calcium %	0.156	0.186	0.269	0.271	0.174	0.228	0.173	0.210
Phosphorus%	0.152	0.174	0.205	0.236	0.158	0.207	0.156	0.197
Titratable acidity %	0.15	0.17	0.21	0.22	0.19	0.18	0.18	0.17
pH value	6.80	6.79	6.66	6.62	6.71	6.73	6.74	6.77

** lactose was calculated by difference.

Table 2: Chemical composition and pH values of permeates from cows' and buffaloes' milks

Constituents	Normal permeate		Permeates as a result from (DF)* by			
			Water		1% Salt solution	
	Cows	Buffaloes	Cows	Buffaloes	Cows	Buffaloes
Total solids %	5.70	6.01	3.08	3.48	3.23	3.66
Fat %	ND**	ND	ND	ND	ND	ND
Lactose %	5.13	5.24	2.76	3.13	2.86	3.21
Ash %	0.26	0.28	0.24	0.27	0.29	0.33
Total protein %	0.313	0.491	0.077	0.083	0.083	0.121
Calcium %	0.017	0.019	0.015	0.016	0.012	0.02
Phosphors %	0.011	0.014	0.009	0.012	0.008	0.010
Titratable acidity %	0.06	0.07	0.012	0.05	0.011	0.04
PH value	6.47	5.92	6.84	6.61	6.83	6.65

* DF: Diafiltration. ** ND: Not determined

(NaCl) of Mozzarella cheese was determined by the method described by BSI (1989). Calcium content was determined as described by Roadsveld & Klomp (1971) and Francesco & Raffaello (1980). Total phosphorus content was measured using the method of IDF (1987). The total nitrogen and non-protein nitrogen were determined according to IDF (1991b) while the soluble nitrogen and total volatile free fatty acids were determined as described by Kosikowski (1982). Soluble tyrosine and tryptophan of cheese were determined according to the method of Vakaleris & Price (1959). Lactose content was calculated by difference. The meltability of Mozzarella cheese was determined using the method described by Olson & Price (1958) which modified by Rayan *et al.* (1980). However, the method described by Kindstedt & Fox (1991) was used to expess the oiling off for the produced cheeses. The distribution of cheese milk constituents between permeate, whey, stretching water and cheese was calculated according to the method of Rao & Renner (1988).

Sensory Evaluation

The organoleptic properties of the Mozzarella cheese were evaluated by 10 staff members of Food Sci., Dept., Fac., of Agric., Benha Univ., and Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt using the following scoring sheets: flavour 50, body & texture 35, appearance 15.

Statistical Analysis

Analysis of variance were carried out according to the methods described by Clarke & Kempson (1997). Trials of all the treatments were replicated for three times.

RESULTS AND DISCUSSION

Chemical composition of the produced Mozzarella cheeses

- **Moisture content**

Data in Tables (3) and (4) show the change in the chemical composition of Mozzarella cheese made from traditional milk, UF-retentate, diafiltered retentates either with water or with 1 % salt solution when fresh and after storage period up to 30 days at ~5°C.

The results revealed that, there are a significant differences in moisture content between all treatments ($P<0.0001$). In general, fresh traditional Mozzarella cheese had slightly higher moisture content than UF-Mozzarella cheese, either made from cows' or buffaloes' milk. On the other hand, the lowest moisture content was recorded for Mozzarella cheese made by direct acidification of UF-retentate. The moisture content of all fresh Mozzarella cheese treatments are within the limits of Egyptian Legal Standards (2005) for part skimmed Mozzarella cheese (not more than 57%). It was observed also that Mozzarella cheese made from cows' milk or its retentate retained higher moisture than the corresponding cheese made from buffaloes' milk or retentate. This agrees with Abd-El-Gawad (1998).The moisture content of all expermental cheeses was markedly decreased after 30 days of refrigerated storage.

These results are agree with (Fernandez 1981, Nilson, 1989, Hickey & Versteeg, 1993, El- Batawy *et al.*, 2004). The results of moisture on a fat free-basis (MFFB) content took the same

Table 3 : Gross chemical composition of different Mozzarella cheese treatments

	Treatments	Moisture		Fat		Salt		Ash %	Lactose %
		%	MFFB** %	%	/ DM %	%	S/M*%		
Fresh	T1	50.21	64.21	21.80	43.78	1.21	3.13	2.49	1.74
	T2	49.64	62.92	21.10	41.89	1.26	3.34	2.81	1.93
	T3	48.15	61.57	21.80	42.04	1.15	3.14	2.45	2.13
	T4	48.70	62.19	21.70	42.30	1.13	3.06	2.30	1.08
	T5	48.76	62.19	21.60	42.15	1.27	3.34	2.68	0.93
	T6	46.36	58.46	20.70	38.51	1.13	2.44	2.91	2.47
	T7	46.26	57.83	20.00	37.22	1.18	2.55	3.23	2.37
	T8	45.71	57.21	20.10	39.19	1.23	2.69	2.76	2.66
	T9	45.94	57.86	20.60	38.11	1.20	2.61	2.61	1.44
	T10	46.11	58.29	20.90	38.78	1.66	3.60	3.11	1.30
30 days	T1	47.49	61.99	23.40	44.56	1.44	3.75	2.81	0.87
	T2	47.44	61.53	22.90	43.57	1.49	3.83	3.01	1.06
	T3	45.41	59.05	23.10	42.32	1.34	3.61	2.74	1.88
	T4	46.72	60.99	23.40	43.92	1.31	3.52	2.66	0.22
	T5	46.53	60.59	23.20	43.39	1.54	4.04	2.83	0.40
	T6	42.84	54.78	21.80	38.14	1.37	3.19	3.38	1.05
	T7	42.15	53.63	21.40	36.99	1.48	3.51	3.54	1.14
	T8	41.18	52.93	22.20	37.74	1.61	3.91	3.24	1.74
	T9	41.96	54.28	22.70	39.11	1.51	3.59	2.86	1.03
	T10	42.01	53.99	22.20	38.28	1.89	4.49	3.44	1.02

* S/M: Salt –in-moisture content ** MFFB: Moisture on a fat- free basis

trend of moisture content. The MFFB content of all resultant Mozzarella cheese agree with the Codex classification of semi hard cheese (54-69 %).

Fat and fat/dry matter (F/DM) content

It was also observed that Mozzarella cheese made from cows' milk or its retentate were higher in fat content than those made from buffaloes' milk or its retentate. The average of fat content of fresh traditional Mozzarella cheese made from cows' and buffaloes' milk was slightly higher than UF-Mozzarella cheese (Table 3). This may be attributed to the increase of fat loss in the whey of cheese made from UF-retentates, which is attributed to several factors. The same results were obtained by Dalgleish (1981) and El-Batawy *et al.* (2004). After the storage at 5±1°C, the fat content showed an increase. This is mainly due to some loss of moisture content during storage. The same trend was observed for F/DM. The F/DM % in all cheeses comply the low moisture Mozzarella require cheese moisture to be between 45 and 52 % and F/DM between 30 and 45 %. The differences in, fat and F/DM between all produced Mozzarella cheeses are highly significant ($P < 0.0001$).

Salt and salt –in-moisture content (S/M)

As it known, salt and salt–in-moisture considered to be one of the important characteristics of flavour and cheese texture (Lawrence & Gilles, 1982). The salt results cleared that there are a significant ($P<0.0001$) increase during storage. This increase may be attributed to loss of moisture during the storage period.

Mozzarella cheese made from diafiltration with salt solution (T5 and T10) had a higher content of salt and S/M than other treatments, which may be due to using of salt solution in diafiltration process (Table 3).

The salt content in all produced cheese are within the range given by Nilson and LaClair (1976). On the other hand, the salt content and S/M are higher in cows' traditional and UF- cheese than those of bufflaoes' cheese. These results are agree with those reported by El-Batawy *et al.* (2004).

Table 4 : TN, TP, SN, Ca^{++}, P^{++}, TA and pH values of different Mozzarella cheese treatments

	Treatments	TN %	TP %	SN %	SN/TN %	Ca		P		TA %	pH value
						%	/DM %	%	/DM %		
Fresh	T1	3.724	23.76	0.253	6.79	0.722	1.45	0.698	1.40	0.71	5.18
	T2	3.843	24.52	0.224	5.83	0.840	1.67	0.820	1.63	0.68	5.30
	T3	3.992	25.47	0.194	4.86	0.630	1.22	0.628	1.21	0.75	4.93
	T4	4.110	26.22	0.198	4.82	0.612	1.19	0.611	1.19	0.66	5.08
	T5	4.080	26.03	0.202	4.95	0.610	1.19	0.604	1.18	0.65	5.10
	T6	4.32	27.56	0.145	3.36	0.745	1.39	0.738	1.38	0.67	5.32
	T7	4.41	28.14	0.136	3.08	0.865	1.60	0.852	1.59	0.62	5.36
	T8	4.51	28.77	0.105	2.33	0.649	1.20	0.638	1.18	0.73	4.96
	T9	4.61	29.41	0.109	2.36	0.622	1.15	0.616	1.14	0.59	5.11
	T10	4.48	28.58	0.114	2.54	0.621	1.15	0.613	1.14	0.57	5.16
30 days	T1	3.986	25.43	0.410	10.29	0.731	1.39	0.713	1.36	1.20	4.94
	T2	4.011	25.59	0.380	9.47	0.846	1.61	0.823	1.57	0.98	4.95
	T3	4.212	26.87	0.218	5.18	0.635	1.16	0.620	1.14	1.03	4.85
	T4	4.232	27.00	0.247	5.84	0.615	1.17	0.613	1.16	0.82	4.81
	T5	4.238	27.04	0.260	6.13	0.621	1.16	0.616	1.15	0.82	4.87
	T6	4.78	30.49	0.275	5.75	0.761	1.33	0.747	1.31	1.10	5.10
	T7	4.98	31.77	0.257	5.16	0.887	1.53	0.870	1.50	0.96	5.12
	T8	4.96	31.64	0.195	3.93	0.662	1.13	0.650	1.11	0.99	4.79
	T9	4.93	31.45	0.212	4.30	0.629	1.08	0.615	1.06	0.74	4.89
	T10	4.91	31.33	0.219	4.46	0.637	1.10	0.624	1.08	0.80	4.91

Analysis of variance showed a significant differences between all treatments ($P<0.0001$).

Ash content

It was observed that the ash content of UF-Mozzarella cheese was significantly ($P<0.0001$) higher than those made by traditional method in both cows' and buffaloes (Table 3). This is as a result of retaining of ash in the UF-retentate, similar results were obtained by El-Batawy *et al.* (2004).

Acidification and diafiltration decreased the ash content in both cows' and buffaloes' retentates, but the cheese made from DF retentate with salt had higher ash content than that of DF with water. After the storage perioed the ash content increased, which is due to the moisture loss.

There are significant differences between all treatments in ash content either when fresh or after the storage period, it was highly significant between the treatments with exception of some overlabing for T1, T3 and T4 ($P<0.0001$).

Lactose content

The changes in lactose content of all Mozzarella cheese treatments are due to that most of lactose was metabolized either during making cheese or storage period, mainly through the activity of the starter culture bacteria, and rapidly decreased after 30 days of storage (Table 3). It was obvious that diafiltration process clearly decreased the lactose content of the cheese in both cows and buffaloes milk treatments and it was more clear in case of using salt solution in diafiltration (T5 and T10). (Kosikowski 1983, Bastian *et al.* 1991). There are significant differences in lactose content between all cheese treatments through the storage period ($P<0.0001$).

Total protein content (TP)

A slight increase was observed in the total protein of Mozzarella cheese made from UF-retentates than those made from original milk (Table 4). This is due to the concentration of casein and retaining of whey proteins in the retentates by the ultrafiltration technique. Similar results were obtained by Fernandez & Kosikowski (1986b) and El-Batawy *et al.* (2004).The increase of total protein throughout storage period was due to the decrease of the cheese moisture content. On the other hand, the obtained results reflected that, the TP content in all treatments made from buffaloes' was higher than that made from cows' milk. Results are in accordance with Abd El-Gawad (1998), and El-Batawy *et al.* (2004). Cheese made by direct acidification had higher TP than UF-cheese (control) in both cows' and buffaloes' which, can be attributed to the increase in TS content. Diafiltration process increased the total protein content in Mozzarella cheese than other treatments as the water added removes more calcium salts and increases the protein content (Kosikowski, 1975, Bastian *et al.* (1991).

Statistical analysis revealed that the differences in total protein content of all Mozzarella cheese treatments were highly significant ($P < 0.0001$).

Soluble nitrogen (SN) and Soluble nitrogen/Total nitrogen (SN/TN)

Generally, SN and SN/TN content of UF-Mozzarella cheese treatments were lower than the traditional Mozzarella cheese (control) in both fresh and stored cheeses (Table 4). The results are in accordance with Abd El-Gawad (1998), El-Batawy *et al.* (2004). The low level of proteolysis in Mozzarella cheese made from retentates, may be explained by the high buffering capacity of the protein in UF-retentate which decreases the microbial activity and slower proteolysis in cheese (Fernandez & Kosikowski, 1986b, Hikey & Versteeg 1993). With storage period progress the SN/TN which considered to be one of the cheese ripening indices markedly increased for all the cheese treatments. There are a significant differences either in SN % or SN/TN % between all treatments ($P < 0.0001$) .

Calcium (Ca) ,Ca/DM, Posphorus (P) and P/DM

It was obvious from Table (4) that UF-Mozzarella cheeses, had a higher content of calcium and phosphorus than the other treatments in both cows' and buffaloes' cheese (T2 and T7). This is due to the higher calcium and phosphours content of retentate used in making these cheeses (Glover 1985). Two third of calcium and half of phosphate are found closely linked to the casein as colloidal calcium phosphate (Shmidt & Both, 1987). Acidification decreased the Ca and P content in the cheese of both cows' and buffaloes cheese (T3 and T8). The reduction is due to lower pH of the milk which cause the colloidal calcium and P converted to soluble and subsequently gets lost in whey (Kiely *et al.*, 1992). These results are in agreement with those of Joshi *et al.* (2003), Rehman *et al.* (2003).

Moreover, diafiltration decreased the Ca and P content in both cows' and buffaloes' Mozzarella cheeses as the added water removes some of these salts (Kosikowski, 1975, Bastian *et al.*, 1991). After one month of storage at ~ 5°C Ca, Ca/DM, P and P/DM contents slightly decreased. The results also, revealed that, Mozzarella cheese made from buffaloes' milk and its treatments had higher contents of calcium and phosphours than that made from cows' milk. Some changes occurred in soluble calcium percent during storage of Mozzarella cheese due to the changes of cheese pH, whereas, the acidity increased and thus the pH value decreased. This would lead to more solubilization of calcium in cheese matrix (Kindstedt & Guo, 1998). Analysis of variance showed that, calcium and Ca/DM were affected by treatments and there are a significant differences ($P < 0.0001$)

Titratable acidity (TA) and pH values

Data in table (4) show the titratable acidity and pH values of different Mozzarella cheese treatments made either from cows' or buffaloes' milk. After one month of storage at ~5°C the acidity increased. The titratable acidity of traditional Mozzarella cheese was slightly higher than that made from UF-retentates. This may be attributed to the higher protein and salt contents in the UF-retentates which causes a higher buffering capacity and influences bacterial starter culture activity. Mozzarella cheese made from diafiltered retentates had a lower values of titratable acidity than other treatments. It was obvious that the titratable acidity of cheese made from cows' milk was higher than the corresponding cheeses made from buffaloes' milk. The results are in accordance with those given by Abd El-Gawad (1998) and El-Batawy *et al.*(2004). There are a significant differences for TA and pH values between different Mozzarella cheese treatments ($P<0.0001$)

Total volatile fatty acids (TVFA)

From results showed in Table (5), it was clear that the traditional Mozzarella cheese had a higher content of TVFA, followed by UF, direct acidification, diafiltration with salt and diafiltration with water- Mozzarella cheese. The concentration of TVFA increased after storage perioed in all cheese with different rates. The low amount of TVFA of both T4 and T9 may be due to the technique of diafiltration with the water which lead to removing some of these volatiles compounds. Mozzarella cheese treatments made from cows' milk had a higher con-

Table 5: TVFA*, Tyrosine and tryptophan of different Mozzarella cheese treatments

Treatments		TVFA*	Tyrosine (mg/100g cheese)	Tryptophan (mg/100g cheese)
Fresh	T1	8.20	5.62	2.81
	T2	7.60	5.43	2.63
	T3	7.10	4.60	2.10
	T4	6.00	4.62	2.10
	T5	6.30	4.76	2.13
	T6	4.50	3.97	1.83
	T7	4.30	3.84	1.71
	T8	4.00	3.11	1.50
	T9	3.50	3.31	1.56
	T10	3.70	3.40	1.59
30 days	T1	21.40	48.70	41.51
	T2	20.70	44.30	40.03
	T3	17.50	39.00	32.00
	T4	17.40	39.70	32.14
	T5	18.00	40.00	32.81
	T6	13.40	43.60	35.20
	T7	12.30	41.16	31.01
	T8	10.70	34.15	25.14
	T9	9.80	34.21	26.06
	T10	9.90	34.92	26.19

* ml Na OH 0.1 N / 100 g cheese.

tent of TVFA than that made from buffaloes' milk, this may be due to activation of lipase enzyme and the higher moisture content in Mozzarella cheese made from cows' milk (50.21%). UF-Mozzarella cheese had a lower content of TVFA than that of traditional. These results are in agreement with those of Abd El-Gawad (1998), El-Batawy *et al.* (2004). There are a significant differences between all treatments (P<0.0001).

Soluble tyrosine and tryptophan content

It was noticed that the traditional Mozzarella cheese had a higher content of soluble tyrosine and tryptophan followed by UF-Mozzarella cheese. But, the lower content of soluble tyrosine and tryptophan was found in Mozzarella cheese made by direct acidification, either that made from cows' or buffaloes' retentates. This may be due to the increase of acidity, which affect the proteolytic activity of added starter culture bacteria. Moreover, the results revealed that, Mozzarella cheese made from cows' milk had a higher content of soluble tyrosine and tryptophan than the corresponding treatments made from buffaloes' milk either when fresh or after storage. Similar results were found by Abd El-Gawad (1998). This may be due to the higher proteolysis of cows' casein than buffaloes' casein. The differences between treatments were hilghly significant (P<0.0001) .

Rhelogical properties of Mozzarella cheese:

Meltability

Meltability may be defined as the ease of cheese to flow or spreads upon heating. It is considered to be the capacity of cheese particles to flow together and form a uniform continuous melted. Data in Table (6) show the meltability development (both tube and disc methods) of different Mozzarella cheese treatments when fresh and after storage at ~5°C for one month. All Mozzarella cheese treatments exhibited an increase in meltability values with extending storage period. This could be due to the development of acidity which increased the solubility and partly removing of calcium, as well as the progressive cheese proteolysis during storage (McMahon *et al.*, 1996 & Rudan *et al.*, 1998). The obtained results revealed that, Mozzarella cheese treatments made from cows' milk had a higher meltability than that made from buffaloes' milk. This may be due to

Table 6: Some rheological properties of different Mozzarella cheese treatments

	Treatments	Meltability		Oiling off %
		Disc (cm^2)	Tube (mm)	
Fresh	T1	16.85	61.00	4.30
	T2	15.71	51.00	4.80
	T3	10.55	29.00	4.50
	T4	15.40	41.00	4.60
	T5	15.60	47.00	4.60
	T6	12.39	46.00	3.20
	T7	12.22	39.00	3.90
	T8	8.75	26.00	3.40
	T9	10.41	32.00	3.60
	T10	10.51	35.00	3.50
30 days	T1	44.38	146.00	5.50
	T2	41.56	116.00	6.10
	T3	29.12	86.00	5.60
	T4	36.27	105.00	5.80
	T5	37.35	113.00	5.70
	T6	34.18	111.00	4.40
	T7	32.23	97.00	4.90
	T8	21.49	69.00	4.50
	T9	23.40	83.00	4.60
	T10	23.53	89.00	4.70

the characteristics of fat in Mozzarella cheese made from cows' milk, which makes the cheese less firm and more meltable. These results are in accordance with those obtained by McMahon (1995), Rudan *et al.*(1999), and Rowney *et al.* (1999).

In general, the results indicated that traditional Mozzarella cheese had higher meltability than UF-Mozzarella cheeses. This may be due to the lower amount of calcium and phosphorus in the traditional Mozzarella cheese. So, calcium reduction improves the melt and flow properties of Mozzarella cheese. As it is known that as curd calcium and phosphorus levels decreased the meltability increased. These results are in agreement with those reported by Anis & Ladkani (1988), Kindstedt (1993) and Metzger *et al.* (2001).The decreasing of meltability in UF-cheeses, also, seems to be due to whey proteins precipitation on the casein network. The denaturation of the whey proteins during heating, and their fixing on the casein makes it difficult or impossible for casein strands to move relative to each other (Savello, 1982).Another factor to put it in considerition is the high water binding properties of denaturated whey proteins generally reduce the free water in the cheese, thereby reducing the flow properties of the cheese when heated. It has been argued that cheese made from UF-milk will produce curd having a coarser protein net work than that of traditional cheese. It is believed that this affects the melting properties of the cheese (Nilson, 1989). Mozzarella cheese made by direct acidification recorded the lowest meltability in both cows' and buffaloes' cheese. It was reported that Mozzarella cheese made from diafiltration had lower meltability than UF-and traditional cheese. This may be attributed to the increase in calcium content. There are a significant differences between treatments ($P<0.0001$).

Oiling off

This is one of the most critical defects associated with Mozzarella or Pizza cheeses. If the oiling off (free fat) appears on the surface of the pie during cooking, it creates enormous problems for the pizza during the storage.

Generally, the results revealed that, Mozzarella cheeses made from cows' milk had higher oiling off than that made from buffaloes' milk. This may be due to the effects of a coarser protein and fat distribution in the cheese. Concentrated UF-retentate have less casein molecules directly involved in curd formation. Less casein is incorporated into the curd matrix, resulting in less fat entrapment. Similar results were reported by Nilson (1989), Abd- El-Gawad (1998) and El-Batawy *et al.* (2004). The differences between treatments there are a significant (P<0.0001).

Chemical composition of different Mozzarella cheese whey and stretching water

A reduction in the amount of total whey produced, including drain whey and stretch water, was noted when higher milk solids were used during cheese making. The chemical composition of whey and stretching water of different treatments is recorded in Tables (7) and (8), respectively.

From the obtained results it was clear that Mozzarella cheese whey obtained from the direct acidification treatment had the highest total soids (TS) content either in cows' or buffaloes' cheeses. The higher whey TS content of diafiltration with salt than diafiltration with water may be due to the presence of salt solution which used in diafiltration process. This agree with Lucey *et al.* (2005).

Concerning the TS of stretching water, it was clear that traditional Mozzarella cheese made from cows' milk had the highest TS content (4.34 %) while that of diafiltered with salt solution of buffaloes' Mozzarella cheese had the lowest TS content "3.14 %" (Table 8).

It was obvious that excess fat was existed in the whey from cheese made from UF-retentates than that from traditional cows' and buffaloes' Mozzarella cheese. Dalgleish (1981) suggested that concentrated UF-retentates have relatively less of their casein molecules directly involved in curd formation, therefore, less casein is incorporated into the curd matrix, resulting in less fat entrapment. These results are in accordance with those

Table 7: Chemical composition and pH value of different Mozzarella cheese whey

Constituents \ Treatments	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Total solids %	6.03	5.66	6.07	3.09	3.98	5.67	5.17	6.27	2.48	2.59
Fat %	0.30	0.50	0.40	0.30	0.50	0.20	0.55	0.75	0.30	0.25
Lactose %	4.70	3.94	4.90	2.23	2.91	4.43	3.28	4.57	1.54	1.66
Ash %	0.60	0.82	0.58	0.41	0.39	0.59	0.76	0.75	0.46	0.51
Total protein%	0.43	0.40	0.19	0.15	0.18	0.45	0.58	0.20	0.18	0.17
Whey proteins %	0.265	0.310	0.125	0.066	0.076	0.325	0.358	0.251	0.077	0.081
Calcium%	0.046	0.056	0.061	0.038	0.036	0.054	0.058	0.069	0.039	0.038
Phosphorus %	0.042	0.048	0.054	0.029	0.029	0.044	0.046	0.056	0.032	0.030
Titratable acidity	0.42	0.40	0.47	0.29	0.31	0.34	0.33	0.39	0.28	0.31
PH value	4.33	4.40	4.23	4.71	4.65	4.58	4.62	4.55	4.76	4.68

Table 8: Chemical composition and pH values of different Mozzarella cheese stretching water

Constituents \ Treatments	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Total solids %	4.34	3.50	3.45	3.39	3.49	3.54	3.52	3.56	3.33	3.14
Fat %	0.40	0.30	0.40	0.30	0.40	0.30	0.30	0.40	0.30	0.40
Ash %	2.64	2.90	2.95	2.71	2.65	3.05	3.01	2.97	2.76	2.48
Total protein%	0.07	0.12	0.10	0.15	0.14	0.08	0.09	0.09	0.11	0.10
Whey proteins %	0.049	0.063	0.056	0.087	0.082	0.025	0.030	0.036	0.049	0.044
Calcium%	0.083	0.081	0.077	0.061	0.065	0.096	0.093	0.095	0.088	0.084
Phosphorus %	0.078	0.073	0.071	0.052	0.052	0.081	0.083	0.080	0.076	0.071
Titratable acidity	0.13	0.12	0.14	0.11	0.10	0.12	0.13	0.11	0.12	0.10
PH value	5.12	5.23	5.10	5.29	5.33	5.26	5.21	5.31	5.25	5.33

reported by Fernandez & Kosikowski (1986a) and Lucey *et al.* (2005). Fat content of stretching water, ranged from 0.3 % to 0.4 % in all stretching water of different Mozzarella cheese treatments.

The average of lactose content in UF-cheese whey is lower than that of traditional in both cows' and buffaloes' cheese, which agree with Lucey *et al.* (2005). The lower content of lactose in whey from diafiltered treatments either from cows' or buffaloes' milk may be due to the effect of diafiltration technique, which lead to passing lactose into the permeate.

The results of ash content of different Mozzarella cheese whey indicated that cows' Mozzarella cheese whey of UF-treatments had the highest ash content, while whey from diafiltered treatments were the lowest either in cow's or buffaloe's. Fernandez & Kosikowski (1986a) found higher ash content in whey of UF-cheeses than traditional. This may be attributed to the increase of titratable acidity in UF-retentates, this means the fermentation in the early stage of UF and direct acidification– Mozzarella cheese manufacture (ripening of milk) made more solubilization of the colloidal calcium phosphate which emigrate to the whey during cheese manufacture (Walstra & Jenness ,1984).

The data of ash content of stretching water of different Mozzarella cheese treatments reflected that, stretching water of traditional buffaloes' and UF- buffaloes' Mozzarella cheese had the highest ash content and direct acidification of cows' Mozzarella cheese stretching water was the lowest one. These results may be due to increasing the ash content of retentate which used in manufacture of Mozzarella cheese.

Total Protein (TP) and whey Protein contents

As it seen from Table (7), whey drained from UF–Mozzarella cheese of standardized buffaloes' milk had the highest protein content .The difference between treatments in TP contents may be due to different whey protein nitrogenous componuds present in the whey. The lower TP contents of whey from diafiltered treatment could be attributed to decrease of the total solids content of these treatments.

These results were confirmed by Dalgleish (1981) who indicated that, the amount of casein micelles unattached by rennet at the coagulation time increased with the increase in the concentration factor of the concentrated milk, because of the aggregation of soluble casein is slow and complicated after coagulation, a significant amount of casein may be found in the whey. Concerning the TP content of the stretching water, the results reflected that stretching water of diafiltration with water and with salt solution, cows' Mozzarella cheese had the highest TP. On the other hand, stretching water of traditional cows' and buffaloes' Mozzarella cheese had the lowest TP content .

Whey proteins percent of different Mozzarella cheese whey took the same trend of total protein. These results could be attributed to the plasmin level and activity in cheese which related to the pH of the curd during whey drainage, (Rao & Renner, 1988).

Calcium (Ca) and Phosphorus (P) contents

Data of Ca and P of different Mozzarella cheese whey clear that UF- buffaloes' and cows' Mozzarella cheese whey contained higher calcium and phosphorus than that in whey from other treatments. Moreover, Ca and P were higher in whey of buffaloes' cheeses than the corresponding values of whey from cows' cheeses. This can be due to solubilization of colloidal calcium by the added acid to the retentate, this soluble calcium emigrates to the whey during cheese manufacture (Walstra & Jenness, 1984, Walstra *et al.* 1999).

The results in Table (8) indicated that, stretching water from buffaloes' Mozzarella cheese had higher calcium and phosphorus contents than that made from cows' Mozzarella cheese. This could be attributed to increasing of calcium and phosphorus contents in the buffaloes' milk than cows' milk, which used for making the cheese. But, stretching water from diafiltered retentate with water and with salt solution cows' Mozzarella cheese, had the lowest Ca and P contents. On the other hand, stretching water of UF, traditional, and direct acidification buffaloes' Mozzarella cheese had a higher phosphorus content. These results are in agreement with those found by Zammar (2000).

Titratable acidity (TA) and pH values

Direct acidified cows' Mozzarella cheese whey had the highest TA as compared to whey drained from other treatments and the lowest pH value. Generally, the TA of whey from cows' Mozzarella cheeses recorded higher acidity than the corresponding values of those from buffaloes' cheeses. These results are in agreement with the observation of Rao & Renner (1988). The highest acidity of stretching water was for that of cheese made by direct acidification-cows' Mozzarella cheese. While, the lowest acidity was in stretching water from diafiltered with salt solution Mozzarella cheese from either cows' or buffaloes' milk.

Transfer rate of cheese milk constituents and cheese yield

Total solids content

From the data in Tables (9 & 10) there was a noticeable increase in the transfer rate of the total solids in UF and direct acidification in cows and buffaloes' Mozzarella cheese compared with traditional Mozzarella cheese, This may be attributed to the high retention of TN substances, fat and ash as compared with traditional Mozzarella cheese. On the other hand, the transfer rate of total solids for buffaloes' Mozzarella cheese treatments had a higher rate than that made from cows' milk. This may be due to the decrease of moisture content of Mozzarella cheese made from buffaloes' than that made from cows' milk (Table 3).

Regarding to Mozzarella cheese made from diafiltered milks, the transfer rate of total solids decreased as compared to that made from UF and direct acidification of either cows' or buffaloes' milk. This was accompanied by a proportional loss increase of total solids in stretching water and permeates (Tables 9 & 10).

Fat content

A considerable increase in the transfer rate of fat in traditional cows' and buffaloes' in UF-Mozzarella cheese for both types of milk in the same order. Also, the fat had a higher transfer rate in diafiltered treatments for the same two types compared with the traditional Mozzarella cheese. These results are in agreement with that obtained by Rao & Renner (1988) for UF-cheeses.

Total protein content

The transfer rate of total protein increased in UF-Mozzerella cheeses than that of the traditional Mozzarella cheese either made from cows' or buffaloes' milk (Tables 9 & 10). The increasing in transfer rate of total protein in UF-Mozzarella cheeses may be due to the decrease of total protein loss in the stretching water.These results also can be due to the inclusion and incorporation of whey proteins in the UF-retentate and subsequently into the UF-cheese treatments.

Table 9: Transfer rate of milk components to cheese, whey, stretching water and permeate of cow's milk

Treatments		Total solids TS %	Fat %	Protein %	Ash %	Ca %	P %
Cheese	T1	62.12	89.16	90.41	74.24	74.23	73.35
	T2	62.63	91.71	92.22	74.52	73.45	74.15
	T3	62.81	90.01	89.14	68.52	67.71	69.23
	T4	60.43	91.21	88.94	69.73	65.82	69.53
	T5	62.43	90.95	92.15	72.14	71.26	72.72
Whey	T1	32.16	7.15	8.13	21.03	22.15	24.65
	T2	29.52	7.27	6.54	19.82	21.94	22.21
	T3	27.27	8.93	8.64	19.35	20.12	20.43
	T4	28.32	7.52	9.13	20.17	21.22	23.81
	T5	30.53	7.97	7.15	20.08	20.14	21.25
Stretching water	T1	5.72	3.69	1.46	4.73	3.62	2.00
	T2	3.43	1.02	0.87	1.23	1.76	2.41
	T3	5.50	1.06	1.85	7.98	9.32	9.11
	T4	5.90	1.27	1.65	6.12	8.83	3.92
	T5	3.76	1.08	0.47	4.44	4.35	3.62
Permeates	T1	--	--	--	--	--	--
	T2	4.42	--	0.37	4.43	2.85	1.23
	T3	4.42	--	0.37	4.43	2.85	1.23
	T4	5.35	--	0.28	3.98	4.13	2.74
	T5	3.28	--	0.23	3.34	4.25	2.41

Table 10 : Transfer rate of milk components to cheese, whey, stretching water and permeate of buffaloes' milk

Treatments		Total solids TS %	Fat %	Protein %	Ash %	Ca %	P %
Cheese	T6	64.17	90.01	92.18	79.71	79.13	79.19
	T7	66.10	90.50	92.24	80.33	79.23	80.13
	T8	66.43	89.16	91.83	75.18	76.18	77.25
	T9	63.23	91.07	89.47	77.17	76.53	77.51
	T10	63.13	91.14	88.15	75.24	76.09	77.27
Whey	T6	30.91	6.91	6.17	16.37	17.14	18.25
	T7	27.32	7.07	6.21	15.06	15.86	15.51
	T8	26.49	6.81	6.88	18.15	17.18	15.08
	T9	28.15	6.78	7.50	17.41	18.21	17.12
	T10	27.37	6.54	7.63	18.03	17.92	17.33
Stretching water	T6	4.92	3.08	1.65	3.92	3.73	2.56
	T7	3.11	2.43	1.11	3.08	4.03	2.01
	T8	3.61	4.03	0.85	5.14	5.56	7.04
	T9	4.05	2.15	1.23	2.86	4.21	2.79
	T10	3.98	2.32	2.18	3.11	3.97	3.09
Permeates	T6	--	--	--	--	--	--
	T7	3.47	--	0.44	1.53	1.08	2.35
	T8	3.47	--	0.44	1.53	1.08	2.35
	T9	4.57	--	1.80	2.56	1.05	2.58
	T10	5.52	--	2.04	3.62	2.02	2.31

Ash, calcium and phosphorus contents

The transfer rate of calcium and phosphate increased in traditional and UF-Mozzarella cheese made from cows' milk. This could be attributed to decrease of the loss mount in the stretching water.

The noticeable decrease of phosphorus transfer rate accounted in direct acidification Mozzarella cheese made from cows' and buffaloes' milks, could be the result of the increase in phosphorus loss in the stretching water.

Cheese yield

Data in Table (11) show the cheese yield of different Mozzarella cheese either made from cows' or buffaloes' milk. compared with the traditional cheese. It was clear that buffaloes' milk gaves a higher yield in all Mozzarella cheese treatments than the crresponding cheese made from cows' milk. The highest increase rate in yield was observed for that cheese made from retentate by direct acidification of both cows' and buffaloes'. This may be due to the high recovery of total solids in cheese (Tables 8 & 9).

Sensory evalution

Data given in Table (12) represents the average scores of organoleplic properties of different Mozzarella cheese treatments when fresh and after storage period up to 30 days at ~ 5°C. From these results it could be concluded that fresh cheeses was characterized by lack of flavour. The flavour increased after the storage period but with slight acid taste. This attributed to the particular proteolysis of the cheese. Whereas, it was clear from the SN, tyrosine and tryptophan (Table 8) that body and texture was a little but sticky and there was a variations in the appearance.

The sensory quality of all produced cheeses improved after storage whereas, there was an increase in the total scores for all treatments. Body and texture of Mozzarella cheese tended to improve with ripening due to proteolysis of protein which was more pronounced in cows' cheeses than buffaloes'. In general, Mozzarella cheese made from cows' milk and its treatments had higher scores than that made from buffaloes' milk and its treatments. The high total scores were for UF-and traditional cows' Mozzarella cheeses, respectively

Table 11 : Yields and rate of increase in Mozzarella cheese made from different cows' and buffaloes' retentates

Treatments	Cow's milk		Standardized Buffaloes' milk	
	Yield %	Increase rate of yield %	Yield %	Increase rate of yield %
Control milk	11.00	----	13.36	---
UF- retentate (UF)	13.12	19.27	16.52	23.65
UF- with direct acidification (DA)	13.37	21.55	16.67	24.78
Diafiltered milk with water (DFW)	13.21	20.09	16.65	24.63
Diafiltered milk with 1% salt solution (DFS)	13.19	19.91	15.82	18.41

Table 12: Sensory evaluation score of different Mozzarella cheese

Treat-ments		Flavour (50)	Body & Texture (35)	Appearance (15)	Total (100)
Fresh	T1	44	33	14	91
	T2	43	34	15	92
	T3	44	27	12	83
	T4	41	32	13	86
	T5	43	32	13	88
	T6	42	32	15	89
	T7	41	31	14	86
	T8	40	29	12	81
	T9	41	30	13	84
	T10	41	31	13	85
30 days	T1	46	34	15	95
	T2	45	35	15	95
	T3	45	28	13	86
	T4	43	32	14	89
	T5	44	33	13	90
	T6	43	33	15	91
	T7	42	32	15	89
	T8	41	30	13	84
	T9	42	30	14	86
	T10	42	31	14	87

followed by traditional Mozzarella cheese made from buffaloes' milk. The sensory evaluation results indicated that, total scores had the same trend after of the storage period, with an improvement of its quality. These results are in accordance with Abd El-Gawad (1998) & El-Batawy *et al.* (2004). There was a significant differences between all the treatments for flavour, body & texture, appearance and total scores (P<0.0001)

In conclusion, the foregoing results clearly indicate that, manufacture of Mozzarella cheese from UF- cows' retentate gave cheese of close composition and somewhat, quality to the traditional Mozzarella cheese. It gave a reasonable increase in cheese yield (from 19.27 to 21.99%. But, Mozzarella cheese made from buffaloes' milk had some defects e.g., decrease in their meltability and body & texture.

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إمكانية تصنيع الجبن الموزاريللا من اللبن البقرى والجاموسى المركز بتكنولوجيا الترشيح الدقيق

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تم تصنيع الجبن الموزاريللا من اللبن البقرى أو الجاموسى المركز بالترشيح الدقيق وذات جوامد كلية حوالي ٢٠ ٪ وباستخدام بادئ بنسبة ١.٥ ٪. تم إجراء بعض المعاملات على الناتج المركز قبل التصنيع بغرض تحسين خواص الجبن الناتج مثل إضافة حامض HCl إلى المركز قبل التصنيع direct acidification أو غسله بكمية مساوية له سواء بالماء أو بـ١ ٪ محلول ملحي Diafiltration ثم مقارنة كل هذه المعاملات بالطريقة التقليدية لصناعة الجبن الموزاريللا وتم تخزين الجبن الناتج لمدة شهر على درجة حرارة ٥° م وتم تحليله وهو طازج وبعد انتهاء مدة التخزين. ويمكن تلخيصها والنتائج المتحصل عليها في هذا البحث في النقاط الآتية:

- الجبن الموزاريللا المصنعة من اللبن البقري والـ Retentate الناتج منه كانت أفضل من تلك المصنعة من اللبن الجاموسي والـ Retentate الناتج منه في خواص التسوية والخواص الريولوجيه.
- أدي استخدام تكنولوجيا الـ UF إلي خفض نسبه الرطوبة – اللاكتوز – وكذا معدلات التسوية وخاصية ذوبان الجبن الناتج بينما زاد من نسبه البروتين والتصافي للجبن الناتج.
- أدت عمليه الـ Diafiltration إلي تقليل الـ Ca^{++} وP – اللاكتوز – الحموضة – معدلات التسوية بينما تأثيرها علي الخواص الريولوجيه بسيط.
- أدت عمليه التحميض المباشر إلي تقليل الـ Ca^{++} وP – اللاكتوز ودلائل التسوية وكذا خصائص الذوبان.
- أظهرت الخصائص الحسيه أن الجبن الموزاريللا المصنعة من اللبن البقري والمركز الناتج منه كانت أفضل المعاملات وكانت تماثل تلك المصنعة بالطرق التقليدية بينما تلك المصنعة من اللبن الجاموسي والمركز الناتج منه كان به بعض العيوب والتي تحتاج إلي تحسين في الدراسات التالية.