Minufiya J. Agric. Res. Vol.36 No. 2: 303-322 (2011) "http://www.mujar.net"

THE EFFECT OF SOME TECHNOLOGICAL TREATMENTS ON MOZZARELLA CHEESE PROPERTIES

S. A. Abou-donia[1] A. A. Khattab[1], H. S. El-tawel[2] and M.M. El-ddahma[1]

1- Food Sci. Dept., Fac. Agric. Alex. Univ.

2- Food Tech. Res. Ins. Agic. Res. Center. Cairo, Egypt.

(Received: Jan. 5, 2011)

ABSTRACT: *Technological modifications, direct acidification with Gluconic acid δ- lactone (GδL), substitution of milk fat with palm oil and fortification of milk with calcium caseinate on the chemical composition, microbiological content and rheological properties of Mozzarella cheese were studied.*

The results revealed that using direct acidification by GδL decreased the time of manufacturing from 339 to 177 min.

Direct acidification caused the increase the yield, pH values and moisture content but decreased ash content, and total volatile fatty acids (TVFA) in all treatments was observed.

Direct acidification with GδL caused a significant decrease on the total bacterial count (TVBC), lactic acid bacteria count (LABC), coliform count and staphylococci count and from aerobic spore former. All samples didn't manifest colony on yeast and molds count which indicated the absence of yeasts and fungi because of the milk pasteurization and high heating in the step of kneading. Also, Direct acidification led to a significant increase in all values of rheological properties that were estimated in all treatments.

Key Words: *Mozzarella cheese, Direct acidification, Palm oil*

INTRODUCTION

Mozzarella cheese is defined by Scott (1981) as a member of pasta-filata family (pulled curd, soft cheese). Mozzarella cheese has various shapes, round cake form, oval shape or rectangular. It was first made from buffalo's milk and then successfully made from cow's and ewe's milk. In Egypt, Mozzarella cheese for pizza pie is produced from cow's milk in modern dairy plants and from mixed milk in small private dairy plants. The cheese has loaves shape and stored in deep freezers (El-Zoghby, 1994).

Mozzarella cheese is a soft, unripened cheese variety of the pasta filata family which had its origin in the Buttipaglia region of Italy. The finished cheese is white, soft with a very lively sheen surface and has a unique property called stretchability to form fibers or strings when it is hot, therefore it is considered the most suitable cheese variety as a topping on pizza. (Kosikowski, 1970). Some technological applications were carried out to modifi Mozzarella cheese production. This was done either by using direct acidification methods instead of using lactic acid starter (Demott (1983); Singh and Ladkani (1984); Anon (1987) Guinee *et al.*, (2002) and Angelis *et al.*, (2008)) or by fortification with some protein sources (milk protein concentrate, whey proteins, sodium caseinate, calcium caseinate, nonfat dry milk and Soya protein concentrates). Jensen *et al.*, (1987) and Yun *et al.*, (1998) Hassan and Abd El-Gawad (2000); Shakeel-Ur-Rehman *et al.*, (2003); Badawi *et al.*, (2004, a). In Egypt, some plastic curd cheese varieties are adopted and produced with some slight modifications in the manufacturing process, therefore it is considered local Egyptian adopted cheese varieties, such as Egyptian provolone, Mozzarella, Medaffarah, Haloumi and Kashkaval. The production of the plastic curd cheese was highly increased in all of the Egyptian provinces during the last decade because the fresh curd after kneading treatment in hot water of the above cheese varieties could be utilized as a topping on pizza, but the most known one is Mozzarella cheese. (Abou-Donia, 2005).

The aim of the present investigation was carried out to study the technological modifications, direct acidification with GδL, substitution of milk fat with palm oil and fortification of milk with calcium caseinate on the chemical composition, microbiological content and rheological properties of Mozzarella cheese.

MATERIALS AND METHODS

Materials

Buffaloes' milk

Buffalo's milk was obtained from the buffaloes' herd, Mottobes (kafr Elsheikh Governorate). The average of chemical analysis was acidity, 0.18%, pH 6.7, fat 6.7%, protein 4.89% and total solids 16.75%.

Cows' milk

Cows' milk was obtained from the Frezian herd, Mottobes (kafr Elsheikh Governorate). The average of chemical analysis was; acidity 0.16%, pH 6.6, fat 4%, protein 3.58% and total solids 12.59%.

Mixed milk

Mixed milk was obtained by mixing Cows' and Buffaloes' milk in ratio (2:1). The average of chemical analysis was; acidity 0.17%, pH 6.51, fat 3%, protein 3.98% and total solids 12.93%.

Calcium caseinate:

Calcium caseinate was obtained from (Lactoprot Deutschland Gmoh Kaltenkirchen/Germany). It contained 73% protein, 12.9% lactose, 4% moisture, 2.1% fat and 8% ash.

Palm oil:

Palm oil was obtained from Extracted oils & Derivatives Co. Alex. ;35 Canal Elsuwis Str. (Melting points 38°C, color 2.3, peroxide number 0.56 and acidity 0.048%).

Starters:

Yoghurt starter culture of *Streptococcus salavarius ssp. thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus* (was obtained from Wiesby GmbH and Co. KG. Niebull, Germay).

Rennet:

Animal rennet was purchased from the local market, Alexandria. It was checked for strength before use and added to cheese milk in a sufficient amount to coagulate milk within 0.5 hour at 35°C.

Salt:

Fine food grade edible salt was obtained from El-Nasr Company, Alexandria.

Calcium chloride:

Fine good grade of calcium chloride was obtained from El-Nasr Pharmaceutical Company, Alexandria.

Acidulant

Gluconic acid δ-lactone (1, 5-Gluconolactone (GδL) (Searle Company, Chadwell Heath Essex England) was used for the acidification of the milk and the curd. It was added only to the milk as a powder at rate of 6.5 gm/1 kg of milk. While, the amount of GδL which added to standardized milk plus 1% calcium caseinate added at a rate of 8.7 gm/1 kg

Methods:

Cheese manufacture:

Mozzarella cheese was made from mixed milk (buffaloes': cows' milk with a ratio of 1:2) and then divided into 3 portions;

1)The first portion served as a control was standardized to 3% fat and it was left without additives.

2)The second portion was standardized to 3% fat and contained calcium caseinate which was added at a level of 1.0% at 33°C..

3)The third portion contained 3% palm oil as a substitute for milk fat. It was emulsified in skim milk by blender with lecithin as emulsifier (Limited by GMP)

Standardized mixed milk was heat treated at 72°C for 15sec., and then cooled to 33°C; each portion was divided into two treatments which were differed only in their acidification process .i.e. acidification with starter composed of (1% *Streptococcus salavarius ssp thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus*) or direct acidification with gluconic acid δ- lactone (GδL). Mozzarella cheese was made as described by Kosikowski (1970).

Sampling:

Milk:

Samples of milk before the addition of starters were kept in a deep freezer for chemical analysis, for immediate titratable acidity, pH, fat, moisture and protein determination.

Cheese:

Samples of fresh cheese and after 30 days were taken for microbiological, rheological and chemical analysis.

Yield calculations:

The actual yield:

The actual yield of cheese was determined by weighing the cheese obtained in each vat after removal from the brine and expressed as a percentage of the milk weight in the respective vat (Shakeel-Ur-Rehman *et al.*, 2003).

$$\text{Cheese yield} = \frac{\text{Cheese weight (kg)}}{\text{Milk weight (kg)}} \times 100$$

The adjusted yield:

According to Metzger *et al.,* (2000,b), Moisture and salt adjusted cheese yield was calculated by the following formula:

$$\text{The adjusted yield} = \text{Actual yield} \times \frac{100 - (\text{\% Actual moisture + salt})}{100 - (\text{\% Desired moisture + salt})}$$

Microbiological examinations:

Total viable bacterial count (TVBC):

Plate count Agar (PCA) was used for enumeration the total microbial counts as described in Difco Manual (1984).

Lactic acid bacteria count (LABC):

MRS medium as described by Bridson (1990) was used for enumeration lactic acid bacteria.

Coliform count:

Violet Red Bile Agar (VRBA) was used for enumerating coliform bacteria according to Difco Manual (1984).

Moulds and yeasts count:

Sabouraud Agar medium was used for the enumeration of yeasts and moulds as recommended by Difco Manual (1984).

Staphylococci count.

Mannitol salt Agar (MSA) was used for enumeration of staphylococci according to Difco Manual (1984).

Aerobic sporeforming count.

Plate count Agar medium was used in this determination detection of these bacteria as described by Difco Manual (1984).

Chemical analysis:

Moisture content:

Moisture content of cheese was determined according to the Association of Official Analytical Chemists AOAC (2000)

Titratable acidity:

It was estimated as lactic acid % according to Ling (1963).

pH value:

The pH value of cheese was estimated using glass electrode pH meter, Accumet® model 810 pH meter (Fisher scientific) according to AOAC (2000).

Fat content:

The conventional Gerber's method was used to determine the fat content (AOAC, 2000).

Salt content:

The modified Volhard's method as described by Kosikowski (1970) was used to determine the salt content.

Ash content:

It was determined as described by AOAC. (2000).

Total nitrogen (TN.):

Total nitrogen (TN) was determined according to Ling (1963).

Total volatile fatty acids (T.V.F.A.):

Total volatile fatty acids (TVFA.) in cheese was determined as described by Ostoeux *et al.,* (1958) and modified by El-Nemr (1968).

Rheological properties:

Meltability (mm):

Meltability of cheese was measured in duplicate as described by Olson and Price (1958) with the modification of Rayan *et al.,* (1980).

Oiling-off property (ratio):

The fat leakage method as described by Ghosh and Singh (1992, b) was used to determine the oiling-off ratio.

Strechability test (cm):

The stretch quality of Mozzarella cheese was evaluated by Sabikhi and Kanawjia (1992) method as the following procedure. A 250ml beaker was filled to 3/4 its volume with hot water at 85 °C. About 10 gm of the cheese was put in the beaker and allowed to remain immersed for a minute. A glass rod was immersed in the center of the molten mass of cheese and the cheese lifted with the rod. The length of the thread formed was measured as cm. longer threads indicated better stretching characteristics.

RESULTS and DISCUSSION

Effect of Direct acidification on chemical, microbial and rheological properties of Mozzarella cheese.

Table (1) shows the effect of acidification methods either by using the starter or gluconic acid δ- lactone. Using direct acidification by GδL decreased the time of manufacturing from 334 to 177 min. Substituting the milk fat by palm oil then acidifying by the starter or GδL also decreased the time of manufacture from 314 to 136 min. which was shorter than the control. On the other hand, fortifying the standardized milk with 1% calcium caseinate caused an increase in the time of manufacture in comparison with the control either by using starter or GδL but also the direct acidification by GδL decreased the time by 50%. Furthermore, the effect of direct acidification on the time of manufacturing was very clear in the step of milk acidification and renneting then in cheddaring step which show about 60% shorter in the time of the steps mentioned previously. The obtained results agree with those reported by Metzger *et al.,* (2000,b & 2001); Guinee *et al.,* (2002) and Fox *et al.*, (2000).

Table (1): Effect of direct acidification on the time required for each cheese processing steps (minutes).

Processing steps	Treatment					
	Control		Skim milk+Palm oil		Standardized milk+calcium caseinate	
	Starter	GδL	Starter	GδL	Starter	GδL
Acidification and renneting	70	20	60	20	75	20
Coagulate time	30	25	30	20	30	25
Cutting, scalding and whey draining	100	80	95	60	110	90
Cheddaring	125	45	120	30	140	40
Kneading	9	7	9	6	7	5
Total time	334	177	314	136	362	180

pH and Titratable acidity (TA):

Table (2) shows that the pH values of cheese made by lactic acid starter decreased from 5.21 to 5.15 then increased from 5.07 in fresh cheese to 5.20, 5.13 and 5.12 respectively after 30 days of cold frozen, while those acidified by direct acidification increased from 5.43, 5.45 and 5.16 in fresh cheese to 5.45, 5.53 and 5.33 respectively after storing. However, the pH values of the treatments acidified by direct acidification were higher than those made by lactic acid starter. These differences were only significant higher (P< 0.05) when the skim milk + palm oil was acidified by direct acidification in comparison with starter culture in fresh and after frozen storage of the cheese. Also the acidification by both methods for milk + calcium caseinate showed lower pH than the other treatments which may be attributed to the addition of calcium caseinate to the milk. Storing the cheese for 30days under freezing caused insignificant decrease in the pH values for the cheese acidified by starter culture in control and made from milk +palm oil and insignificant increased it in the case of adding calcium caseinate which may increase the buffering capacity. Also the data revealed that the titratable acidity % of Mozzarella cheeses made by lactic acid starter were increased from 1.44, 1.48 and 1.05 in fresh cheese to 1.49, 1.51 and 1.28 respectively after 30 days storage under freezing. These differences were only significant (P< 0.05) when fortified by calcium caseinate. Any way, These result are concurs with Guinee *et al.*, (2002); Feeney *et al.*, (2002) , Fox and Wallace, (1997).

Table (2): Effect of direct acidification on the titratable acidity[1] (TA) and pH of Mozzarella cheese during frozen storage.

Treatments	type of acidification	Storage period(Day)	pH	TA%
Standardized Milk	Starter	Fresh	5.21^{bcd} ±0.017	1.44^{a} ±0.01
		30	5.20^{bcd} ±0.014	1.49^{a} ±0.062
	GδL	Fresh	5.43^{ab} ±0.06	——
		30	5.45^{ab} ±0.028	——
Skim milk+ 3%palm oil	Starter	Fresh	5.15^{cd} ±0.045	1.48^{a} ±0.04
		30	5.13^{cd} ±0.021	1.51^{a} ±0.064
	GδL	Fresh	5.45^{ab} ±0.13	——
		30	5.53^{a} ±0.148	——
Standardized Milk+ calcium caseinate	Starter	Fresh	5.07^{d} ±0.066	1.05^{c} ±0.13
		30	5.12^{cd} ±0.043	1.28^{b} ±0.07
	GδL	Fresh	5.16^{cd} ±0.031	——
		30	5.33^{abc} ±0.075	——

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.

[a,b,c] Means with the same superscripts are not significantly different (P ≤0.05).

Moisture content:

Table (3) revealed that the moisture content values of cheeses made by lactic acid starter were 50.43, 50.05 and 50.22 respectively, while those acidified by direct acidification were 51.01, 50.8 and 54.92 respectively. It was clear that the cheeses made by direct acidification were higher in its moisture content than those made by starter, while only the direct acidification of milk + calcium caseinate was significantly higher ($P \leq 0.05$) than the other treatments. This result concurs with those of Shehata *et al.*, (1967) and Keller *et al.*, (1974); Joshi *et al.*, (2004,a,b,c,d); McMahon *et al.*, (2005).

Ash and salt content:

Table (3) illustrated that the ash and ash/DM values of cheeses made by lactic acid starter were (2.73, 5.5); (2.86, 6.21) and (3.04, 6.1) respectively, while those acidified by direct acidification were (2.71, 5.54); (2.52, 5.12) and (2.9, 6.43) respectively, which seems that applying direct acidification on the cheese making reduce the percentage of ash which may be due to increase the calcium solubility. Whereas the addition of calcium caseinate increased the ash content significantly than other treatments. Demott (1983) reported that ash concentrations of the products made by the two methods were not significantly different ($P \leq 0.05$). Angelis *et al.*, (2008) used three different starters to prepare Mozzarella cheese in comparison with a treatment made by DA.

Table (3): Effect of applying direct acidification on moisture[1], ash, ash/DM, salt and salt/DM in Mozzarella cheese.

Treatments	Type of acidification	Moisture%	Ash%	Ash/DM%	Salt%	Salt/DM%
Standardized Milk	Starter	$50.43^{b} \pm 1.194$	$2.73^{ab} \pm 0.39$	$5.50^{b} \pm 0.882$	$1.65^{c} \pm 0.17$	$3.47^{c} \pm 0.382$
	GδL	$51.01^{b} \pm 2.900$	$2.71^{b} \pm 0.013$	$5.54^{b} \pm 0.315$	$1.55^{d} \pm 0.25$	$3.16^{c} \pm 0.70$
Skim milk+ 3%palm oil	Starter	$50.05^{b} \pm 0.042$	$2.86^{ab} \pm 0.286$	$6.21^{a} \pm 0.007$	$1.79^{c} \pm 0.243$	$4.40^{b} \pm 0.060$
	GδL	$50.80^{b} \pm 0.707$	$2.52^{b} \pm 0.015$	$5.12^{c} \pm 0.100$	$1.53^{d} \pm 0.017$	$3.12^{c} \pm 0.054$
Standardized Milk+ calcium caseinate	Starter	$50.22^{b} \pm 0.506$	$3.04^{a} \pm 0.089$	$6.10^{a} \pm 0.153$	$2.23^{a} \pm 0.033$	$4.07^{b} \pm 0.046$
	GδL	$54.92^{a} \pm 0.640$	$2.90^{ab} \pm 0.050$	$6.43^{a} \pm 0.200$	$2.03^{b} \pm 0.030$	$4.95^{a} \pm 0.046$
Means	Starter	51.46^{a}	2.87^{a}	5.94^{a}	1.82^{a}	3.98^{a}
	GδL	52.24^{a}	2.71^{a}	5.7^{a}	1.71^{a}	3.58^{a}

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.
[a,b,c] Means with the same superscripts are not significantly different ($P \leq 0.05$).

The salt and salt/DM values of the cheeses made by lactic acid starter were (1.65, 3.47); (1.79, 4.4) and (2.23, 4.07) respectively (Table 3), while those acidified by direct acidification were (1.55, 3.16); (1.53, 3.12) and (2.03, 4.95) respectively, the results showed that a variation in salt content, further more the cheese made by adding calcium caseinate was significantly higher

($P \leq 0.05$) than other cheese treatment which may be attributed to its ability to absorb more salt.

Fat content:

Fat has a great effect on the palatability of any type of cheese, it is responsible for the smoothness and richness of the body and texture as reported by Gunasekaran and mehmet (2003). Table (4) revealed that the fat and F/DM content values of the cheeses made by lactic acid starter were (23.29, 46.82); (22.2, 44.44) and (16.5, 33.15) respectively. While those acidified by direct acidification were (20.88, 42.75); (21.75, 44.22) and (14.13, 31.34) respectively. These results concluded that the direct acidification methods resulted lower fat and F/DM content in the cheese which may be due to the differences in its moisture and total solids contents as in the case of adding calcium caseinate. Guinee *et al.,*(2002); Feeney *et al.,* (2002) reported that the fat content of the control cheese was significantly higher than that of the direct acidification cheeses which had a similar fat content. Moreover, the FDM level in direct acidification cheeses was lower than that of the control cheese, suggesting higher losses of fat to the cheese whey and/or the stretch water during the manufacture of the former cheeses.

Protein content:

Table (4) revealed that the TP and TP/DM content of the cheeses made by lactic acid starter were (20.38, 41.15); (20.73, 43.79) and (26.1, 52.43) respectively. While those acidified by direct acidification were (20.09, 41.14); (20.15, 40.96) and (24.58, 54.52) respectively. The TP and TP/DM % in lactic starter methods were slightly higher than made from direct acidification, further more only the cheese made from milk +calcium caseinate was significantly higher concerning the TP and TP/DM % content by about 25% comparing with the other milk used in Mozzarella cheese preparation. This attributed to the addition of calcium caseinate which raised the protein content of the cheese. Angelis *et al.,* (2008) reported that the concentration of protein in direct acidification Mozzarella cheese was significantly lower at ($P \leq 0.05$) than in the cheeses started with commercial starter and especially, autochthonous multiple strain cultures.

Total Volatile Fatty Acids (TVFA):

As shown in Table (4), the TVFA values of the cheeses made by lactic acid starter were 3.67, 3.75 and 4.17 respectively, while those acidified by direct acidifications were 3.0, 3.67 and 3.5 respectively. The TVFA values of the treatments made by starter were higher than those made with direct acidification but this difference was not significant ($P \geq 0.05$) within the treatments, but this difference was significantly higher between the means of the treatment. The TVFA average of the cheese prepared with starter was 3.86 while it was 3.42 for direct acidification by GδL which may be because of the starter metabolic action on some milk component.

Table (4): Effect of applying direct acidification on the chemical Properties total solids (TS[1]), fat, fat/DM, total protein (TP), total protein/Dry matter (TP/DM) and TVFA* in Mozzarella cheese.

Treatments	Type of acidification	TS%	Fat%	F/DM%	T P%	%TP/DM	TVFA*
Standardized Milk	Starter	49.57^{a} ±1.194	23.29^{a} ±0.356	46.82^{a} ±1.120	20.38^{c} ±0.660	41.15^{d} ±2.284	3.67^{ab} ±0.390
	GδL	49.00^{a} ±2.900	20.88^{b} ±0.629	42.75^{b} ±3.480	20.09^{c} ±0.210	41.14^{d} ±2.860	3.00^{b} ±0.270
Skim milk + 3%palm oil	Starter	49.95^{a} ±0.042	22.2^{0a} ±0.424	4.44^{a} ±0.812	20.73^{c} ±1.340	43.79^{c} ±0.657	3.75^{ab} ±0.500
	GδL	49.20^{a} ±0.707	21.75^{a} ±0.645	44.22^{a} ±1.710	20.15^{c} ±0.101	40.96^{d} ±0.761	3.67^{ab} ±0.500
Standardized Milk+ calcium caseinate	Starter	49.79^{a} ±0.506	16.50^{c} ±0.408	33.15^{c} ±1.064	26.1^{a} ±0.260	52.43^{b} ±0.983	4.17^{a} ±0.340
	GδL	45.08^{b} 0.641	14.13^{d} ±0.854	31.34^{c} ±2.090	24.58^{b} ±0.170	54.52^{a} ±0.840	3.50^{ab} ±0.340
Means	Starter	48.54^{a}	19.95^{a}	41.15^{a}	22.4^{a}	46.13^{a}	3.86^{a}
	GδL	47.70^{a}	19.58^{a}	40.784^{a}	21.605^{b}	45.54^{a}	3.42^{b}

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.
[a,b,c] Means with the same superscripts are not significantly different ($P \leq 0.05$).
* Ml 0.1 N Na OH / 100gm cheese.

Actual & adjusted yield in Mozzarella cheese.

Table (5) showed the actual yield and adjusted yield values of Mozzarella cheese made by lactic acid starter they were (11.32, 12.28); (11.83, 12.15) and (13.23, 14.52) respectively, while those acidified by direct acidification were (11.75, 12.95); (11.9, 13.04) and (14.07, 13.86) respectively. No significant difference were noticed between the starter and direct acidification except in case of actual yield percentage in milk fortification by calcium caseinate. Any way, obtained results agree with those reported by Shakeel-Ur-Rehman *et al.*, (2003).

Table (5): Effect of direct acidification on actual[1] & adjusted yield on Mozzarella cheese.

Type of milk	Type of acidification	Actual yield%	Adjusted yield%
Milk	Starter	$11.32^{c} \pm 0.686$	$12.28^{c} \pm 0.254$
	GδL	$11.75^{c} \pm 0.354$	$12.95^{bc} \pm 0.821$
Skim milk+ palm oil	Starter	$11.83^{c} \pm 0.058$	$12.15^{c} \pm 0.982$
	GδL	$11.90^{c} \pm 0.283$	$13.04^{b} \pm 0.509$
Milk+ calcium caseinate	Starter	$13.23^{b} \pm 0.035$	$14.52^{a} \pm 0.0001$
	GδL	$14.07^{a} \pm 0.099$	$13.86^{a} \pm 0.143$

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.
[a,b,c] Means with the same superscripts are not significantly different ($P \leq 0.05$).

Microbial content

The result reported in Table (6) showed an increase of $\log_{10}$ cfu/gm in Mozzarella cheese made with the starter on all tested media in compared with the cheese made with direct acidification. The yeast and mold were not detected in the Mozzarella cheese treatment made either with starter or direct acidification. In general, making the cheese by starter resulted in higher total bacterial count (TVBC), lactic acid bacteria count (LABC), coliform count and staphylococci count in comparison with those made by direct acidification for all the treatments tested because of adding the lactic acid starter. Predominant colonies from either VRBA media were gram positive rods, while those picked from MSA media were negative for coagulase test. All the treatments were free of yeast and fungi which may be due to the high cooking temperature applied.

Table (6): Count (log_{10} CFU/gm) of some microbial groups on certain specific media found in Mozzarella cheese made by using starter culture or DA (GδL).

Treatments	Type of acidification	Count (log_{10} CFU/gm cheese)					
		TVBC	LABC	Coliform count	Staphylococci count	Mold and yeast	Aerobic Spore Former
Standardized Milk	Starter	6.03 ±0.014	5.46 ±0.226	2.95±0.000	3.00 ±0.262	ND	2.69 ±0.049
	GδL	4.22 ±0.799	3.56 ±0.057	2.15 ±0.050	2.15 ±0.212	ND	2.21 ±0.297
Skim milk+ 3% palm oil	Starter	5.86 ±0.679	5.81 ±0.608	4.36 ±0.594	2.15 ±0.212	ND	2.68 ±0.035
	GδL	4.91 ±0.014	3.01 ±0.177	2.39 ±0.184	ND	ND	2.50 ±0.014
Standardized Milk+ calcium caseinate	Starter	6.72 ±0.028	4.48 ±0.615	3.50 ±0.771	2.63 ±0.078	ND	2.50 ±0.014
	GδL	5.38 ±0.389	3.03 ±0.071	2.22 ±0.304	2.41 ±0.149	ND	2.39 ±0.014

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.
ND, Not detected.

Meltability of Mozzarella cheese

As shown in Table (7) using direct acidification raised the meltability of the resultant cheese significantly ($P \leq 0.05$) compared with those made by using lactic acid starter. The meltability of the fresh cheese from standardized milk, skim milk + palm oil and standardized milk with calcium caseinate were 106.25, 75 and 81.5 mm., respectively by using the starter culture, while the corresponding values of the treatments made by direct acidification were150.25, 149.75 and 124.25 mm., respectively. Storing the cheese under freezing for 30days decreased the meltability values for all treatments and acidification methods used. The meltability values of the cheese made by using the starter culture decreased from 106.25, 75 and 81.5 mm. in fresh cheese to 96, 69.5 and 68.25 mm. after storing, respectively. In the case of direct acidification. The corresponding values were 150.25, 149.75 and 124.25 mm. in fresh cheese which decreased to 145, 136.75 and 93.75 mm. after storing, respectively; Mostly the treatments had no significant effect on the meltability at ($P \leq 0.05$), however, adding calcium caseinate to milk decreased the meltability markedly. On the other hand, adding palm oil and using the starter culture decreased the meltability significantly at ($P \leq 0.05$) in comparison with the control, while the addition of calcium caseinate had insignificant decrease on it. These significant differences were not noticed between the treatments when acidified by GδL in direct acidification.

Storing the cheese for 30 days under freezing decreased the meltability values for the cheese acidified by starter culture, furthermore the meltability of the control was significantly higher ($P \leq 0.05$) than those made by either palm oil and calcium caseinate , while storing the cheese made by direct acidification resulted in a decrease in meltability which was significantly lower ($P \leq 0.05$) in the case of adding calcium caseinate compared with the other treatments. Obtained results agree with, McMahon *et al.*, (2005); Guinee *et al.*, (2002) and Oberg *et al.*, (1992)

Stretchability of Mozzarella cheese

Using direct acidification raised the stretchability of the resultant cheese significantly ($P \leq 0.05$) compared with those made by using lactic acid starter Table (7). The stretchability of the fresh cheese from standardized milk, skim milk + palm oil and standardized milk with calcium caseinate and acidified by the starter culture were : 92.75, 131.5 and 92.5 cm., respectively, while the corresponding values of the treatments made by direct acidification were :146.5, 166.25 and 178.75 cm., respectively.

Storing the cheese under freezing for 30 days led to insignificant increase at ($P \leq 0.05$) in the stretchability values for all the treatments and both acidification methods used.

Table (7): Effect of direct acidification on rheological properties during storage period.

Treatments	type of acidification	Storage period(Day)	Meltability (mm)	Stretchability (cm)	Oiling off (Ratio)
Standardized Milk	Starter	Fresh	106.25^{bc} ±76.64	92.75^{d} ±24.500	2.40^{b} ±0.050
		30	96.00^{c} ±66.42	95.50^{d} ±20.43	2.49^{b} ±0.048
	GδL	Fresh	150.25^{a} ±5.91	146.50^{b} ±17.54	3.08^{a} ±0.560
		30	145.00^{a} ±4.08	155.25^{b} ±11.93	3.16^{a} ±0.449
Skim milk+ 3% palm oil	Starter	Fresh	75.00^{d} ±22.620	131.50^{c} ±5.970	1.79^{d} ±0.270
		30	69.50^{d} ±20.52	132.75^{c} ±6.5	1.98^{cd} ±0.222
	GδL	Fresh	149.75^{a} ±4.720	166.25^{a} ±27.780	2.26^{bc} ±0.140
		30	136.75^{a} ±6.990	175.75^{a} ±26.370	2.49^{b} ±0.163
Standardized Milk+ calcium caseinate	Starter	Fresh	81.50^{cd} ±10.600	92.50^{d} ±6.460	1.25^{d} ±0.282
		30	68.25^{d} ±9.610	93.00^{d} ±11.940	1.38^{d} ±0.273
	GδL	Fresh	124.25^{ab} ±2.990	178.75^{a} ±23.230	1.42^{d} ±0.101
		30	93.75^{cd} ±8.540	185.25^{a} ±21.600	1.54^{d} ±0.099

[1]Mean values± standard deviations for two batches of each cheese, analysed in duplicate.

[a,b,c] Means with the same superscripts are not significantly different ($P \leq 0.05$).

The stretchability values of the cheese made by using the starter culture were : 92.75, 131.5 and 92.5 cm. In fresh cheese which slightly increase to 95.5, 132.75 and 93.0 cm. after storing, respectively. In the case of direct acidification, the stretchability values were : 146.5, 166.25 and 178.75 cm. in fresh cheese increase slightly to 155.25, 175.75 and 185.25 cm. after storing, respectively. However, the stretchability of Mozzarella cheese made from the standardized milk or in the milk fortified with calcium caseinate had no significant difference ($P \leq 0.05$), furthermore substitution of the milk fat with palm oil increased the stretchability of Mozzarella cheese in corresponding with the other two treatments, but this increase was significant ($P \leq 0.05$) in the case of starter acidification in fresh and stored cheese. The stretchability of Mozzarella cheese made with direct acidification value were significantly higher ($P \leq 0.05$) either by adding calcium caseinate or palm oil to the milk in comparison with the control in fresh and stored cheese, while the differences between the Mozzarella cheese from skim milk + palm oil and standardized milk + calcium caseinate was not significant ($P \leq 0.05$).

The results obtained were correlated with those obtained by Joshi et al., (2004,a,b), Guinee *et al.,* (2002)and Oberg *et al.*, (1992)

Oiling off property (Ratio) of Mozzarella cheese

As shown in Table (7) using direct acidification in the manufacture of Mozzarella cheese raised the oiling off ratio of the resultant cheese. This increase was significant ($P \leq 0.05$) for the cheese made from milk and skim milk + palm oil, while it was insignificant in the case of adding calcium caseinate to the milk. The oiling off property of the fresh cheese from standardized milk, skim milk + palm oil and standardized milk with calcium caseinate were 2.4, 1.79 and 1.25, respectively by using the starter culture, while the corresponding values of the treatments made by direct acidification were : 3.08, 2.26 and 1.42, respectively. Storing the cheese under freezing for 30days led to insignificant increase in the oiling off values for all the treatments and both acidification methods used for example the cheese made by using the starter culture were : 2.4, 1.79 and 1.25 in fresh cheese which increase to 2.491, 1.98 and 1.38 after storing, respectively, while in the case of direct acidification, the oiling off values were : 3.08, 2.26 and 1.42 in fresh cheese which slightly increase to 3.16, 2.5 and 1.54 after storing, respectively. The oiling off values were differed according to the difference of treatments, for example, adding the calcium caseinate or palm oil decreased it in corresponding with the control. This decrease was significant ($P \leq 0.05$) in the case of adding calcium caseinate and using direct acidification in fresh and stored cheese, furthermore fortification with calcium caseinate decreased the oiling off ratio of Mozzarella cheese significant ($P \leq 0.05$) in corresponding with substitution of milk fat with palm oil. This decrease was not significant in the case of using starter culture which was significantly lower ($P \leq 0.05$) than the acidified by direct acidification in fresh and stored cheese. However, the substitution of milk fat with palm oil decreases the oiling off significant ($P \leq 0.05$) in comparison with the control when the Mozzarella cheese made by starter culture in fresh and stored cheese. This significant differences were not noticed when storing the cheese for 30days under freezing which resulted in the cheese made by starter culture insignificant increase on the oiling off values on Mozzarella cheese made by different types of milk and both acidification methods i.e. starter culture and direct acidification with Gluconic acid δ- lactone. The obtained results were correlated with these obtained by Ghosh and Singh (1992,b) who reported that the fat leakage increased slowly with the storage period in deep frozen samples at (-10 to -20°C).

REFERENCES

Abou-Donia, S.A. (2005). Egyption adopted plastic curd cheese varieties, Provolone, Mozzarella, Medaffarah and Halloumi : An overview. Alex. J. Fd. Sci. & Technol. 2: 35-41.

Angelis, M.D. S.D. Candia, Maria M.P. Piera Calasso, M. Faccia, T.P. Guinee, M.C. Simonetti and M. Gobbetti (2008). Selection and use of autochthonous multiple strain cultures for the manufacture of high-moisture traditional Mozzarella cheese. Intr. J. Food Microbiology 125: 123–132.

Anon, (1987). Annual Report N.D.R.I. karnal, 52 (c.f. Indian J. Dairy Sci. 44, 2,1991).

Association of Official Analytical Chemists (AOAC). (2000). Pages 1– 80 in AOAC International, Vol. II, 17th ed., Gaithersburg, MD. Atherton, H. V., and J. A. Newlander. 1987. Chemistry and Testing of Dairy Products, 1st Indian edition, AVI Pub. Co. Inc., West- port, CT.

Badawi, R. M., A. N. Zedan, A. I. Okasha and G. M. Omara (2004,a). Change in chemical composition and sensory properties of low fat Mozzarella cheese during storage. Egyptian J. Dairy Sci., 32: 327-340.

Bridson, E. Y. (1990). The Oxoid Manual, 6th Ed. Unipath Ltd, wade road, Basing stoke RG240PN

Demott, B. J. (1983). Recovery of milk constituent in mozzarella like product manufacture from non – fat dry milk and cream by direct acidification at 4 and 35°C. J. Dairy Sci. 66 (2):1501-06.

Difco's Manual, (1984). Manual of Dehydrated Culture and Reagents for Microbiology Detroit, Michigan, USA.

El-Nemr, A. A. (1968). Nonenzymatic coagulation of milk and its use in soft cheese making. Ph. D. Thesis Fec. of Agric. Cairo Univ. Egypt.

El-Zoghby, A. S., (1994). Studies on Mozzarella cheeses. Ph.D. Thesis, Zagazaig Univ. Egypt.

Feeney, E. P., T. P. Guinee and P.F. Fox (2002). Effect of pH and Calcium Concentration on Proteolysis in Mozzarella Cheese. J. Dairy Sci. 85:1646–1654.

Fox, P. F. and J. M. Wallace (1997). Formation of flavour compounds in cheese. Adv. Appl. Microbiol. 45:17–85.

Ghosh, B. C. and S. Singh (1992b).Storage studies of Mozzarella cheese part I-sensory and rheological characteristics. Indian J. Dairy Sci., 45: 199-202.

Guinee, T. P., E. P. Feeney, M.A. E. Auty and P. F. Fox (2002). Effect of pH and calcium concentration on some textural and functional properties of Mozzarella cheese. J. Dairy Sci. 85:1655–1669.

Gunasekaran, S. and A. M. Mehmet (2003). Cheese Rheology and Texture.Boca Raton London New York Washington, D.C. by CRC Press LLC.

Hassan, Fatma, .A.M. and Mona, A.M. Abd El-Gawad (2000). Manufacture of Mozzarella cheese supplemented with different protein concentrate. Egyptian J. Dairy Sci., 28: 28-37.

Jensen, K.G., R. H. Ipsen and C. Ilsoe (1987). Functionality and application of dairy products. Food Technol. 41 (10): 66.

Joshi, N. S., K. Muthukumarappan and R. I. Dave (2004,a). Effects of reduced-calcium, test temperature and storage on stretchability of part-skim Mozzarella cheese. Aust. J. Dairy Technol. 59:60–65.

Joshi, N. S., K. Muthukumarappan and R. I. Dave (2004,b). Viscoelastic properties of part skim Mozzarella cheese: Effect of calcium, storage, and test temperature. Int. J. Food Prop. 7:239–252.

Joshi, N. S., K. Muthukumarappan and R. I. Dave (2004,c). Modeling rheological characteristics and calcium content of Mozzarella cheese. J. Food Sci. 69:FEP97–FEP101.

Joshi, N. S., K. Muthukumarappan and R. I. Dave (2004,d). Effect of calcium on microstructure and meltability of part skim Mozzarella cheese. J. Dairy Sci. 87:1975–1985.

Keller, B., N. F. Olson and T. Richardson (1974). Mineral retention and rheological properties of Mozzarella cheese made by direct acidification. J. Dairy Sci. 57:174–180.

Kosikowski, F. V. (1966). Cheese and Fermented Milk Foods. 2nd printing published by the author. New York. 1966.

Kosikowski, F. V. (1970). Cheese and Fermented Milk Product" 2nd edn., Edwards Brothers Inc., Am. Arbor, Michigan, USA.

Ling, E. R. (1963). A text book of Dairy Chemistry. Vol. 2. 3rd ed., Chapman and Hall, London.

McMahon, D. J., B. Paulson and C. J. Oberg (2005). Influence of Calcium, pH, and Moisture on Protein Matrix Structure and Functionality in Direct Acidified Nonfat Mozzarella Cheese. J. Dairy Sci. 88:3754-3763

Metzger, L. E., D. M. Barbano, M. A. Rudan and P. S. Kindstedt (2000,b). Effect of Milk Preacidification on Low Fat Mozzarella Cheese. I. Composition and yield. J. Dairy Sci. 83:648–658 , 83: 1-10.

Metzger, L. E., D. M. Barbano, P. S. Kindstedt and M. R. Guo (2001). Effect of milkpreacidification on low fat Mozzarella cheese: II. Chemical and functional properties during storage. J. Dairy Sci. 84:1348–1356.

Olson, N. F. and W. V. Price (1958). A melting test for pasteurized process cheese spreads. J. Dairy Sci. 41:999–1000.

Oberg. C. J., R. K. Merril, R. J. Brown and G.H. Richardson (1992). Effects of milk-clotting enzymes on physical properties of Mozzarella cheese. J. Dairy Sci. 7.5669.

Osteux, R., J. Guillavne and J. Laturaze (1958). Separation of volatile aliphatic acids by paper chromatography. J. chromatography 1:70. (c.f. Microbiological and Chemical studies on Kachkaval-like cheese. Ph. D. Thesis of Shoukry, Y.M.R. (1982). Alexandria Univ).

Rayan, A. A., M. Kalab and C. A. Ernstrom (1980). Microstructure and rheology of pasteurized process cheese. Scanning Electron Microscopy. 3: 635-643.

Rowland, S. J. (1938). The determination of nitrogen distribution in milk. J. Dairy Res. 9: 42-49.

Sabikhi, Latha and S. K. Kanawjia (1992). Effect of admixing of Goat and buffalo milks on sensory, compositional and textural characteristics of direct acid Mozzarella cheese. IndianJ. Dairy Sci. 45 (10); 562.

Scott, R. (1981). Cheese Making Practice. (Text book). Applied Sci. pub. Ltd. London.

Singh, S. and B. C. Ladkani (1984). Annual Report, NDRI., Karnal,82.

Shakeel-Ur-Rehman, N.Y. Farkye, T. Considine, A. Schaffner, and M.A. Drake. (2003). Effects of standardization of whole milk with dry milk protein concentrate on the yield and ripening of reduced-fat Cheddar cheese. J. Dairy Sci. 86:1608–1615.

Shehata, A. E., Olson, N. F. Meenalyer and T. Richardson (1967). Effect of type of acid used in direct acidification procedure on moisture. Fermness and calcium levels of cheese. J. Dairy Sci. 50:824.

Yun, J. J., D. M. Barbano, K. L. Larose and P. S. Kindstedt (1998) Mozzarella Cheese: Impact of Nonfat Dry Milk Fortification on Composition, Proteolysis, and Functional Properties J. Dairy Sci., 81:1–8

تأثير بعض المعاملات التكنولوجية على خواص الجبن الموزاريللا

سمير احمد أبو دنيا[1] – على عبد اللطيف خطاب[1] – حمدي سيد محمد الطويل[2] – محمود محمد دسوقي الدهمة[1]

١- كلية الزراعة – جامعة الإسكندرية-

٢- معهد بحوث تكنولوجيا الأغذية ـ مركز البحوث الزراعية- وزارة الزراعة .

الملخص العربي

يهدف هذا البحث إلى دراسة اثر استخدام بعض المعاملات التكنولوجية على الخواص الكيماوية والميكروبيولوجية و الريولوجية للجبن الموزاريللا حيث تم استخدام التحميض المباشر بالحامض العضوى جلوكونو دلتا لاكتون (GδL) وكذلك تم تعديل نسبة الدهن في اللبن الفرز إلى ٣% باستخدام زيت النخيل Palm oil والمعاملة الثالثة اشتملت التدعيم بإضافة ١% كازينات كالسيوم المحتوية على ٧٥% بروتين ولقد أوضحت النتائج المتحصل عليها ما يلي:

١ – أدى التحميض المباشر إلى تقليل الوقت اللازم للتصنيع في جميع المعاملات وكذالك أدى إلى زيادة الريع المتحصل علية وكانت هذة الزيادة معنوية عند التدعيم بكازينات الكالسيوم.

٢ – أدى التحميض المباشر إلى إرتفاع قيم ال pH والرطوبة بصفة عامة في جميع المعاملات كما أدى إلى انخفاض محتوى الجبن من الرماد و الدهن والبروتين والمادة الصلبة الكلية والأحماض الدهنية الطيارة الكلية (T.V.F.A) في جميع المعاملات.

٣ – أدى التحميض المباشر إلى انخفاض أعداد total bacterial count (TVBC), lactic acid bacteria count (LABC), coliform count and staphylococci count و Aerobic spore former في كل المعاملات ولم تظهر العينات اى نمو على بيئة Sabouraud مما يدل على خلوها من الخمائر والفطريات وكذلك أظهرت خلواً من بكتريا القولون المنتجة للغاز وكذلك خلوها من

بكتريا *Staphylococcus aureus* الموجبة لاختبار التجلط.

٤ - أظهرت دراسة الخواص الريولوجية لجبن الموزاريللا تفاوت كبير حيث :

أ - أدى التحميض المباشر إلى زيادة معنوية في كل قيم الصفات الريولوجية وفى كل المعاملات حيث زادت درجة الانصهار والمطاطية ومعامل انفصال الدهن.

ب - اظهر التحليل الاحصائى للخواص الريولوجية فروقاً معنوية في صفة الانصهار فقط عند التحميض بالبادىء بين معاملة استبدال الدهن بزيت النخيل والكونترول.

ت - كذلك أعطى استبدال دهن اللبن بزيت النخيل أعلى قيم معنوية لصفة المطاطية عند استخدام البادىء بينما أعطى الكونترول اقل قيمة معنوية للمطاطية عند استخدام التحميض المباشر.

ث - سجلت صفة انفصال الدهن في معاملة استبدال دهن اللبن بزيت النخيل أعلى قيمة معنوية عن باقي المعاملات عند استخدام البادىء بينما سجل التدعيم بكازينات الكالسيوم اقل قيمة لانفصال الدهن بالبادىء وبالتحميض المباشر.

ج - وفى دراسة تأثير التخزين بالتجميد على الصفات الريولوجية فقد أدى التخزين تحت تجميد لمدة ٣٠ يوم إلى حدوث زيادة طفيفة وغير معنوية في المطاطية وكذلك زيادة قيمة صفة انفصال الدهن زيادة غير معنوية أيضا بينما انخفضت قيمة صفة درجة الانصهار عند استخدام البادىء انخفاض غير معنوي وانخفاض معنوي في حالة التدعيم بكازينات الكالسيوم.