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YIELD IMPROVEMENT AND PRODUCT QUALITY OF MOZZARELLA CHEESE FROM COW MILK FORTIFIED WITH DRIED SKIM MILK OR DRY MILK PROTEIN CONCENTRATE

BY

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ABSTRACT

Mozzarella cheese was produced from cow milk fortified with dried skim milk (DSM) in ratios 2, 4, 6% or dry milk protein concentrate (MPC) in ratios 0.5, 1, 2%. Control treatment of Mozzarella was made from fresh untreated cow milk. Resultant Mozzarella cheeses were analyzed fresh and followed up to 4 weeks during storage in refrigerator for its physicochemical properties (moisture, total protein, ash, lactose, pH value, soluble nitrogen, total calcium, and total volatile fatty acids, TVFA). Functional characteristics (meltability, firmness, stretchability and oil separation) and sensory quality attributes were also determined. Actual yield, cheese microstructure and texture profile were estimated in fresh treatments. Fortifying cow milk with DSM and MPC increased significantly the actual yield being higher with higher ratio of added materials. Mozzarella cheese of cow milk fortified with DSM or MPC showed lower moisture and pH while ash, lactose, total calcium, total protein, soluble nitrogen, and TVFA values were significantly increased. Meltability and stretchability of Mozzarella were not significantly affected by adding DSM or MPC to cheese milk except in highest ratios of DSM and MPC. Mozzarella cheese fortified with MPC showed much better functional properties than that of DSM. The microstructure of fortified Mozzarella cheeses revealed that addition of DSM or MPC resulted in denser protein strands and close structure. Mozzarella cheese showed higher hardness, gumminess, and chewiness with low springiness by adding DSM or MPC to cow milk. All treatments were sensory acceptable showing higher significant quality attributes in treatments with MPC than that of DSM being best in treatment with 1% MPC. Storage of Mozzarella caused a significant increase in SN, TVFA, meltability, stretchability and oil separation while moisture, lactose, and firmness were decreased.

Key words: Yield, Mozzarella, Functional properties, Dried Skim milk, Milk protein concentrate, Texture.

INTRODUCTION

Mozzarella cheese has a unique property called stretchability to form fibers or strings when heated which depends on its pH and proportion of colloidal calcium phosphate that has been removed (Ghosh and Singh, 1996). With the spread of fast foods, especial-lly pizza stores, the annual production of Mozzarella cheese has been increased in USA from about 705 thousand tons (1990) to reach up to 1.277 thousand tons in 2006 (AAE, 2006). Mozzarella is an irreplaceable cheese for pizza because of its strechability, and it has a number of precise functional requirements. There has been a sharp increase in the con-sumption of pizza worldwide, resulting in high demand for Mozzarella or Pizza cheese. Mozzarella cheese classified as a semi hard cheese is regularly produce a lower yield percentages especially with cow milk. Increa-sing Mozzarella cheese yield without affecting its functional quality needs more research to maxima the advantages especially with introduction of new dairy ingredients. The yield of cheese and its control are of great economic importance, determining the profit of cheese plants. Cheese yield can be expressed simply as the quantity of cheese produced from a given quantity of milk (kg /100 kg) with a defined protein and fat content (Walstra, 2000). The raw milk costs about 80-90% of the wholesale price of cheese. An increase in the retention of milk components in the form of cheese, and thus increase in cheese yield has been a major driver in the design of cheese equipment and process optimizations through reducing the loss of milk components (mainly fat & protein) into the whey. The composition of cheese milk may be altered by technological interventions, involving standardization of casein/fat ratio, fortification with reconstituted skim milk and incorporation of whey proteins (Fox *et al.*, 2000).

The use of concentrated milk for cheese processing presents advantages for regions where there is a shortage of milk and milk products but it can bring some negative effects on the process. It is often necessary to adjust the component concentrations in raw milk to satisfy the type and functionality of the cheese being manufactured. Standardization of milk by increasing solids not-fat (SNF) through adding skim milk powder to improve the body & texture, consistency as well as yield percent is considered as one of the most useful process in some dairy products like yoghurt (Lankes *et al.*, 1998, Folkenberg & Martens 2003), ice cream (Arbukle, 1986; Awad & Metwally, 2000) and cheese (Jensen & Nielsen, 1982; Hefny & Kandeel, 1990; Jana & Thakar, 1996; Brito *et al.*, 2000; Hefny *et al.*, 2004). Several alternatives have been explored to describe the manufacture of Mozzarella using reconstituted skim milk powder or UF concentrates. The resultant cheeses had acceptable quality but poor melting, stretching, and shredability properties due to gumminess (Kindstedt, 1993, El-Batawy *et al.*, 2004). Concentrated milk proteins are recently introduced and now are commercially available as dairy products. It has a wide range of protein percentages and generally contains low lactose content with high ratio of proteins than milk powder, which may produce different quality of dairy products. Ur-Rehman *et al.* (2003) and Harvey, (2006) used milk protein concentrate to fortify cheddar cheese and found that protein & fat retention and yield were increased with no defect in sensory attributes by fortification at lower protein ratios. Mozzarella cheese yield was also improved by treating the milk with phospholipase enzyme as a result of improved fat and moisture retention in the cheese curd (Lilback *et al.*, 2006).

Since, Mozzarella has unique functional characteristics which may be affected with any changes in milk composition. Therefore, this study was conducted to investigate the actual yield improvement and functional quality of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or dry milk protein concentrate (MPC). This investigation was also planned to find out how much and which is better of DSM or MPC to fortify cow milk without any significant adverse effects on functional characteristics.

MATERIALS AND METHODS

Materials:

Fresh cows' milk was obtained from the herd of Higher Institute of Agricultural Cooperation, Giza, Egypt. Low heat dried skim milk, product of Dairy Farmers of America, MO, USA, and dry milk protein concentrate produced by Australian Dairy products, Pty Ltd., Australia, were used. The composition of previous materials is summarized in Table (1). Starter culture consists of *Str. salvarius* subsp. *thermophilus* and *Lacto. delbreuckii* subsp. *bulgaricus*, was obtained from Cairo MIRCEN Culture Collection Center, Faculty of Agric., Ain Shams

University. Calf rennet powder (Chr. Hansen's Laboratories, Denmark) was used as coagulant.

Mozzarella cheese manufacture

Mozzarella cheese was manufactured from fresh cows' milk standardized to 3% fat and heat treated at 72°C / 15 sec. Cheese milk was divided into 7 equal portions; first portion was served as control without any additives. Dried skim milk (DSM) was added to three portions in ratios of 2, 4, and 6%. Rest three portions were fortified with dry milk protein concentrate (MPC) in ratios of 0.5, 1, and 2%. The calculated amounts of DSM or MPC were mixed properly in the cheese milk, then starter culture was added and the mixture was left at 38±2°C till the pH reached 6.4 within 15-30 min. Thereafter, the coagulation of cheese milk was completed by adding rennet as coagulant to complete the process within 40-60 min, and then the manufacture steps were continued as described by Kosikowiski (1982).

Cheese analysis:

Mozzarella cheese samples were examined when fresh and biweekly during storage at 5±2°C up to 4 weeks for moisture and soluble nitrogen (SN) contents as descry-bed by Ling (1963), and ash and total nitrogen (TN) as described in AOAC (1995). Values of pH were measured with a digital pH meter (Chemcadet Cole-Palmer, Chicago, IL) by inserting the pH electrode (Orion, MA) directly into cheese samples. The method of Lawrance (1968) was used to determine the lactose content. Total calcium content was determined according to the method described by Metzger *et al.* (2000). Total volatile fatty acids (TVFA) was determined in cheese samples by the distillation method (Kosikowski, 1982) and expressed as ml 0.1 N NaOH/100g cheese. The actual cheese yield was calculated by dividing the weight of cheese by the weight of milk using the formula mentioned by Fox *et al.* (2000) as follows:

$$Actual\ yield\ \% = \frac{Weight\ of\ cheese}{Weight\ of\ milk} X\ 100$$

Meltability and fat leakage (oil separation) of cheese samples was determined by the method of Nilson and Lacshair (1976). Cheese firmness was measured using a penetrometer "Koehler" Co. Inc., USA as mentioned by El-Shabrawy *et al.* (2002). Cheese stretchability was measured using the Wessenberg test according to Nelson (1980) as modified by Anis and Ladkani (1988). Microstructure of fresh Mozzarella cheese samples was performed by scanning electron microscopy (JEOL T330A) using the modified method of Tamime *et al.* (1990). Texture profile of fresh Mozzarella cheese was measured with Instron Universal Testing Machine model 1100, Stable Micro System Ltd. (SMS), UK, loaded with Dimension software. Sensory evaluation of cheese samples was carried out on fresh, 2 and 4 weeks of storage according to the method of Nelson and Trout (1956). The data obtained of three replicates were statistically analyzed according to SAS (1994) using General Linear Model (GLM), and Duncan's multiple range was used to separate among means.

RESULTS AND DISCUSSION

Actual yield and chemical properties of Mozzarella cheese:

Actual yield values of Mozzarella cheese made of cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC) are illustrated in Fig.1. The data indicate that the yield value significantly increased with adding DSM or MPC to the cheese milk before manufacture. This means that, fortifying cow milk with DSM or MPC will lead to higher cheese yield which were proportion with the type and ratio of addition. The increase in cheese yield with fortifying the milk by DSM or MPC is due to the increase occurred in the solid content of cheese base milk. It is well known that the yield increases with increasing the total solid contents in the milk used for cheese manufacture (Fox *et al.*, 2000; Walstra, 2000). It can be also noticed that the actual yield was about 6.1 % higher for cheese containing 6% DSM and 5.7% for cheese containing 2% MPC than control without fortifications. Our observations were in similar trend of Brito *et al.*, 2000; Neocleous *et al.* (2002) and Cunha *et al.* (2004) who added milk concentrates in Maribo, Minas Frescal and Cheddar cheeses.

Moisture content of fresh Mozzarella cheese fortified with DSM or MPC showed significant differences with different ratios of added material (Table, 2). Treatments with MPC exhibited significantly higher moisture content in resultant Mozzarella than that fortified with DSM. Control Mozzarella had the highest moisture content while treatment fortified with 6% DSM had the lowest. Generally, addition of DSM or MPC in cheese milk during manufacture of Mozzarella leads to decrease in moisture content of resultant cheeses. This decrease in moisture content of treatments could be related to the changes that occurred in protein ratios as well as the total solid contents in the base cheese milk. These changes will result a higher solid content in cheese curd, i.e. lower moisture. Neocleous *et al.* (2002); Cunha *et al.* (2004); Ur-Rehman and Farkye (2006) reported that moisture content of cheese decreased with increasing the concentration factor of cheese milk by microfiltration and ultrafiltration. During storage of Mozzarella at 5±2°C, the moisture content showed insignificant decrease in all treatments including control. Similar observations were reported by Ghosh and Singh (1992), Mostafa *et al.* (1996) and El-Batawy *et al.* (2004).

Ash contents in fortified Mozzarella with DSM or MPC presented in Table (2) confirmed that all fortified samples had significantly higher ash than that of control without fortification. Treatments with DSM possessed higher ash values than that of MPC. Among all fortified Mozzarella samples, treatment with added 6% DSM had the highest ash contents while that with 0.5% MPC had the lowest. Ash values in the treatments are correlated with ash contents in added materials (Table, 1). Ash contents showed insignificant increase in all samples during storage periods.

Fortifying cheese milk with DSM or MPC increased significantly the lactose contents in resultant Mozzarella (Table, 2). The value was proportionally to the level of added DSM or MPC. Lactose values were significantly higher in treatments with DSM than that of MPC being highest in treatment fortified with 6% DSM. On the other hand, MPC had lower lactose content compared to DSM, thus lactose ratio content in treatments with MPC was lower than that with DSM. Lactose gradually decreased in all treatments even the control (significant at $P \leq 0.05$) during storage of Mozzarella up to 4 weeks at 5±1°C. This decrease could be attributed to the growth and activity of microflora and/or enzymes activity in cheese curd. The findings are in agreement with El-Shibiny *et al.* (1998).

Values of pH presented in Table (2) indicated a slight decrease with adding DSM or MPC to Mozzarella cheese milk. Therefore, control treatment showed the highest pH value among all resultant cheeses. Lower values of pH in fortified treatments would be due to the higher non fat dry matter content (higher protein and mineral) which contributes as a part of natural acidity, thus decrease pH. The pH value significantly decreased in all treatments including control with prolonging the storage period. This could be due to the acidity development, which led to lower pH value in cheese sample. The rate of changes in pH value was slight faster in treatments with added MPC. This may be due to the slightly higher moisture in those treatments which may enhance the acidity developments. These findings are in the same trends of Mostafa *et al.*, (1996); Abd El-Hamid *et al.* (2001) and El-Batawy *et al.* (2004).

Cow Mozzarella cheese (control) contained the lowest total calcium content (TC), while Mozzarella treatment with adding 6% DSM had the highest (Table 3). Addition of DSM or MPC during manufacturing of Mozzarella cheese increased significantly ($P \leq 0.05$) the total calcium in resultant curd. The higher amounts of total calcium in Mozzarella treatments could be attributed to the higher amount of calcium in DSM or MPC added to cheese milk (Table, 1). These findings are in agreement with Ur-Rehman and Farkye (2006) who found an increase in calcium contents in cheese of milk standardized with dry milk protein concentrate. Treatments with MPC had slightly lower TC than that with DSM. This could be due to the method followed during processing of DSM and MPC since all amount of calcium retained in DSM while some of soluble calcium may released in permeate during MPC manufacture. During storage period, the total calcium content showed slight (non-significant) increase in all treatments including control. This increase could be related to the changes in cheese moisture and DM contents (El-Batawy *et al.*, 2004; Abd El-Hamid *et al.*, 2006; Awad *et al.*, 2007).

Total protein percentages of cow Mozzarella cheese fortified with DSM or MPC are presented in Table (3). All fortified treatments exhibited higher protein content than control cow Mozzarella. This is mainly due to that DSM or MPC contain higher percent of protein and therefore will increase the percentage in resultant cheese. The ratio of total protein in treatments of DSM was higher than that of MPC treatments. The higher protein in DSM treatments is mainly due to the higher ratio added than MPC (Table, 1). Storage of Mozzarella cheese resulted in a slight increase in total protein content which could be due to the moisture loss and therefore, higher dry matter and protein contents. Mostafa *et al.* (1996) and Abd El-Hamid *et al.* (2006) mentioned that total nitrogen gradually increased as time of storage advanced.

The data in Table (3) revealed that fortified Mozzarella cheeses from different treatments were characterized by significantly higher percent of soluble nitrogen (SN) than control, either fresh or along the storage period. These observations would be a result of higher SN content in added materials (DSM, MPC) than control without additives. Mozzarella treatments fortified with MPC showed higher SN content than that of DSM. As can be seen from the results, the percentage of SN was increased in treatments with increasing the level of both additives being the highest in treatment with 2% MPC. Values of SN showed a marked and significant increase during storage at 5±2°C in all treatments including control due to the protein breakdown induced by the additives and the higher moisture in the resultant cheese. These results are in agreement with those reported by Yun *et al.* (1993b) EL-Batawy *et al.* (2004), Abd El-Hamid *et al.* (2006); and Awad *et al.* (2007).

Total volatile fatty acids (TVFA) of Mozzarella treatments fortified with DSM or MPC increased with added materials proportionally to the ratio of addition (Fig. 2). The data also illustrated that TVFA values of treatments with DSM were higher than that of MPC. The higher TVFA in DSM treatments would be due to the higher concentration of dry matter (lower moisture) which may involve in release of volatile acids. It is evident from the data illustrated in Fig. 2 that the concentration of TVFA significantly increased with the progress of storage period in all treatments including control one. This could be due to the residual activity or reactivation of heat resistant lipases which may cause the fat hydrolysis (Mostafa *et al.*, 1996; Abd El-Hamid *et al.*, 2001).

Functional properties of Mozzarella cheese:

Meltability values of Mozzarella cheese from cow milk fortified with DSM or MPC (Table, 4) indicated significant differentces among all treatments. Addition of DSM or MPC in cheese milk had a clear effect on meltability values of Mozzarella treatments. The meltability values of resultant Mozzarella cheese decreased gradually with adding DSM in different ratios. Treatment with 6% DSM showed significantly the lowest meltability value than that of all other treatments. On the other hand, meltability improved by adding MPC into cheese milk up to 1% then decreased after that ratio but still as good as in control one. The changes in meltability values among treatments would be a function of several factors such as moisture, pH, calcium content and the nature of proteins in treated Mozzarella and/or casein micelle size modification (Tunick *et al.*, 1991; McMahon and Oberg, 1998 Metzger *et al.*, 2001 and Abd El-

Hamid *et al*., 2001). There was an improvement in melting properties of all cheeses during storage period. The increase in meltability values of stored samples could be related to the partial proteolysis and protein breakdown occurred in the cheese matrix. This could be also owing to the developments of acidity which increase the soluble calcium with partly removed as well as the progressive of cheese proteolysis. Changes that occurred in meltability values of the treatments during storage intervals were significant. The results were in accordance with Mostafa *et al.* (1996); Paduval & Mistry (1999); Abd-El-Hamid *et al.* (2001); Stevens & Shah (2002); El-Batawy *et al.* (2004); Zisu & Shah (2005) and Awad *et al*. (2007).

Mozzarella cheese treatments fortified with DSM or MPC showed significantly different stretchability values compared to Mozzarella control (Table, 4). The cheese stretchability increased with adding 2% DSM, but decreased after that with increasing the ratio added. On the other hand, Mozzarella cheese fortified with MPC exhibited higher stretchability values at 0.5 and 1% addition, then decreased after that at 2%. This means that the functional property improved by adding DSM up to 2% or MPC up to 1% into cheese milk. Improvements in stretchability could be attributed to the decrease of protein binding profile with improve in water functionality and protein relaxation in the cheese body (Anis and Ladkani, 1988). Stretchability values were increased in all Mozzarella samples with extending the storage period. This could be due to the reduction in concentration of intact para-casein and increased water binding capacity of the casein (Kindstedt and Guo, 1997). These findings are in agreement with Guinee *et al.* (2001); Abd-El-Hamid *et al.* (2001); Zisu and Shah (2005); Abd-El-Hamid *et al.* (2006) and Awad *et al.* (2007) who reported a marked increase in stretchability during the first 30 days of Mozzarella cheese ripening.

The values of penetration are inversely related to cheese firmness. Cow Mozzarella control had lower firmness than that of all fortified treatments either with DSM or MPC (Table, 4). The lower firmness in cow Mozzarella control could be related to the higher moisture content. Bhaskarācharya and Shah (1999) found that, the hardness of Mozzarella cheese decreased with the increase in moisture content. Generally, addition of DSM or MPC significantly increased the firmness of treated cheeses compared to Mozzarella control. Treatment with 6% DSM and 2% MPC exhibited higher firmness values than that of other treatments. Penetration values significantly increased which mean a decrease in cheese firmness with extending the storage period up to 4 weeks. The changes in firmness values of cheese during storage could be related to the protein network breakdown. Kanawjia *et al.* (1996); Abd-El-Rafee *et al.* (1998) and Abd-El-Hamid *et al.* (2001) reported that the hardness of Mozzarella cheese decreased during storage at refrigeration temperature.

Fortifying cow milk with DSM or MPC lowered significantly the oil separation of Mozzarella cheese (Table, 4). The additives were more effective in this issue and cheese fat became more emulsified when MPC was added to milk before coagulation. Oil separation index of treated cheese exhibited lower values with the increase of ratio added. This could be due to the effect of added materials as emulsifying agent since it increase the protein content, which may help to retain moisture, fat, and other milk constituents and therefore, create a more emulsification conditions in resultant cheese. The differences in oil index values among treatments could be also due to the different moisture retention in the curd through water absorption. Mozzarella treatments with MPC were more effective and exhibited the lowest value of free oil compared to treatments with DSM or control. The oil separation percentage was gradually and significantly increased as the storage period progressed in all treatments including controls. The increase in oil separation of Mozzarella cheese with extending the storage period could be due to the breakdown of casein matrix through proteolysis process which makes the fat to be release easier. The results are in line with the finding of Yun *et al.* (1993a); Abd-El-Hamid *et al.* (2001) and Awad *et al.* (2007).

Table (1): Chemical composition (as %) of dried skim milk (DSM), milk protein concentrate powder (MPC) and fresh cow milk used in manufacture of Mozzarella cheese

Product	Moisture	Fat	Total protein	Soluble nitrogen	Lactose	Ash	Total calcium
DSM	3.87	1.48	35.377	1.859	50.91	8.14	1.832
MPC	3.96	1.82	80.515	4.475	5.87	7.71	1.519
Cow milk	87.83	3.18	3.452	0.184	4.61	0.79	0.129

Table (2): Physicochemical properties of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC)

Storage periods	Control	DSM %			MPC %		
		2	4	6	0.5	1	2
Moisture %							
Fresh	53.75^{A}	52.59^{AB}	49.83^{CD}	47.45^{D}	53.29^{A}	52.14^{AB}	51.78^{B}
2 weeks	53.55^{A}	52.41^{AB}	49.53^{CD}	47.32^{D}	53.07^{A}	52.00^{AB}	51.61^{B}
4 weeks	53.40^{A}	52.36^{AB}	49.41^{CD}	47.17^{D}	52.90^{A}	51.82^{AB}	51.48^{B}
Ash %							
Fresh	3.17^{C}	3.85^{BC}	4.61^{AB}	5.14^{A}	3.61^{C}	4.02^{BC}	4.67^{AB}
2 weeks	3.29^{C}	3.94^{BC}	4.70^{AB}	5.21^{A}	3.71^{C}	4.11^{BC}	4.72^{AB}
4 weeks	3.46^{C}	4.04^{BC}	4.81^{AB}	5.30^{A}	3.88^{C}	4.22^{BC}	4.81^{AB}
Lactose %							
Fresh	1.55^{Ca}	1.98^{BCa}	2.54^{ABa}	3.39^{Aa}	1.64^{Ca}	1.73^{BCa}	2.09^{BCa}
2 weeks	1.38^{Cb}	1.64^{BCb}	2.08^{ABb}	2.94^{Ab}	1.42^{Cb}	1.50^{BCb}	1.79^{BCb}
4 weeks	0.98^{Cc}	1.52^{BCc}	1.88^{ABc}	2.11^{Ac}	1.14^{Cc}	1.33^{BCc}	1.58^{BCc}
pH value							
Fresh	5.58^{Aa}	5.54^{Aa}	5.51^{ABa}	5.46^{Ba}	5.56^{Aa}	5.54^{Aa}	5.51^{ABa}
2 weeks	5.51^{Aab}	5.48^{Aab}	5.42^{ABab}	5.35^{Bab}	5.50^{Aab}	5.47^{Aab}	5.45^{ABab}
4 weeks	5.45^{Ab}	5.40^{Ab}	5.32^{ABb}	5.27^{Bb}	5.43^{Ab}	5.38^{Ab}	5.35^{ABb}

Table (3): Total calcium, total protein, and soluble nitrogen (SN) of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC)

Storage periods	Control	DSM %			MPC %		
		2	4	6	0.5	1	2
Total calcium %							
Fresh	0.603^{Eb}	0.638^{BCb}	0.664^{ABb}	0.707^{Ab}	0.619^{DEb}	0.627^{CDb}	0.639$^{BCb\,BCb}$
2 weeks	0.623^{Eab}	0.649^{BCab}	0.680^{ABab}	0.722^{Aab}	0.627^{DEab}	0.641^{CDab}	0.648^{BCab}
4 weeks	0.648^{Ea}	0.666^{BCa}	0.705^{ABa}	0.748^{Aa}	0.642^{DEa}	0.655^{CDa}	0.662^{BCa}
Total protein %							
Fresh	17.83^{D}	19.35^{BC}	21.16^{AB}	23.40^{A}	18.33^{CD}	20.17^{AB}	22.85^{A}
2 weeks	17.91^{D}	19.44^{BC}	21.25^{AB}	23.50^{A}	18.47^{CD}	20.25^{AB}	23.10^{A}
4 weeks	18.40^{D}	19.61$^{BC\,BC}$	21.60^{AB}	23.93^{A}	18.65^{CD}	20.44^{AB}	- 23.66^{A}
Soluble nitrogen %							
Fresh	0.256^{Cc}	0.282^{ABc}	0.326^{Ac}	0.344^{Ac}	0.271^{BCc}	0.295^{ABc}	0.322^{ABc}
2 weeks	0.277^{Cb}	0.291^{ABb}	0.341^{Ab}	0.355^{Ab}	0.284^{BCb}	0.312^{ABb}	0.334^{ABb}
4 weeks	0.314^{Ca}	0.307^{ABa}	0.353^{Aa}	0.371^{Aa}	0.296^{BCa}	0.330^{ABa}	0.351^{ABa}

A,B,C: Means with same letter among treatments in the same storage period are not significantly different.
a,b,c: Means with same letter for same treatment during storage periods are not significantly different

Table (4): Functional properties of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC)

Storage periods	Control	DSM %			MPC %		
		2	4	6	0.5	1	2
Meltability %							
Fresh	86.5^{ABc}	86.3^{ABc}	85.4^{BCc}	74.6^{Cc}	88.2^{ABc}	90.6^{Ac}	86.7^{ABc}
2 weeks	101.2^{ABb}	104.5^{ABb}	$100.9^{BCb\,BC}$	90.7^{Cb}	103.2^{ABb}	110.5^{Ab}	102.8^{ABb}
4 weeks	124.6^{ABa}	130.1^{ABa}	126.3^{BCa}	109.8^{Ca}	127.4^{ABa}	134.6^{Aa}	129.4^{ABa}
Stretchability (mm)							
Fresh	9.2^{ABc}	9.9^{Ac}	9.1^{BCc}	8.5^{Bc}	9.6^{ABc}	10.2^{Ac}	9.2^{ABc}
2 weeks	12.6^{ABb}	14.1^{Ab}	12.3^{BCb}	10.6^{Bb}	14.0^{ABb}	16.7^{Ab}	13.9^{ABb}
4 weeks	19.8^{ABa}	20.2^{Aa}	18.9^{BCa}	15.4^{Ba}	19.9^{ABa}	24.1^{Aa}	19.1^{ABa}
Penetration (mm)							
Fresh	7.16^{Ac}	6.43^{ABc}	6.07^{BCc}	5.58^{Dc}	6.63^{ABc}	6.13^{BCc}	5.88^{CDc}
2 weeks	10.11^{Ab}	8.95^{ABb}	7.92^{BCb}	7.01^{Db}	9.44^{ABb}	9.96^{BCb}	7.27^{CDb}
4 weeks	15.62^{Aa}	12.61^{ABa}	10.94^{BCa}	$8.97^{D\,a}$	15.71^{ABa}	$14.99^{BCa\,a}$	11.86^{CDa}
Oil separation %							
Fresh	40.11^{Ab}	37.41^{ABb}	30.51^{BCb}	24.65^{CDb}	35.44^{ABb}	27.55^{CDb}	20.43^{Db}
2 weeks	49.14^{Aab}	39.87^{ABab}	$34.41^{BCab\,BCc}$	29.75^{CDab}	39.10^{ABab}	29.97^{CDab}	24.44^{Dab}
4 weeks	55.36^{Aa}	46.12^{ABa}	40.67^{BCa}	38.67^{CDa}	43.24^{ABa}	35.16^{CDa}	29.86^{Da}

A,B,C: Means with same letter among treatments in the same storage period are not significantly different.
a,b,c: Means with same letter for same treatment during storage periods are not significantly different

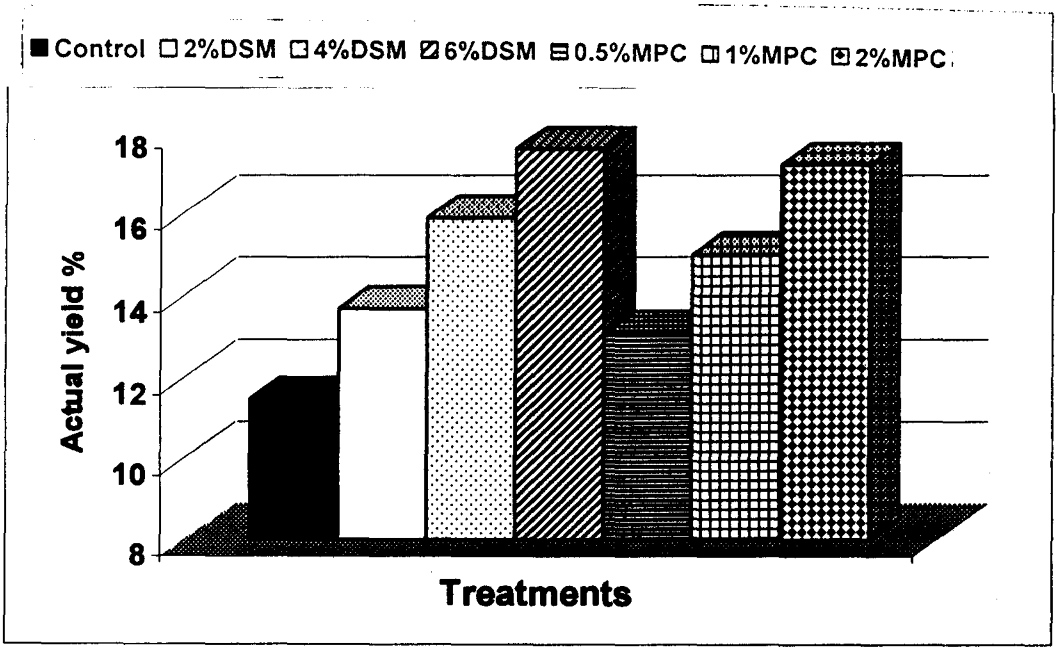

Fig. (1): Actual yield (%) of Mozzarella cheese from milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC).

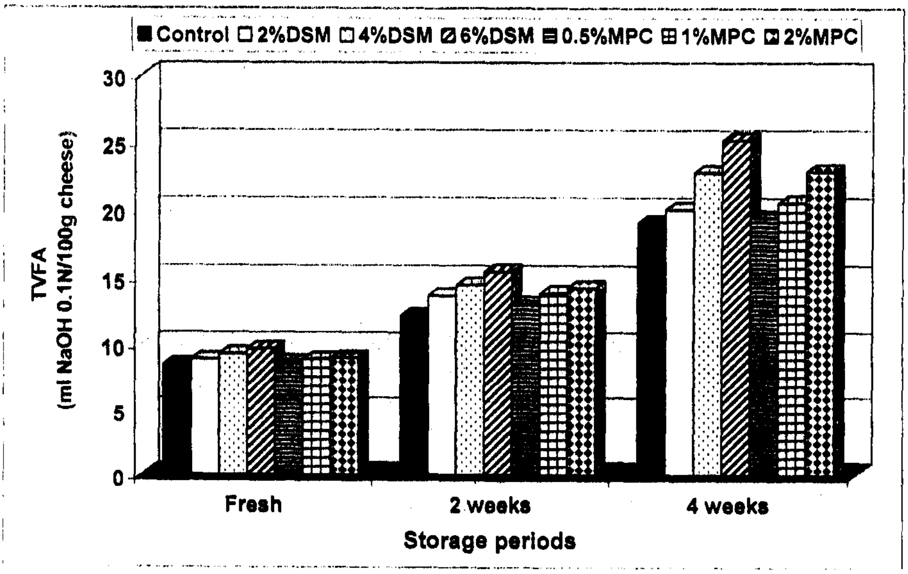

Fig. (2): Total volatile fatty acids (TVFA) of Mozzarella cheese from milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC), fresh and during storage.

Texture and microstructure of Mozzarella cheese:

Texture characteristics of Mozzarella cheese fortified with DSM or MPC (Table, 5) stated that the hardness increased in all fortified treatments being relatively to the ratio added. Treatments with DSM were harder than that of MPC which were closer to control. Mozzarella cheese made of cow milk fortified with DSM or MPC became more gummy and chewy proportionally to the ratio added. This mean that the energy required to disintegrate and masticate the cheese to a state ready for swallowing was increased. On the other hand, springiness value of Mozzarella decreased with adding DSM or MPC into cheese milk which mean that the height that the cheese able to recover was reduced. These findings would be confirmed from the data obtained of cheese stretchability values since it was decreased with added materials. The strength of the internal bonds making up the body of resultant cheese, which mean cohesiveness, was also increased by adding DSM or MPC to the cheese milk. This of course, is due to the higher total solids of cheese milk through the ratio of added materials. The results agree with Stevens & Shah (2002) and Zisu & Shah (2005) who mentioned that cheeses with low moisture and fat exhibited greatest hardness, gumminess and chewiness.

The microstructure of Mozzarella cheese made of cow milk fortified with DSM or MPC is illustrated in Fig. (3). The cow control (CC) showed numerous small vacuoles, less dense protein matrix and more open structure, while fortified treatments had considerably fewer vacuoles, more dense protein matrix, with rough and fewer protein strands and open poorly fused network of paracasein particles in the curd. Treatment with 4% DSM added to cheese milk showed dense protein strands and close structure which was interspersed with large and small voids. Addition of DSM led to decrease in the water distributions and therefore lower serum channels which would allow retention of less serum. When such small serum channels are distributed throughout the casein matrix, the cheese became harder and less pliable because of the decrease in moisture and impeded coalescence of protein strands. McMahon *et al.* (2005) mentioned that microstructure of cheese with high level of calcium had an increase in protein folds and serum pockets while that with low calcium content had more homogeneous structure. Protein matrix in low calcium cheese appeared less dense indicating that the proteins were more hydrated but in high calcium cheeses the protein appeared more aggregated and had larger spaces between protein aggregates. Treatment with

1% MPC in cheese milk showed an end product with fibrous structure and spongy protein matrix close to that of cow Mozzarella (CC) with more elongated protein network and distributed serum in lower size, but the structure was homogeneous. It can be also seen from the micrograph of MPC that the fibers of casein are more elongated, showing good protein strands with lower fusion of paracasein particles. Better protein strands distributed in the cheese matrix appeared in treatment of MPC could be attributed to the effect of adding milk protein concentrate powder to the cheese milk which may contribute in giving the final structure. Variations in Mozzarella microstructure are generally associated with the differences in manufacture conditions such as moisture, fat, salt and protein contents as well as pH, calcium, calcium to total protein ratio (Kiely *et al.* 1992).

Sensory quality attributes:

Quality attributes of fortified Mozzarella cheese with DSM or MPC gained close points for flavour as that of cow control (Table, 6). Addition of DSM and MPC at lower ratios slightly improved the flavour of treated cheeses than control. Increasing the ratio added of DSM up to 6% produced Mozzarella with significantly lower flavour score than all other treatments. The scores of body and texture of treated cheeses were significantly affected by the type and ratio of added materials. Adding DSM or MPC to cheese cow milk improved the body and texture in resultant Mozzarella being highly improvements with MPC at ratio 1%. Incorporating MPC or DSM into cheese milk at lower ratio produced somewhat slightly harder body and smooth texture being better in treatments of MPC showing the best with 1% addition. Fortified Mozzarella cheese showed better appearance than control except at highest ratio of both added materials. As can be seen from Table (6), the use of DSM up to 4% or MPC up to 1% enhanced the total quality and acceptability of Mozzarella cheese. Treatments with MPC showed better sensory attributes and that with 1% MPC in cheese milk gained the highest score and was even better than cow Mozzarella control, while Mozzarella of 6% DSM scored the lowest. There was no significant difference among most of treatments and cow Mozzarella cheese except at higher ratios of additions. The sensory quality of all cheeses was continually and gradually improved during storage period reaching the highest score at the end of storage period (4 weeks) at 5±2°C. These improvements during storage may be attributed to the partial proteolysis of cheese protein leading to more soft body & texture as well as flavour enhancement. The results are coinciding with Abd-El-Hamid *et al.* (2001); El-Batawy *et al.* (2004) and Awad *et al.* (2007).

Table (5): Texture parameters of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC)

Texture profile	Control	DSM %			MPC %		
		2	4	6	0.5	1	2
Hardness (N)	9.92^{C}	10.72^{BC}	11.18^{AB}	12.01^{A}	9.88^{C}	10.14^{BC}	11.04^{AB}
Cohesiveness (-)	0.541^{B}	0.549^{AB}	0.557^{A}	0.567^{A}	0.540^{B}	0.545^{AB}	0.551^{A}
Gumminess (N) (cm)	5.36^{C}	5.88^{AB}	6.23^{A}	6.81^{A}	5.34^{C}	5.53^{BC}	6.08^{A}
Springiness (cm)	11.06^{A}	10.79^{AB}	10.29^{A}	9.62^{B}	11.23^{A}	11.12^{A}	10.42^{AB}
Chewiness (N/cm)	59.28^{C}	63.44^{AB}	64.11^{A}	65.51^{A}	59.97^{C}	61.38^{BC}	63.35^{AB}

A,B,C: Means with same letter among treatments are not significantly different.

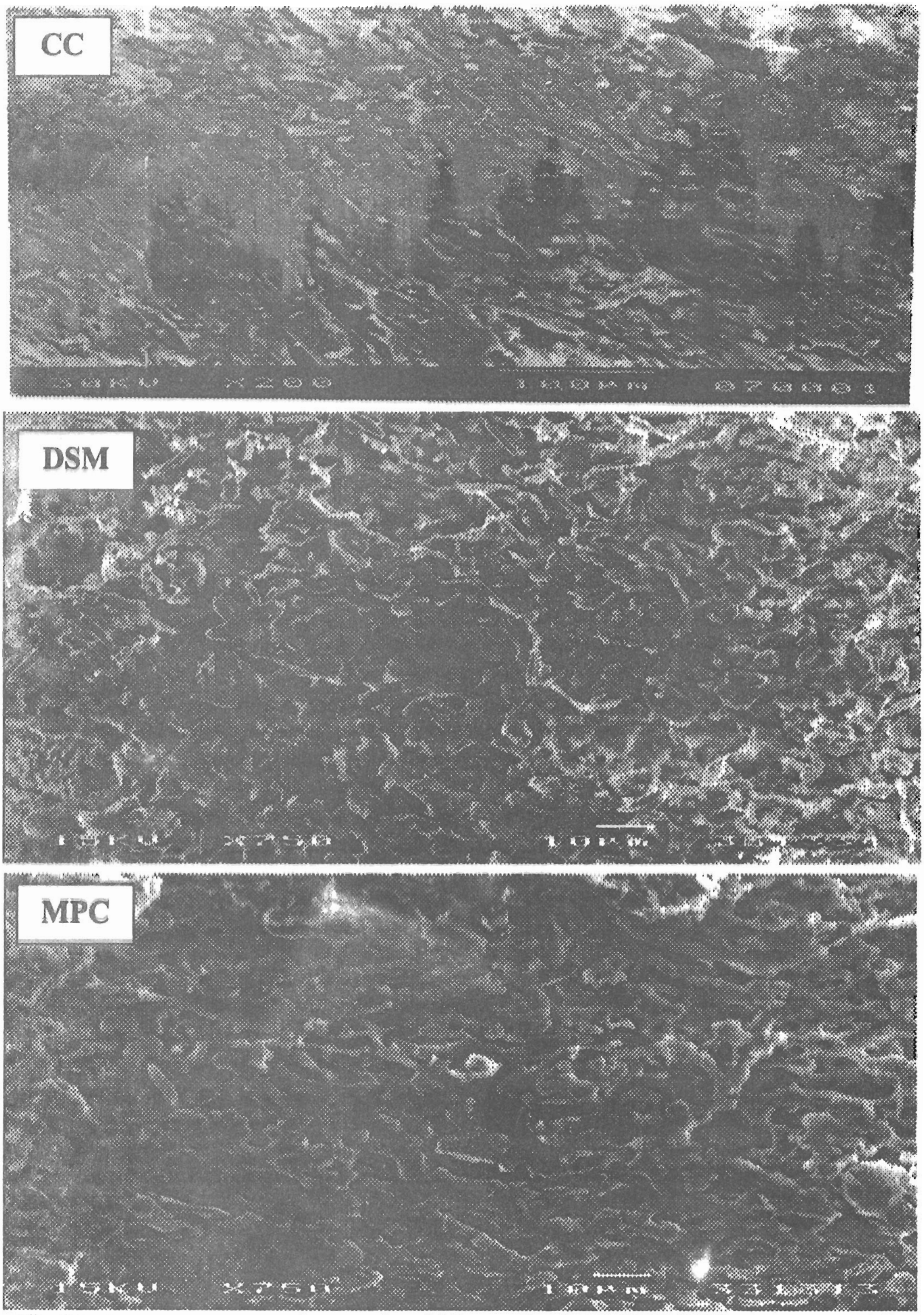

Fig (3): Scanning electron micrographs of Mozzarella cheese from cow milk control (CC), milk fortified with 4% dried skim milk (DSM) or milk fortified with 1% dry milk protein concentrate (MPC). White area: protein matrix, black areas: fat and serum pockets

Table (6): Sensory quality attributes of Mozzarella cheese from cow milk fortified with dried skim milk (DSM) or milk protein concentrate powder (MPC)

Character assessed	Storage periods	Control	DSM %			MPC %		
			2	4	6	0.5	1	2
Flavour (50)	Fresh	45.8^{ABb}	46.1^{Ab}	45.9^{ABb}	44.4^{Cb}	46.3^{Ab}	46.4^{Ab}	45.1^{BCb}
	2 weeks	46.2^{ABab}	46.4^{Aab}	46.2^{ABab}	44.6^{Cab}	46.9^{Aab}	47.2^{Aab}	45.5^{BCab}
	4 weeks	47.1^{Aa}	46.9^{ABa}	46.6^{ABa}	45.1^{Ca}	47.7^{Aa}	48.1^{Aa}	46.2^{BCa}
Body & texture (35)	Fresh	31.5^{ABb}	31.9^{Ab}	31.2^{ABb}	30.9^{Cb}	31.9^{Ab}	32.3^{Ab}	31.1^{BCb}
	2 weeks	31.9^{ABab}	32.2^{Aab}	32.8^{Aab}	31.3^{Bab}	32.3^{Aab}	33.1^{Aab}	31.7^{ABab}
	4 weeks	32.7^{ABa}	32.8^{ABa}	33.6^{Aa}	32.0^{Ba}	33.1^{ABa}	34.0^{Aa}	32.8^{ABa}
Appearance (15)	Fresh	13.1^{ABb}	13.2^{Ab}	13.4^{Ab}	12.8^{Bb}	13.2^{Ab}	13.5^{Ab}	12.9^{Bb}
	2 weeks	13.5^{ABab}	13.8^{Aab}	13.6^{ABab}	13.2^{Bab}	13.6^{ABab}	14.0^{Aab}	13.2^{Bab}
	4 weeks	14.0^{ABa}	14.1^{Aa}	13.9^{ABa}	13.5^{Ba}	14.3^{Aa}	14.6^{Aa}	13.9^{ABa}
Total (100)	Fresh	90.4^{ABb}	91.2^{Ab}	90.5^{ABb}	88.1^{Cb}	91.4^{Ab}	92.2^{Ab}	89.1^{BCb}
	2 weeks	91.6^{ABab}	92.4^{ABab}	92.6^{ABab}	89.4^{Cab}	92.8^{ABab}	94.3^{Aab}	90.4^{BCab}
	4 weeks	93.8^{ABa}	93.8^{ABa}	94.1^{Aa}	90.6^{Ca}	95.1^{Aa}	96.7^{Aa}	92.9^{Ba}

A,B,C: Means with same letter among treatments in the same storage period are not significantly different.
a,b,c: Means with same letter for same treatment during storage periods are not significantly different

CONCLUSION

It could be generally concluded from the obtained results that fortifying cow milk with DSM or MPC has significantly improved the yield of Mozzarella cheese. The use of DSM or MPC increased Mozzarella cheese yield by 53% (6% DSM) or 49.6% (2% MPC) relative to control treatment. Chemical properties of resultant Mozzarella has been affected by the type and ratio of added material. The functional properties and sensory attributes of all treatments were also affected being related to the fortification material and its ratio. Adding DSM up to 4% or MPC up to 1% into cheese milk produced Mozzarella cheese without any significant difference than control one. Adding MPC to cow milk in Mozzarella manufacture at lower ratio enhanced the functional properties and sensory attributes of produced cheese. However, using MPC in fortifying Mozzarella cheese milk was more effective and produced Mozzarella with much better functional quality compared to treatments with DSM.

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تحسين التصافى وجودة جبن الموزاريلا الناتج من تدعيم اللبن البقرى باللبن الفرز المجفف أو مركز بروتينات اللبن

رزق عزب عواد

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تم تدعيم اللبن البقرى المستخدم فى صناعة الجبن الموزاريلا بإضافة اللبن المجفف الفرز بنسب ٢، ٤، ٦% أو مركز بروتين اللبن المجفف بنسب ٠,٥، ١، ٢% مع المقارنه بعينه بدون إضافات. تم حساب التصافى الناتجه من كل معامله وكذلك أجرى تحليل الجبن الناتجه وهى طازجه وأثناء التخزين من حيث خواص الفيزوكيماويه والوظيفيه وكذلك خواص الجوده الحسيه. كما تم تقدير خواص التركيب وكذلك التركيب الدقيق بالميكروسكوب الإلكترونى فى العينات الطازجه. وأظهرت النتائج تحسن معنوى واضح فى التصافى مع الإضافات السابقه بدرجه تتناسب مع النسبة المضافه. أدت إضافة اللبن المجفف أو مركز بروتين اللبن فى صناعة الجبن الموزاريلا إلى إنخفاض فى نسبة الرطوبه ورقم الحموضه (pH) بينما زادت قيم كل من اللاكتوز، الكالسيوم الكلى، ونسبة البروتين الكلى والذائب وكذلك الأحماض الدهنيه الطياره. لم تتأثر الخواص الوظيفيه معنويا مع النسب المنخفضه من الإضافات ولكن تأثرت فقط بالنسبه المرتفعه خصوصا من اللبن المجفف وكانت الخواص الوظيفيه للجبن المضاف لها مركز بروتين اللبن هى الأفضل. حدث تغير فى خواص التركيب بدرجات مختلفه حيث أدت الإضافات السابقه إلى زياده الصلابه والصموغيه واللدانه بينما إنخفضت المرونه فى العينات وأظهر التركيب الدقيق زياده فى كثافة جزيئات البروتين مع تركيب مقفول وكانت العينات المصنعه بإضافة مركز بروتين اللبن الأفضل والأقرب إلى عينة المقارنه. كانت كل العينات مقبوله حسيا وأظهرت المصنعه بإضافة اللبن المجفف جوده أقل من المصنعه بإضافة مركز بروتين اللبن وكانت أفضل عينه تلك المضاف لها ١% من مركز البروتين . أثناء التخزين حدثت زياده معنويه فى قيم النتروجين الذائب والأحماض الدهنيه الطياره والإنصهار والمطاطيه وفصل الدهن بينما إنخفضت الرطوبه واللاكتوز والصلابة. وتوصي الدراسه بإضافة مركز بروتين اللبن المجفف لتدعيم اللبن البقرى فى صناعة الجبن الموزاريلا بنسبة ١% حيث أدت إلى زيادة التصافي دون أى تأثير على الخواص الوظيفيه او الحسيه.