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Research Article

Physicochemical Properties and Functionality of the Novel Instant Mozzarella Cheese Powder

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ABSTRACT

The aim is to evaluate the physicochemical and functional properties of the novel instant Mozzarella cheese powder, and to identify the suitable casein chemical form and ratio to palm oil to achieve particular desirable functional attributes in the final cheese powder. Casein of cow's milk was modified by renneting and/or carbonation and mixed with palm oil in specific conditions to form high and low fat slurries which were spray dried and mixed with Nano-sized stabilizing salts. The results indicated that casein form had no effect on a_w, tapped density, flowability and cohesiveness of powders. The carbonation led to increase the values of protein, lactose, sodium, pH, loose density and lightness. While renneting led to increase moisture, ash, calcium, reconstitution time, particle size, stretch extension, Tex, yellowness, post melt hardness and gumminess. The mixed casein forms powder was associated with the highest span and tenacity. The high fat powders were characterized with increased aw, reconstitution time, particle size and all stretchability indicators, as well as decreased lactose, minerals, pH, cohesiveness and flowability.

Keywords: Stretch profile; Flowability; Cheese supply

INTRODUCTION

Mozzarella cheese is one of the most popular versatile cheese varieties in the world because of its primary use on Pizzas, related bakeries and fast foods [1]. The demand of Mozzarella cheeses is growing as the global demand for Pizza and other foods has increasing manifold. Because of the expensive cost of the conventionally made Mozzarella cheese, the analogue one may form a promising chance to substitute a conventional product and offer the same or better nutritional and functional characteristics with lower cost [2]. Cheese analogues have better storage stability with regard to their functional properties such as shred fusion, stretch, fat leakage etc., to give consistent product throughout its storage life [3]. Nevertheless, both the conventional and analogue Mozzarella cheeses are suffering from their very limited shelf life; The conventional Mozzarella has a shelf life of 4 weeks at refrigerated temperature and a year at -18°C, while the Mozzarella cheese analogue has a storage life expectancy of not more than 3 days at the refrigerator temperature because of its starch content which undergoes the phenomenon of starch retrogradation which is defined as the recrystallization of the starch polymers amylose and amylopectin upon cooling of starch containing systems [4], and that could increase the cheese hardness leading to damaging its meltability and related attributes, so freezing is a must to keep the functional properties of Mozzarella cheese analogues. On the other hand several studies indicated sever adverse effects on those cheeses rheological and functional properties due to freezing such as the formation of pores, ruptures and clumps of bacteria in the cheese protein matrix [5]. Moreover, frozen cheese takes about 30 minutes to thaw before application on Pizza and cannot be frozen again for hygienic reasons. Extending the shelf life of Mozzarella cheeses using preservatives was constrained by the codex standards, moreover some of the chemical preservatives had negative effects on the functionality of those cheeses besides the health harms; [6] Mizuno reported that the preservative liquid caused defects in Mozzarella cheese like affecting its hardness and forming a skin on the surface of cheese. Whole over the world, Mozzarella cheese contributes with a significant portion in export, making the extension of shelf life important. For that in view, the present study was conducted to evaluate the physicochemical and functional properties of the novel instant Mozzarella cheese powder, and to identify the suitable casein chemical form and ratio to palm oil

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for achieve particular desirable functional attributes in the final cheese powder. The novel powder product was designed for the rapid preparation at homes and restaurants by adding a certain amount of the dry product to an equal amount of water in a cooking pot and heating slowly on a simmer with stirring for five min., after that the Mozzarella cheese would be ready to be poured directly on Pizza or for forming, cooling then shredding to obtain Mozzarella cheese similar to the common market one. The low fat Mozzarella cheese could be made through this manner and poured after preparation (in the melted form) on the baked Pizza base to avoid the breakdown defect which occurs because of moisture loss from the low fat cheese inside oven through Pizza baking [7]. This product could be offered in the markets requiring lower size during presentation, storing and transportation with no needs to fridges or freezers, besides its role in extending the supply of the natural cheese.

MATERIALS AND METHODS

Materials

Fresh skimmed cow's milk was obtained from Lamar farm, Kilo 75, El Nasr Canal, Alexandria-Agriculture Company, An Nubariyah, Al Buhayrah, Egypt, (TS 9.55 ± 1.02%, 0.2 ± 0.11% fat, 3.44 ± 0.12% protein and pH 6.7±0.1). Dried microbial rennet was obtained from MAYSA GIDA San ve Tic. A.S., Tuzla Kimya Sanayicileri Organize Sanayi Bolgesi Melek Aras Bulvari No: 54 TUZLA, Istanbul, 34956, Turkey. Food grade L-lactic acids was obtained from BBCA Glactic (B&G) Co.,Ltd, Road, Bengbu, Anhui,China. Anhydrous citric acid (99% purity) and popular pure sodium bicarbonate (80-100 mesh) were obtained from Guangzhou Rikewei Chemical Co., Ltd., China. Tri-sodium citrate dihydrate was obtained from Qualigens Fine Chemicals, Mumbai, India. Sodium chloride was obtained from El-Nasr for Salt Production Co. Egypt. Maltodextrin (12 DF, 5.89% moisture and 0.4873% ash) was obtained from Henan Boom Gelatin Co., Ltd., China. Food grade palm oil was obtained from United oil processing and packaging S.A.E., 10th of Ramadan, Sharkeya, Egypt.

Manufacturing procedure of Instant Mozzarella cheese powders

Skimmed cow's milk was heat treated at 72°C for 15 sec, cooled rapidly to 30°C and divided into two portions. The first portion was directed for the making of the carbonated casein slurry as a diluted lactic acid solution was added gradually to precipitate casein at pH 4. After curdling the temperature was raised to 45°C and curd was separated from whey, then the curd was washed twice with water at the same temperature and pH. The drained curd was treated by 5% sodium bicarbonate solution up to reaching a final pH of 7 at 60°C. While rennet was added to the second portion of skimmed cow's milk at a rate of 1.5 - g/100 kg milk (the powdered rennet was diluted 40 times in d.H_2O prior addition) to make rennet casein slurry. Curd was allowed to set in 20 min, cut, separated from whey and washed twice with 60°C neutral water. The total solids of the curd were adjusted by water to 25%, then a mixture was formed from equal portions of each slurry. Palm oil was added to the three slurries to form 1:1 and 2:1 ratios of protein to fat, and mixed at 100 rpm for 10 min., maltodextrein was added at a rate of 0.5% to each formula during mixing. The homogeneous mixtures were then spray dried in SMST lab model spray dryer, designed by SM Scientech Pvt. Ltd., Calcutta, India. The conditions of drying were adjusted to inlet/outlet air temperature: 164-205°C/ 85-110°C, air pressure: 2.2-3 kg/cm^2, slurry total solids 30-35% and flow rate 20–40%. The resultant powders were collected from an acrylic cyclone and mixed with Nanoparticles of sodium chloride, emulsifying salts and citric acid at rates of 3, 5 and 0.6% respectively. It was packed in Nitrogen/ Carbon dioxide gas pillow bags and stored at the room temperature.

Analytical methods

Dry matter, fat, total nitrogen sodium chloride and ash contents were determined according to AOAC [8]. Lactose contents were determined according to Lawrence [9]. Sodium and calcium contents were determined using flame photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) as described by Kirk and Sawyer [10]. pH was measured using a 315i/SET pH-meter with a Sentix 42 electrode (WTW) after a 10-g sample was dissolved in 100 mL of distilled water, standard buffer solutions (pH 4.01 and 7.01; WTW) were used for calibration. Reconstitution time was measured using a stop watch calculating the time in seconds needed to a 100 g of powders to reach the viscous lumps free well known stretchable paste of Mozzarella cheese upon reconstitution in 100 g water at 80°C with the applying of normal hand stirring and maintaining the temperature at 80 ± 5°C. Water activity was determined by Novasina LabTouch-a_w apparatus (Novasina AG, Lachen, Switzerland) after calibration with Salt-T relative humidity standards. Loose density was measured through weighing a 100 mL standard cylinder filled with the powder sample carefully, leveled without compacting, till an established level, and expressed with the follows:

Loose density=Powder weight (g)/powder volume (cm^3).

The tapped density was measured on the cylinder containing the sample that was gently tapped on a table top for at least 10 min., and in any case until negligible difference in volume between succeeding measurements was observed. The new volume obtained after tapping was read on the graduated cylinder and the density is expressed as follows: Tapped density=powder weight (g)/volume of tapped powder (cm^3). Flowability and cohesiveness were expressed in terms of Carr's index (CI), also called compressibility index, and Hausner ratio (HR), respectively, using the following formulas of Reddy [11]:

CI = 100 × (Tapped density - Loose density)/Tapped density; HR = Tapped density/Loose density.

The analyses were performed in triplicate. For particle size evaluation, the method of Ilari and Mekkaoui [12] was followed as the dry method was applied in a laser diffraction particle size analyzer (Mastersizer 2000; Malvern Instruments Ltd., Worcestershire, UK) fitted with a Scirocco 2000 dry powder feeder unit. The mean values of the particle size measured in micron were expressed as: D (4,3) which represents the volume weighted mean, and D (3,2) which represents surface weighted

mean, as well as D10, D50 and D90 which represent the size of the sample lying below 10, 50 and 90% of the entire distribution, respectively. Size dispersion was evaluated using the span index (SI), according to the formula; SI=(D90-D10)/D50. Post melt hardness and gumminess were measured after reconstituting the cheese powders by CT3 Brookfeild-Texture analyzer using computer interface software (Texturepro CT V1.2 Build 9) according to Nishinari [13]. A custom made spindle of 150 mm length and 1.5 mm diameter was attached to Lloyd LR10 K plus extensometer (10 kN Universal Materials Testing Machine) to stretch 50 g of each reconstituted sample at a rate of 300 mm/min. The force exerted by the cheese on the spindle was recorded along with the instantaneous distance of load cell movement. Nexygen Plus software was used to collect data such as extension at which the strands broke, peak load before breaking and break point during the stretch tests. The weight of a 100 mm cheese strand (cut from the middle of the stretched strand) was taken using an analytical balance and compared among the tested cheese samples. Colorimetric characteristics were measured using a Minolta Chroma Meter CR-300; Minolta Corporation, Ramsey, New Jersey, USA), cheese powder and reconstituted samples were placed as a uniform 25-mm layer on a 50-mm diameter petri dish and analyzed for color. Before measurements, the chroma meter was calibrated with a white reference tile according to Francis [14]. The L, a, and b values for the samples, which correspond to whiteness, red-green and blue-yellow were measured in cheese powders before reconstitution and immediately after reconstitution in triplicate.

RESULTS AND DISCUSSION

Physicochemical properties of the instant Mozzarella cheese powders

Data given in Table 1 revealed that, all factors studied had led to significant differences in all determined criteria. The instant Mozzarella cheese powders based on the form of rennet casein obtained higher moisture content than those based on the carbonated casein, while the powders containing a mixture of the two casein forms had an intermediated moisture levels. That could be ascribed to the shrinkage and the decrease in Donnan pressure occurred to casein after treating the curd by the 50% sodium bicarbonate solution during the carbonated casein making [15].

Table 1: Ls means values for casein form, casein to fat ratio in the drying slurry and casein form x casein to fat ratio in the drying slurry on the physicochemical properties of the instant Mozzarella cheese powders.

Source of variation	Moisture (%)	Protein as TNx6.38 (%)	Fat (%)	Ash (%)	Lactose (%)	Sodium (%)	Calcium (%)	pH	Reconstitution time at 80°C (Sec.)	aw
Casein Form (CF)										
Rennet Casein (RC)	4.35^{a}	46.64^{c}	30.57^{aa}	12.64^{a}	2.04^{c}	2.172^{c}	1.431^{a}	6.32^{c}	201.66^{a}	0.321^{a}
Carbonated Casein (CC)	3.28^{c}	50.97^{a}	28.72^{b}	10.43^{c}	2.33^{a}	2.895^{a}	0.069^{c}	6.46^{a}	160.83^{b}	0.344^{a}
Mixture of the two forms (MF)	4.07^{b}	48.96^{b}	30.32^{a}	11.77^{b}	2.13^{b}	2.530^{b}	0.755^{b}	6.44^{b}	138.00^{c}	0.285^{a}
P value	<0030.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1854
Casein to fat ratio in the drying slurry (CFR)										
1:01	4.12^{a}	39.94^{b}	40.01^{a}	10.75^{b}	2.08^{b}	2.471^{b}	0.611^{b}	6.36^{b}	189.88^{a}	0.352^{a}
2:01	3.68^{b}	57.77^{a}	19.72^{b}	12.48^{a}	2.26^{a}	2.594^{a}	0.893^{a}	6.45^{a}	143.77^{b}	0.281^{b}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0141
CF × CTR										
RC × 1:1	4.51	37.28	41.17	12.05	1.94	2.175	1.158	6.28	237.66	0.353
RC × 2:1	4.19	56	19.96	13.24	2.14	2.17	1.705	6.37	165.66	0.288
CC × 1:1	3.55	42.56	38.42	10.09	2.26	2.775	0.061	6.41	180.33	0.376

CC × 2:1	3.01	59.38	19.02	10.77	2.4	3.015	0.078	6.51	141.33	0.313
MF × 1:1	3.31	39.98	40.44	10.12	2.03	2.463	0.614	6.41	151.66	0.328
MF × 2:1	3.84	57.94	20.19	13.42	2.24	2.596	0.895	6.47	124.33	0.242
P value	0.0013	0.0807	0.023	<0.0001	0.1283	<0.0001	<0.0001	0.009	<0.0001	0.9133

Similar findings were obtained by [16] Bulbul who reported that there was a positive correlation between whey drainage pH and moisture retained to protein. The drying slurries containing casein to fat ratio of 1:1 led to have higher moisture content in the final powder than those containing the ration of 2:1, possibly due to the initial higher moisture content in the former slurries than the latter ones as a result of the increase in the added palm oil. The results with respect to protein content stated that, treating the drying slurry with sodium bicarbonate led to increase the protein content in the final instant powder as compared to depending on the other slurry resulted from renneting, while the combination between the two forms of casein i.e., rennet and carbonated casein led to obtain a moderate protein level in the final product. That could be due to the exchange between the added sodium ions and calcium bounded to casein which in turn causes a decrease in the electrostatic repulsion forces between casein micelles leading to enhance the protein aggregations. Similar observations were reported by Mekmene [17]. Regarding the fat content, the formula containing the carbonated casein obtained statistically lower fat content as compared to the other two forms which led to obtain similar fat content to each other's, possibly due to the comparatively high protein of the powder resulted from the former formula. Concerning the ash content, the obtained data stated that the drying slurry which contained casein at the form of rennet casein led to obtain Mozzarella cheese powder with higher ash content than that resulting from the other two slurries. The lowest ash level was to the powder from the carbonated casein slurry. That could be ascribed essentially to the high coagulation pH during the rennet casein slurry making which helped in minerals retention and reducing its losing with whey. Similar was reported by Yazici and Akbulut [18]. Increasing the added palm oil to the drying slurry was associated with comparatively low ash content in the final dried product, possibly as a result of its lower protein content than the powder from slurries having the 2:1 casein to fat ratio. Those findings were in accordance with those of Mistry and Anderson [19] who reported that the ash content of hard cheeses increased with the decrease in fat and the increase in protein. With regard to the lactose content, the statistical analysis confirmed that the depending on the rennet casein in the instant Mozzarella cheese powder manufacture was associated with significant decrement in the lactose content, while the highest lactose levels were attained when the carbonated casein form was applied. The combination between rennet and carbonated casein led to moderate the lactose levels in the final dried products. That could be ascribed to the lactose degradation by the residual lactic acid bacteria during the applied incubation period through the renneting procedure. Moreover, the increase in the added palm oil to the drying slurry was associated with a significant decrease in the lactose content of the resultant powders, possibly as a result of the higher milk solids contents of the low fat powders. This phenomenon was in accordance with those reported by Pugliese [20]. Regarding the sodium contents, the obtained data indicated that, treating the precipitated casein with sodium bicarbonate led to obtain the highest sodium levels in the final cheese powders when compared to the formulas made with the addition of rennet which resulted in obtaining the lowest sodium levels. Likewise the combination between renneting and carbonation led to obtain medium sodium levels in the resultant powders. That could be due to the depletion of calcium in casein by exchanging with sodium. The full fat powders gained the highest sodium levels as compared to the reduced fat ones. That could be ascribed to the relatively high protein contents of the former powders. Concerning the calcium content of cheese powders, the presence of casein at the form of rennet casein was associated with the highest calcium levels of all cheese powders, possibly due to the calcium bonds dominating the structure of the rennet milk gels. Those observations were in accordance with that previously reported by Liu [21]. Likewise, the formulas of 2:1 casein to fat ratio resulted in significant increments in the calcium levels of the final powders. With regard to the pH values, data revealed that the powders containing the form of carbonated casein alone was associated with the highest pH values of all cheese powders, while the application of the rennet casein alone or incorporating it with carbonated casein led reduce the pH values as the lowest values were to cheese powders having the rennet casein alone. That could be ascribed essentially to the highest sodium levels of the powders of carbonated casein occurred due to the alkaline sodium bicarbonate addition. This observation was in agreement with that of McMahon [22] who found a positive correlation between the sodium content and the pH of the full fat Cheddar cheese. Reducing the added palm oil during the slurry preparation led to increase the pH values of cheese powders, possible due to the increase in protein and its buffering capacity [23]. Speaking about the reconstitution time, the formula of the mixed casein forms took the lowest time to reach the viscous lumps free well-known paste of Mozzarella cheese upon reconstitution in water at 80oC with hand stirring. Whereas, having the casein at the form of rennet casein led to attain the highest required time for reconstitution at the same conditions. Increasing the added palm oil led to alter the reconstitution time, possibly due to that fat acted as a barrier protecting the casein peptides from the action of the emulsifying salt. With respect to the water activity) aw (, it was very important to determine the aw of the resultant innovative powders to ensure their stability during storage [24].

The casein form had not any significant effect on the aw of the resultant powders. That could be due to the little differentiation between samples in the contents of ash, lactose and sodium. Likely, that observation was in agreement with the previous findings of Marcos [25]. The drying slurry containing casein to fat ratio of 1:1 led to obtain cheese powder with significantly higher aw as compared to when the slurry of the 2:1 was applied, possibly due to the relatively high moisture content of the powder of the former slurry.

Density and flowability of the instant Mozzarella cheese powders

Its noteworthy to mention that the loose density of dairy powders takes in considers the presence of the air inside the particles, which was created during moisture evaporation through drying, together with the contribution of the air molecules between the powder's particles. The obtained results stated that, the powders of carbonated casein obtained the highest values of loose density, on the other hand the depending on rennet casein or combining it with carbonated casein led to reduce the loose density of the Mozzarella cheese powders. That could be ascribed essentially to the relatively low fat contents of the powders of the carbonated casein. Likewise, the formulas of 1:1 casein to fat ratio resulted in significant decrements in the loose density values of the final powders. These findings were in accordance with the results of Pugliese [20] who reported that there was a negative correlation between loose density and the fat content of milk powders. Regarding the tapped density, the differences between cheeses because of the casein form were not significant, possibly due to that the effect of casein form on the fat content of the powders was little as revealed from Table 1. On the other hand, the tapped density took the same trend of the loose density upon the casein to fat ratio, possibly due to the homogeneity of the shape of particles as a result of stabilizing the conditions of drying. With regard to Carr's index, it's known as the compressibility index that measures the ability of powders to reduce their volume by tapping. The powder with Carr's index higher than 28% is considered as cohesive and has low flowability [12]. The data of Table 2 elucidated that the casein form in the drying slurry had no significant effect on the compressibility of the final powders. That could be ascribed to the similarity in the agglomeration behavior in all samples. That was in agreement with the findings of Sharma [26]. Likewise, reducing the added fat in the drying slurry led to increase the compressibility index and hence the cohesion of the powders, possibly due to the increase in protein and its Van der Walls forces. In order to evaluate the flowability of the Mozzarella cheese powders, the values of Carr's index were confirmed by calculating another indicator called Hausner ratio reflecting the cohesion of the particles of cheese powders. The Hausner ratio values took in the current study the same trends as the compressibility index regarding the two studied factors. The round figures of the cohesion ratio were in the same range for skim milk powder that previously reported by Szulc [27]. The overall flowability of all the studied cheese powders was considered as acceptable according to the pharmaceutical criteria of the council of Europe for pharmacopoeia [28].

Table 2: Ls means values for casein form, casein to fat ratio in the drying slurry and casein form x casein to fat ratio in the drying slurry on the loose density, tapped density, Carr's index and Hausner ratio of the instant Mozzarella cheese powders.

Source of variations	Loose density (g/cm3)	Tapped density (g/cm3)	Carr's index	Hausner ratio
Casein Form (CF)				
Rennet casein (RC)	1.057^{b}	1.413^{b}	25.15^{a}	1.336^{a}
Carbonated Casein (CC)	1.069^{a}	1.440^{b}	$25.68a^{a}$	1.345^{aa}
Mixture of the two forms(MF)	1.058^{bb}	1.421^{bb}	25.55^{aa}	1.343^{aa}
P value	0.0004	0.003	0.2753	0.258
Casein to Fat Ratio in the drying slurry (CFR)				
1:01	1.003^{b}	1.339^{b}	25.05^{b}	1.334^{b}
2:01	1.120^{a}	1.511^{a}	25.87^{a}	1.349^{a}
P value	<.0001	<.0001	0.0094	0.008
CF × CTR				
RC × 1:1	0.994	1.323	24.85	1.33
RC × 2:1	1.12	1.503	25.46	1.341

CC × 1:1	1.018	1.356	24.91	1.331
CC × 2:1	1.121	1.524	26.45	1.36
MF × 1:1	0.998	1.338	25.4	1.34
MF × 2:1	1.118	1.505	25.7	1.346
P value	0.0013	0.5207	0.1854	0.1655

Particle size distribution of the instant Mozzarella cheese powders

It was very important to measure the particle size and particle size distribution of the powders as it is affecting their behavior and physical properties [29]. The results stated that the casein form led to affect both the volume weighted and surface weighted means significantly, where the highest values were for the rennet casein powders as compared to the carbonated casein ones which came in the latest order. That could be due to the relatively low pH value reached during making the slurry of the carbonated casein, which encouraged the dissociations of casein micelles during heating. These phenomena are in agreement with those of Ye and Harte [30]. Furthermore, the mentioned two indicators were increased significantly with the increase in the added fat, possibly due to incorporating that fat within the casein dried matrix. Similar observation was reported by Pugliese [20] who found that the particles of whole milk powder were larger in size than the skimmed one. Likewise, the median particle size of the resultant cheese powders underwent the same trends as both the volume weighted and surface weighted means towards casein form and casein to fat ratio. Regarding the span index values which measure the amplitude of particles size distribution, the data of Table 3 revealed that the lowest values were for the powders of rennet casein, providing high homogeneity. That could be due to the more uniform structures of the rennet casein gels, controlled by calcium bonds. While the carbonated casein powders came in the second order followed by the powders of mixed casein forms, which reflected the highest span values and hence the highest inhomogeneity levels of all experimental Mozzarella cheese powders. Furthermore, increasing the fat content in the drying slurries led to increase the span index values of powders. The round figures of these results were in accordance with those of Nikolova and Sert [31,32] about skimmed and whole milk powders.

Table 3: Ls means values for casein form, casein to fat ratio in the drying slurry and casein form x casein to fat ratio in the drying slurry on the particle size (micron) and size distribution (percentile) of instant Mozzarella cheese powders.

Source of variation	D [4,3]	D [3,2]	D10	D50	D90	Span index
Casein Form (CF)						
Rennet casein (RC)	150.07^{a}	91.10^{a}	76.90^{a}	124.93^{a}	257.89^{a}	1.444^{c}
Carbonated Casein (CC)	89.20^{c}	41.83^{c}	37.82^{c}	105.09^{c}	205.88^{c}	1.618^{b}
Mixture of the two forms(MF)	102.37^{b}	56.98^{b}	42.85^{b}	113.84^{b}	243.55^{b}	1.753^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Casein to Fat Ratio in the drying slurry (CFR)						
1:01	119.43^{a}	72.49^{a}	69.51^{a}	130.42^{a}	277.79^{a}	1.595^{a}
2:01	108.32^{b}	54.12^{b}	35.54^{b}	98.82^{b}	193.76^{b}	1.616^{aa}
P value	0.0005	<.0001	<.0001	<.0001	<.0001	0.4728
CF × CTR						
RC × 1:1	156.69	99.37	107.09	137.34	311.5	1.489
RC × 2:1	143.44	82.84	46.71	112.52	204.29	1.4

CC × 1:1	96.5	51.9	48.01	120.84	228.04	1.489
CC × 2:1	81.89	31.76	27.64	89.35	183.72	1.746
MF × 1:1	105.1	66.19	53.42	133.09	293.85	1.805
MF × 2:1	99.64	47.77	32.28	94.59	193.26	1.701
P value	0.276	0.2785	<0.0001	0.0006	<0.0001	0.0003

Melt and stretch profile of the reconstituted instant Mozzarella cheese powders

Data given in Table 4 revealed that, the rennet casein reconstituted cheese obtained the highest hardness followed by the mixed casein forms cheese, while the cheese from the powder of carbonated casein came in the latest order having the lowest post melt hardness of all samples. That could be attributed to the positive correlation between the calcium content of cheese and its hardness degree. Similar was reported by Biswas [33] who studied the role of calcium on processed cheese hardness. Moreover, the cheeses from the slurry containing the ratio of 2:1 casein to fat were harder than those from the other casein to fat ratio slurry. Similar observations were reported by Fife [34] who reported that the reduction in fat increased the hardness of Mozzarella cheeses due to compactness of the protein matrix. It was observed that, there was strong correlation between the post melt gumminess and hardness of cheese powders, where the rennet casein cheeses as well as the low fat cheeses were the gummiest ones. That could be attributed to the relatively high protein contents of those cheese powders. These phenomena are in agreement with the findings of Gholamhosseinpour [35]. With regard to the stretch extension of the reconstituted cheese powders, the rennet casein cheese powders were statistically similar to the mixed casein forms cheeses and higher than the carbonated casein powders. That could be due to the high calcium to casein ratio in the rennet casein, which leads to a degree of calcium sequestration and para-casein aggregation easy to be controlled by the added emulsifying salts leading to a suitable degree of fat emulsification which in turn improves the stretchability of cheese [36]. Likewise the reduced fat cheese powders gave longer extension than the high fat ones. Tex is a parameter of weight used to measure the density of yarns and here it is used for the stretched cheese strands, where the cheese strands were considered similar to nylon fibers as explained by Othmer [37]. The Tex value indicates the linear density and is calculated as weight in g of 1000 m of stretched cheese strands which are similar to yarn. The results stated that, the variation in casein form led to obtain significant differences in the Tex values of the reconstituted cheese powders as the rennet casein cheese powders obtained the highest Tex followed by the mixed form cheeses while the carbonated casein cheese powders came in the latest order. That could be ascribed to the more tightened protein matrix of the reconstituted rennet casein cheese powders and the increased fat emulsification occurred in those reconstituted cheeses. Likewise, the powders from the slurry containing the 2:1 casein to fat ratio possessed higher Tex values than the powders of the slurry containing the other casein to fat ratio, possibly due to the thicker protein fibers of the former reconstituted cheese powders. The stretch maximum load is the force required to stretch the reconstituted cheese powders. The results elucidated that, the reconstituted rennet casein cheeses required the highest force to be stretched, followed by the mixed casein forms cheeses while the carbonated casein ones came in the latest order. That could be due to the relatively high hardness of the rennet casein reconstituted powders compared to the other samples. Break point is the length of stretched cheese at which the yield load was attained. The results revealed that, the casein form affected the break points of all experimental cheese powders, where the carbonated casein powders possessed statistically lower breakpoints than both rennet casein and the mixed casein forms powders which obtain statistically similar breakpoints to each other's; likely due to the comparatively low hardness degree of the former cheeses. Similarly, the reduction in the added palm oil led to increase the break points of the final reconstituted cheese powders. Another measure termed as tenacity (or toughness) was also considered to estimate the differences in the stretchability of casein fibers [38]. Tenacity is measured as the tensile stress at breakpoint. It is expressed as force per unit linear density of unstrained sample, and hence this measure seemed to reflect the overall stretch quality. Data demonstrated that, all factors studied caused significant differences in cheese tenacity where, the form of mixed casein led to obtain the highest tenacity, followed by the rennet casein one, while the carbonated casein came in the latest order. On the other side, the increase in protein content led to increase the tenacity of the reconstituted samples. Regarding the sensorial evaluation of the stretch quality, the high fat powder of carbonated casein which had the best sensory stretch quality, obtained the lowest tenacity degree, so it could be concluded that the lower is the tenacity, the better is the overall stretch quality in case of the instant Mozzarella cheese powders. The results showed moreover, that this instrumental method of stretchability evaluation of cheeses can be objectively carried out with great reliability; the test was easy to perform and

was less effort-consuming than the test of using a fork, and the outputs were reproducible.

Table 4: Ls means values for casein form, casein to fat ratio in the drying slurry and casein form x casein to fat ratio in the drying slurry on the Melt and stretch profile of the reconstituted instant Mozzarella cheese powders.

Source of variation	Post melt Hardness (g)	Post melt gumminess (g)	Stretch Extension (mm)	Tex (g/1000m)	Stretch maximum load (gf)	Break point (mm)	Tenacity (gf/tex)
Casein Form (CF)							
Rennet casein (RC)	11.42[a]	27.09[a]	589.83[a]	13398.33[a]	32.71[a]	578.16[a]	0.00239[b]
Carbonated Casein (CC)	7.61[c]	21.12[c]	375.16[b]	9550.50[c]	17.88[c]	359.16[b]	0.00187[c]
Mixture of the two forms(MF)	10.48[b]	21.50[b]	592.33[a]a	11593.50[b]	31.73[b]	584.50[aa]	0.00271[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Casein to Fat Ratio in the drying slurry (CFR)							
1:01	8.52[b]	12.83[b]	505.44[b]	10733.56[b]	22.06[b]	493.66[b]	0.00205[b]
2:01	11.15[a]	33.64[a]	532.77[a]	12294.67[a]	32.82[a]	520.88[a]	0.00260[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CF × CTR							
RC × 1:1	8.41	9.25	580.33	12301.33	23.11	575.33	0.00187
RC × 2:1	14.44	44.93	599.33	14495.33	42.31	581	0.00292
CC × 1:1	7.21	14.2	348.66	9203.33	16.76	329	0.00182
CC × 2:1	8.01	28.04	401.66	9897.66	19.01	389.33	0.00192
MF × 1:1	9.96	15.04	587.33	10696	26.31	576.66	0.00246
MF × 2:1	11	27.96	597.33	12491	37.15	592.33	0.00297
P value	<0.0001	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	<0.0001

Hunter colour values of the instant Mozzarella cheese powders

Data demonstrated that, the carbonated casein cheese powders gained the highest L-value, followed by those of the mixed casein forms, while the powders of rennet casein came in the latest order. Moreover the latter powders kept their high lightness after reconstitution. That could be due to the very low median particle size of the carbonated casein powders. Similar observations were obtained by Banavara [39]. The reduced fat powders possessed higher whiteness than the high fat ones, possibly due to the comparatively high protein of the former powders which form more compact protein matrix in comparison with the high fat powders. Regarding Hunter colour a-values, the casein form had a significant effect on powders red/brown colouration, where the powders of carbonated casein had the worst colouration reflecting the highest a-values, followed by those of the mixed casein, while the rennet casein powders possessed the lowest values. That could be ascribed essentially to the comparatively high lactose content of the carbonated casein powder which might have undergone Maillard's reaction during the slurry preparation especially that the slurries of that powder underwent to longer heating time that the other slurries. Moreover, the carbonated cheese powders kept their higher a-values after reconstitution, while adding water to the rennet casein powders led to increase their red/brown colouration, possibly due to the relatively high particle size and the less compact protein matrix which encouraged the extend of Maillard's reaction. Furthermore the powders of mixed casein forms obtained the lowest a-values after reconstitution. The increase in fat led to increase powders' a-values, whereas the low fat powders reflected the highest a-values after reconstitution. These phenomena are in partial accordance with those of Thomas [40]. Regarding Hunter b-values which represent the yellowish colouration, the results stated that the

casein form affected the yellowness significantly, as the rennet casein powders had the highest values, followed by the mixed casein powders, while the carbonated casein ones came in the latest order Table 5. That could be attributed to the relatively low lactose and protein contents of the rennet casein powders which led to slow the extent of Maillard's reaction, also the comparatively high moisture contents of those powders may played its turn in diluting the Maillard's reaction products. Likewise, the high fat powders possessed higher yellowness than the low fat ones, due to the slow extent of Maillard's reaction besides the direct contribution of palm oil in the powders' colour. Similar observations about the contribution of palm oil and its derivatives in processed cheese colouration were reported by Ismail [41-43].

Table 5: Ls means values for casein form, casein to fat ratio in the drying slurry and casein form x casein to fat ratio in the drying slurry on the Hunter colour values of instant Mozzarella cheese powders before[1] and after[2] reconstitution.

Source of variation	L1	L2	a1	a2	b1	b2
Casein Form (CF)						
Rennet casein (RC)	96.09^{c}	86.49^{c}	-2.65^{c}	2.18^{b}	11.39^{a}	6.01^{a}
Carbonated Casein (CC)	98.18^{a}	88.44^{a}	-1.52^{a}	2.53^{a}	9.10^{c}	4.62^{c}
Mixture of the two forms(MF)	96.34^{b}	87.49^{b}	-1.96^{b}	1.66^{c}	10.85^{b}	5.52^{b}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Casein to Fat Ratio in the drying slurry (CFR)						
1:01	96.09^{b}	85.25^{b}	-1.46^{a}	2.01^{b}	11.70^{a}	5.63^{a}
2:01	97.65^{a}	89.69^{a}	-2.62^{b}	2.24^{a}	9.19^{b}	5.13^{b}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CF × CTR						
RC × 1:1	95	84.29	-1.76	2.15	12.44	6.26
RC × 2:1	97.18	88.69	-3.54	2.21	10.34	5.76
CC × 1:1	97.25	86.49	-1.06	2.21	10.46	4.92
CC × 2:1	99.11	90.38	-1.98	2.85	7.74	4.32
MF × 1:1	96.02	84.99	-1.58	1.67	12.22	5.72
MF × 2:1	96.67	89.99	-2.34	1.66	9.49	5.32
P value	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0017

CONCLUSION

In this study a patented novel style of Mozzarella cheese at the form of instant powder was made from spray dried skimmed cow's milk slurries containing the protein at the chemical form of carbonated and / or rennet casein. Slurries were mixed with palm oil before drying to form high and low fat cheese powders. The study findings led to conclude that, the final cheese powders were expected to have the acceptability of several markets because of its ease in reconstitution, miscellaneous applications and very strong keeping quality at the room temperature.

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