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Research Article

Rheological and Sensorial Characteristics of the Reformed Ras Cheese Made Using Cheese Trims and Different Starches

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The objective was to study the technological suitability of using the Ras cheese trims and starch as casein stabilizer in making novel reformed Ras cheese (RRC) product and to evaluate the effect of two levels of corn, potato, and rice starches whether at the native form or pregelatinized, on the rheological and sensorial properties of that reformed Ras cheese which was supposed to be very close to conventional Ras cheese. Cheese trims were shredded, and table salt was added and kept at 25°C for 24 h. Starch was added in the form of whipped transparent paste, then the mixture was cooked without emulsifying salts to 75°C for 5 minutes at 120 rpm, the cooking temperature was then lowered until reaching 55°C at the same stirring speed, and then, the mixing speed was raised to 1400 rpm for another 1 minute. The molten cheese mass was poured into custom-made moulds. The height from which the cheese was poured into moulds was adapted to be 50 cm from the bottom of the mould. The samples were allowed to set at 5°C for 24 hours. The obtained results indicated that increasing the starch level significantly decreased the values of dry matter, protein, lactose, titratable acidity, water activity (a_w), consistency coefficient (K), flow behavior index (n), Tan δ, hardness, springiness, melt distance, and shredding efficiency and increased the values of ash, pH, critical strain, adhesiveness, and sliceability. The starch source had no significant effect on critical strain, K, Tan δ, and sliceability. The rice starch RRCs were distinguished with the highest significant values of a_w, n, cohesiveness, springiness, flavour, and total sensorial scores. The potato starch RRCs had the lowest hardness, fracturability, shreddability, and total sensorial score, as well as the highest melt distance, free oil, and adhesiveness. The corn starch RRCs were characterized with the lowest a_w, n, springiness, body, and texture scores, as well as the highest hardness, fracturability, and shreddability. The pregelatinized starch RRCs were associated with increased a_w, critical strain, n, Tan δ, fracturability, springiness, melt distance, shredding efficiency, sliceability, and all sensorial characteristics except appearance. The native starch RRCs were characterized with the highest pH, hardness, adhesiveness, free oil, and appearance score values.

1. Introduction

Ras cheese is considered the most popular hard cheese type in Egypt and takes the first place in the consumption of hard cheeses in Egypt and probably in the Arab world. It is very similar to the Greek hard Kefalotyri cheese and produced in medium scale dairy plants all over Egypt. The commercial names of this cheese are Romi cheese or Torky cheese [1]. It is conventionally made from cow's milk or a mixture of cow's and buffalo's milks under artisanal conditions. After the curd is formed and cut, the whey is drained, and the curd is moulded and pressed using mechanical force. The aim of moulding and pressing is to merge all the individual particles of curd into one cheese block that can be then ripened and stored, as well as to speed up the removal of excessive whey, moreover, to produce the desired size and shape of cheese. During pressing of the traditional Ras cheese, cheese trims or scraps are produced in relatively high amounts (Figure 1) and form economical losses, especially these trims contain considerably high levels of dry matter as these are cut from the outer layers of the cheese block. Trails were made to cut these trims and repress it with curd, but it impaired the body and texture quality of the final product. The only use of these trims is to make processed Ras cheese by cooking with emulsifying salts. However, the processed cheese is significantly different in body, texture, and flavour

Figure 1: Emergence of trims during moulding and pressing of Ras cheese.

from the original cheese and has a high sodium content due to the addition of emulsifying salts. Starch had a great interest to be used in the unregulated cheese products such as imitation cheeses, and this attracted the interest of many researchers. Starch is available in the food ingredients market in two major forms: native and modified. The term "native starch" refers to any starch granule that has been extracted from its plant source which has not undergone any form of modification. Native starches have inherent useful characteristics, but it lacks the versatility to function effectively across the entire range of food applications [2]. To satisfy specific functional needs in food production and quality, modified starches were developed to provide additional roles not typical to native starches and further enhance its native attributes [3]. The physical modification of starch has attracted the attention because of its advantages, such as no chemical usage, safety, and simplicity. Pregelatinization is the most common physical modification method which can change the swelling power and water holding capacity of starch and hence affect the rheological properties of the systems that contain starch [4]. Starches were used for partial or full replacement of casein or fat in cheese. In imitation cheese, casein forms a continuous hydrated matrix that stabilizes the fat by acting as emulsifier. Emulsifying salts are added to the mixture to ensure adequate casein hydration and enable casein to emulsify the fat [5]. Mounsey and O'Riordan [6, 7] reported that replacing casein with starches can result in changes in texture and melting quality of the analogue cheese, and when native maize, wheat, potato, or cross-linked rice starch was added to imitation cheese, firmness, hardness, and brittleness were increased, and flow was decreased. Moreover, Noronha et al. [8] studied the effect of increasing starch level and found that varying starch level and type affected water uptake and changed texture from soft to brittle. The changes in rigidness, meltability, and hardness, when replacing casein with starch, could be partly ascribed to the differences in fat emulsification and starch retrogradation. The destabilization of emulsion when starch replaces protein can be overcome by using a modified starch with emulsifying properties. Depending on the effects of starches in processed cheese products, the development of a reformed Ras cheese product using starch as a substitute for emulsifying salts was progressed. Starch was utilized to accomplish the desired emulsifying functionality and achieve rheological properties that closely resemble the traditional Ras cheese. For that in view, the present study was conducted to evaluate the effect of two levels of corn, potato, and rice starches whether at the native form or pregelatinized, on the rheological and sensorial properties of a novel reformed Ras cheese.

2. Materials and Methods

2.1. Materials. Fresh cow's milk was obtained from the herd of the armed forces farms in Cairo-Ismailia desert road (12.6% TS, 4% fat, 3.55% protein, and pH 6.7). Lyophilized mixed yoghurt starter culture (YC-183) containing *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus*, 1 : 1, was obtained from Chr. Hansen Lab., Denmark. 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. Potassium sorbate and calcium chloride were obtained from SJZ Chem-Pharm Co., Ltd., China. Sodium chloride was obtained from El-Nasr for Salt Production Co. Water soluble annatto extract was obtained from Mifad for food additives, Badr city, Egypt. Ras cheese trims (a byproduct during cheese moulding and pressing) were obtained from Shahencoland Company for dairy products, Foah, Egypt. Native corn starch was obtained from El-Watanya for corn products, 10th of Ramadan City, Egypt. Pregelatinized corn starch was obtained from Cargill, Katameya, New Cairo, Egypt. Native and pregelatinized KMC® potato starches were obtained from Mashreq for business development, Alexandria, Egypt. Native and pregelatinized rice starches were obtained from Tiba for starch and glucose manufacturing, Al-Salheya Al-Gadeda city, 1st industrial zone, Egypt.

2.2. Manufacturing of Reformed Ras Cheese. The recipes illustrated in Table 1 were applied; reformed Ras cheese was made from Ras cheese trims and different types of native or pregelatinized starches. Cheese trims were shredded using

Table 1: Recipes of reformed Ras cheese made using Ras cheese trims and starches from different sources.

Ingredient (%)	Starch form											
	Native						Pregelatinized					
Ras cheese trims	80	80	80	77.5	77.5	77.5	80	80	80	77.5	77.5	77.5
Native corn starch	2.5	0	0	5	0	0	0	0	0	0	0	0
Native potato starch	0	2.5	0	0	5	0	0	0	0	0	0	0
Native rice starch	0	0	2.5	0	0	5	0	0	0	0	0	0
Pregelatinized corn starch	0	0	0	0	0	0	2.5	0	0	5	0	0
Pregelatinized potato starch	0	0	0	0	0	0	0	2.5	0	0	5	0
Pregelatinized rice starch	0	0	0	0	0	0	0	0	2.5	0	0	5
Table salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Potassium sorbate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Water	16	16	16	16	16	16	16	16	16	16	16	16
Total	100	100	100	100	100	100	100	100	100	100	100	100

a custom-made pilot cheese shredder into long strips (about 5 mm wide × 20 – 30 mm long × 0.3 – 0.5 mm thick). Table salt was added to the shredded trims to comply with the typical saltness expected from Ras cheese. The shredded trims and salt mixture were kept at 25°C for 24 h. Starch was added to water with mixing at 120 rpm and heated until reaching a clear transparent paste. The starch paste was cooled to 25°C and whipped using Sear Planetary Mixer at the highest speed to help in the formation of mechanical openings which simulate those of the conventional Ras cheese. The whipped starch paste and the mixture of shredded trims and salt were placed in the cheese cooker (Stephan Universal Machine UMSK 24 E) which was preheated to 70°C and heated to 75°C for 5 minutes at 120 rpm, where a a lumps free paste was obtained. The cooking temperature was then lowered until reaching 55°C at the same stirring speed, and then, the mixing speed was raised to 1400 rpm for another 1 minute. The molten cheese mass was poured into stainless steel cylindrical custom-made moulds with capacity of 5 kg and height of 25 cm. The height from which the cheese was poured into moulds was adapted to be 50 cm from the bottom of the mould. The samples were allowed to set at 5°C for 24 hours prior to evaluation. Control Ras cheese was made from pasteurized cow's milk as described by Hammam et al. [9]. Three replicates were made for each treatment.

2.3. Analytical Methods. Dry matter, fat, total nitrogen, and ash contents were determined according to the Association of Official Agricultural Chemists (AOAC [10]). Lactose contents were determined according to Rynne et al. [11]. The pH values were measured using a microprocessor pH meter (model 8417, Hanna Instruments, Singapore) at 20°C after calibrating with pH 4.0 and 7.0 standard buffers. For determination of water activity, 0.5 g of grated samples was placed in closable plastic bags, stored at 8°C for 30 min, and assayed in triplicates at 25°C on a Novasina LabMaster-aw machine (Novatron Scientific Ltd., UK) which was based on changes in electrolytic resistance. Prior to assay, the machine was calibrated using a certified Novasina 98% humidity standard (cert no. NS2984-2). For determination of shreddability of reformed cheese samples, the experimental samples were cut into blocks of about 4 cm width, 4 cm height, and 8 cm length. Before shredding, the blocks of cheese were weighed (about 500 g) and placed overnight in a refrigerator (5°C). The shredder was adjusted to produce long strips (5 mm wide × 20 – 30 mm long × 0.3 – 0.5 mm thick) and operated for 1 min. The shredded strips were allowed to go out of the shredder and weighed to calculate the percent of the cheese that adhered to the blades. The shredded cheese was shaken for 10 seconds through a sieve with opening of 6.35 mm^2; the shreds that fell through the sieve were classified as fines and weighed to calculate the percent of shred fines. The shredding efficiency was calculated as follows:

$$\text{Shredding efficiency (\%)} = \frac{\text{sample weight before shredding} - (\text{adhered cheese weight} + \text{cheese fines weight})}{\text{sample weight before shredding}} \times 100. \quad (1)$$

The meltability of cheese samples was determined using the method of Poduval and Mistry [12] with a slight modification as follows; 10.0 g of finely grated cheese was transferred into a glass tube measuring 24 mm internal diameter × 250 mm length × 3 mm thickness. The cheese was firmly packed using a plunger, and the glass tube was closed using a rubber stopper having a hole in the middle so that during heating, the hot air inside the tube can escape. The closed tubes containing the cheese plug were placed vertically overnight in a refrigerator (5°C). The length of the cheese plug was measured in each of the tubes. The glass tubes containing the cheese plugs were placed horizontally in a preheated hot air oven, and the cheese plugs were allowed to melt at 110 ± 1 ∘ C for 90 min. The glass tubes were air cooled for 10 min, and the length of the melted cheese plugs was measured again. The difference in initial and final lengths of the cheese plugs was represented as the melt distance. For determination of free oil, grated reformed cheese (6 g) was placed in airtight plastic bags at 4°C for 2 h. Each grated sample was taken in a 200 mm screw cap Pyrex tube. The tube containing sample was dipped in water at boiling temperature for 4 min, and instantaneously, about 10 mL of acidified water at a temperature of 60°C was added into the sample. Subsequently, sample tube was centrifuged for 5 min. After centrifugation, 10 mL of 1 : 1 distilled water: methanol solution (v/v) was added to the sample. Then, the tube was positioned in the water bath at 60°C for 1 min, again centrifuged for 2 min, and then placed at 60°C for 1 min. Due to this, a distinct yellow oil layer was made at the surface of the aqueous methanol. The oil layer was transferred by pipette to a Gerber fat test tube for milk containing water. The Gerber tube was closed and tempered at 60°C for 1 min, centrifuged for 2 min, and again tempered at 60°C for 2 min and then measured. The measured value was divided by two to give free oil expressed as percentage in cheese [13]. The textural profile analyses for some textural properties (hardness, fracturability, springiness, cohesiveness, gumminess, and adhesiveness) were performed in CT3 Brookfield-Texture analyzer using a computer interface software (Texturepro CT V1.2 Build 9) according to Paredes et al. [14]. Sliceability was measured as the average force required for a cutting wire to penetrate and cut the sample surface. The test was performed using a CT3 Brookfeild-Texture analyzer equipped with a TA-26 cutting wire probe (Texture Technologies Corporation, Scarsdale, NY). The samples were tested at a temperature range from 5 to 10°C. The samples were evaluated for texture as strips measuring 20 × 20 × 60 mm. Reformed Ras cheese rheology was studied using a controlled stress HR-1 hybrid rheometer (TA® Instruments, USA). Experimental samples were shaped at the form of discs of 40 mm diameter and 5 mm depth. Geometry and trim gap were set to 2000 and 2100 μm, respectively. Amplitude sweep was measured at a set of 6.28 rad/s frequency at room temperature within 0.1 to 50% strain to form a linear viscoelastic region. Critical strain (ε_{cr}) and loss tangent (Tan δ) were also determined. Power law was applied using the following equations: $G' = K\omega n$ and $G'' = K\omega n$, where, G' is the storage modulus (Pa), G'' is the loss modulus (Pa), ω is the frequency (rad/s), K is the consistency coefficient (Pa.s^n), and n is the flow behavior index. The sensory evaluation of cheese samples was assessed through the recommended criteria by El-Essawi et al. [15]; 50 g of cheese was tempered at 25°C for 5 h and introduced to the panelist; scores were given for flavour, appearance, body, and texture. The obtained results were analysed with the ANOVA procedure followed by Duncan's multiple range tests according to statistical analysis system user's guide [16]. The experimental design was completely randomized with replications.

3. Results and Discussion

3.1. Physicochemical Properties of the Reformed Ras Cheese. Data shown in Table 2 revealed that the starch addition was associated with decreasing the levels of dry matter, protein, fat, lactose, and titratable acidity of the final reformed Ras cheese while increasing the values of ash and pH. The added starch level led to affect the water activity of the reformed Ras cheese significantly as the cheese with 2.5% starch obtained the lowest water activity of all samples, possibly due to its relatively high ash content. The differences in cheese physicochemical properties upon the starch source were significant and could be due to the differences between starches. The rice starch containing cheese samples were distinguished with the highest levels of dry matter, fat, lactose, and aw and the lowest values of protein, ash, and titratable acidity, whereas the corn starch reformed cheeses gained the highest values of protein, ash, and lactose and lowest values of aw. That could be due to the relatively high-water holding capacity of the corn starch compared to the other starches [17]. The potato starch reformed Ras cheeses were associated with the highest values of titratable acidity and the lowest values of dry matter and fat. The statistical analysis confirmed that the starch form whether native or pregelatinized had no significant effect on the levels of dry matter and titratable acidity of the reformed Ras cheese. The native starches led to increase the levels of pH compared to the pregelatinized ones. That could be ascribed to the pH modifications that occurred to assist the pregelatinization process during starch manufacture. This observation was in accordance with the findings of [18] who reported that the starch gelatinization temperature could be reduced by modifying the starch pH. Moreover, the pregelatinized starches led to increase the aw of cheese, possibly due to the relatively low water holding capacity of those starches compared to the native ones [19].

3.2. Power Law Model Coefficients of the Reformed Ras Cheese. Data shown in Table 3 demonstrated that the added starch led to increase the critical strain of the reformed cheese in a concentration-dependent manner, where the cheeses made with the highest level of starch were the rubberiest ones and attained the highest critical strain, possibly due to that starch restricted the mobility of moisture in the reformed cheese matrix. The control Ras cheese reflected the lowest critical strain value of all samples, and hence, it was less stable and more prone to the strain deformation. These observations were in accordance with the previous findings of Faber et al. [20]. On the other hand, the applied starch source had no significant effect on the reformed cheese critical strain. Nevertheless, the application of the pregelatinized starches caused a significant increase in the critical strain of the reformed cheese samples as compared to the added native starches. That could be ascribed essentially to the comparatively low yield pressure of the pregelatinized starches which in turn made the plastic deformation in the pregelatinized starches containing systems occur at lower pressures [21]. Regarding the consistency coefficient, the starches led to decrease the storage modulus consistency coefficient, possibly due to the decrease in protein that occurred during the formula adjustments as well as the interactions took place between the starches and protein through the reforming process which in turn weakened the cohesiveness of cheese matrix. These observations agreed

Table 2: Ls means values for starch level (SL), starch source (SS), starch form (SF), SL × SS, SL × SF, and SS × SF on the physicochemical properties of the reformed Ras cheese.

Source of variation	Dry matter (%)	Protein (%)	Fat (%)	Ash (%)	Lactose (%)	Titratable acidity (%)	pH	a_w
Starch level (SL)								
0% (control)	57.83[a]	21.43[a]	24.56[a]	4.455[c]	0.423[a]	0.67[a]	5.56[c]	0.878[a]
2.5%	51.76[c]	17.72[b]	21.04[b]	5.176[a]	0.335[b]	0.39[b]	5.68[b]	0.551[c]
5%	52.44[b]	16.80[c]	19.98[c]	4.927[b]	0.319[c]	0.23[c]	5.83[a]	0.858[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Starch source (SS)								
Corn starch	54.02[b]	18.72[a]	21.83[b]	4.885[a]	0.360[a]	0.44[b]	5.71[a]	0.73[c]
Potato starch	53.96[c]	18.63[b]	21.78[c]	4.839[b]	0.358[b]	0.46[a]	5.67[b]	0.76[b]
Rice starch	54.05[a]	18.60[c]	21.96[a]	4.834[c]	0.359[a]	0.39[c]	5.70[a]	0.79[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001	0.0097	<0.0001	<0.0001	<0.0001
Starch form (SF)								
Native starch	54.00[a]	18.57[b]	21.74[b]	4.842[b]	0.357[b]	5.69[a]	0.44[a]	0.73[b]
Pregelatinized starch	54.01[a]	18.73[a]	21.98[a]	4.863[a]	0.361[a]	5.69[a]	0.42[b]	0.79[a]
P value	0.1112	<0.0001	<0.0001	<0.0001	<0.0001	0.0041	0.8394	<0.0001
SL × SS								
2.5% × corn starch	51.73	17.92	21.43	5.225	0.338	5.68	0.46	0.83
2.5% × potato starch	51.70	17.40	20.68	5.137	0.333	5.65	0.20	0.81
2.5% × rice starch	51.84	17.83	21.03	5.165	0.335	5.73	0.44	0.87
5% × corn starch	52.49	16.81	19.51	4.974	0.320	5.88	0.26	0.85
5% × potato starch	52.36	17.06	20.11	4.925	0.318	5.80	0.27	0.92
5% × rice starch	52.48	16.55	20.31	4.881	0.320	5.82	0.24	0.90
P value	<0.0001	<0.0001	<0.0001	<0.0001	0.0479	<0.0001	<0.0001	<0.0001
SL × SF								
2.5% × native starch	51.76	17.47	20.56	5.158	0.332	5.68	0.43	0.83
2.5% × pregelatinized starch	51.76	17.96	21.53	5.193	0.339	5.69	0.35	0.92
5% × native starch	52.43	16.81	20.11	4.913	0.317	5.84	0.22	0.81
5% × pregelatinized starch	52.46	16.80	19.85	4.940	0.321	5.82	0.25	0.90
P value	0.0832	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0320	<0.0001
SS × SF								
Corn starch × native	54.01	18.71	21.69	4.892	0.360	5.71	0.45	0.70
Corn starch × pregelatinized	54.02	18.73	21.97	4.878	0.361	5.70	0.43	0.76
Potato starch × native	53.96	18.49	21.77	4.825	0.356	5.66	0.43	0.73
Potato starch × pregelatinized	53.96	18.77	21.80	4.852	0.360	5.67	0.48	0.79
Rice starch × native	54.04	18.51	21.76	4.809	0.357	5.70	0.43	0.76
Rice starch × pregelatinized	54.06	18.69	22.17	4.858	0.362	5.70	0.35	0.82
P value	0.2872	<0.0001	<0.0001	<0.0001	0.0080	<0.0001	0.5864	0.7488

Values with different letters (a-c) within the same column are significantly different at $P < 0.05$.

with those of Kamath et al. [22]. The loss modulus consistency showed increments up on starch presence, possibly due to the obvious role of starch in increasing the rubbery state of the cheese during the loss modulus acting. The effect of starch source on cheese consistency was very little, but the corn starch led to obtain the highest cheese consistency. Similar findings were reported by Saleh et al. [23] who studied the effect of starch from different sources on the rheology of nonfat set yoghurt. The consistency of cheeses reformed by the native starches was statistically like that of the cheeses reformed by the pregelatinized ones. With respect to the flow behavior index (n), the results demonstrated that all samples including the control one acted as pseudoplastic materials, since $n < 1$, but some samples were more pseudoplastic than the others as declared by their n values. The control Ras cheese showed the lowest pseudoplasticity degree of all samples, as starches increased the pseudoplasticity in a concentration-dependent manner. The applied starch source affected the cheese flow behavior significantly as the rice starch cheeses gained the highest n values, followed by the potato starch cheese, while the corn starch ones came in the latest order. That means that the rice starch had its obvious role in decreasing the pseudoplasticity of the reformed Ras cheese to behave like the control cheese. The differences

Table 3: Ls means values for starch level (SL), starch source (SS), starch form (SF), SL × SS, SL × SF, and SS × SF on the power law model coefficients of the reformed Ras cheese.

Source of variation	ε_{cr} (%)	G' K (Pa.s^n)	G' n	G'' K (Pa.s^n)	G'' n
Starch level (SL)					
0% (control)	14.15^c	16146.07^a	0.396^a	799.27^b	0.400^a
2.5%	17.03^b	1753.37^b	0.238^b	897.92^a	0.208^b
5%	18.90^a	1777.63^b	0.222^c	918.42^a	0.189^c
P value	<0.0001	<0.0001	<0.0001	0.0015	<0.0001
Starch source (SS)					
Corn starch	16.62^a	6608.22^a	0.253^c	900.89^a	0.241^c
Potato starch	16.65^a	6561.99^{ab}	0.291^b	875.93^a	0.266^b
Rice starch	16.82^a	6506.86^b	0.313^a	838.79^a	0.291^a
P value	0.6962	0.0536	<0.0001	0.1671	<0.0001
Starch form (SF)					
Native starch	15.67^b	6589.55^a	0.259^b	893.54^a	0.227^b
Pregelatinized starch	17.72^a	6528.49^a	0.312^a	850.20^a	0.305^a
P value	<0.0001	0.0714	<0.0001	0.1082	<0.0001
SS × SL					
Corn starch × 2.5%	17.05	1827.49	0.192	940.91	0.171
Corn starch × 5%	18.65	1851.09	0.170	962.47	0.150
Potato starch × 2.5%	16.53	1758.48	0.241	903.97	0.207
Potato starch × 5%	19.26	1781.42	0.235	924.54	0.191
Rice starch × 2.5%	17.51	1674.13	0.282	848.84	0.245
Rice starch × 5%	18.79	1700.38	0.261	868.23	0.226
P value	0.1888	0.5366	<0.0001	0.7570	<0.0001
SF × SL					
Native starch × 2.5%	15.50	1799.03	0.199	930.84	0.175
Native starch × 5%	17.35	1823.55	0.183	950.51	0.160
Pregelatinized starch × 2.5%	18.57	1707.70	0.278	864.99	0.240
Pregelatinized starch × 5%	20.45	1731.71	0.262	886.32	0.218
P value	<0.0001	0.4306	<0.0001	0.5136	<0.0001
SF × SS					
Native × corn starch	15.60	6642.08	0.226	918.16	0.195
Native × potato starch	15.60	6593.71	0.264	902.65	0.235
Native × rice starch	15.81	6532.86	0.287	859.80	0.251
Pregelatinized × corn starch	17.64	6574.35	0.279	883.61	0.287
Pregelatinized × potato starch	17.69	6530.27	0.317	849.21	0.297
Pregelatinized × rice starch	17.83	6480.86	0.339	817.76	0.330
P value	0.9900	0.9798	1.0000	0.9575	0.0004

Values with different letters (a-c) within the same column are significantly different at $P < 0.05$.

in the cheese flow behavior index values upon the starch source could be ascribed essentially to the differences in the amylose contents of starches from different sources. Similar observations were reported by Karakelle et al. [24]. Moreover, the native starch administration caused the reformed cheeses to be more pseudoplastic than the cheeses reformed by the pregelatinized ones which were very close to control in their behaviors. That could be attributed to the interactions that occurred between the native starches and protein through gelatinization during cheese processing which in turn weakened the protein-protein bonds in the reformed cheeses matrices.

3.3. The Loss Tangent (Tan δ) of the Reformed Ras Cheese. The Tan δ is one of the important parameters to clarify the elastic or viscous properties of cheese. The obtained data of Table 4 revealed that all values were less than 1 and reflected the solid-like behavior. Moreover, the starch addition led to reduce the Tan δ of the reformed Ras cheese samples when compared to the control cheese regardless the adjusted set

Table 4: Ls means values for starch level (SL), starch source (SS), starch form (SF), SL × SS, SL × SF, and SS × SF on the Tan δ values at 0.628, 6.268, 31.416, and 314.16 rad/s of the reformed Ras cheese.

Source of variation	Tan δ			
	0.63 rad/s	6.27 rad/s	31.42 rad/s	14.16 rad/s
Starch level (SL)				
0% (control)	0.571^{a}	0.487^{a}	0.425^{a}	0.396^{a}
2.5%	0.556^{b}	0.465^{b}	0.406^{b}	0.356^{b}
5%	0.552^{b}	0.446^{c}	0.403^{b}	0.347^{b}
P value	0.0249	<0.0001	0.0046	<0.0001
Starch source (SS)				
Corn starch	0.561^{a}	0.466^{a}	0.411^{a}	0.367^{a}
Potato starch	0.558^{a}	0.466^{a}	0.410^{a}	0.367^{a}
Rice starch	0.561^{a}	0.465^{a}	0.411^{a}	0.365^{a}
P value	0.8471	0.9950	0.9798	0.9310
Starch form (SF)				
Native starch	0.537^{b}	0.460^{b}	0.407^{a}	0.351^{b}
Pregelatinized starch	0.583^{a}	0.472^{a}	0.415^{a}	0.381^{a}
P value	<0.0001	0.0340	0.1296	<0.0001
SS × SL				
Corn starch × 2.5%	0.557	0.465	0.407	0.356
Corn starch × 5%	0.556	0.447	0.403	0.350
Potato starch × 2.5%	0.557	0.466	0.405	0.358
Potato starch × 5%	0.546	0.445	0.401	0.347
Rice starch × 2.5%	0.556	0.464	0.405	0.355
Rice starch × 5%	0.556	0.446	0.405	0.344
P value	0.9471	0.9997	0.9993	0.9953
SF × SL				
Native starch × 2.5%	0.531	0.456	0.400	0.334
Native starch × 5%	0.510	0.437	0.396	0.325
Pregelatinized starch × 2.5%	0.582	0.474	0.412	0.378
Pregelatinized starch × 5%	0.595	0.455	0.410	0.369
P value	<0.0001	0.3086	0.5506	0.0022
SF × SS				
Native × corn starch	0.537	0.460	0.407	0.352
Native × potato starch	0.537	0.460	0.406	0.352
Native × rice starch	0.5373	0.459	0.407	0.350
Pregelatinized × corn starch	0.585	0.472	0.416	0.382
Pregelatinized × potato starch	0.578	0.472	0.415	0.381
Pregelatinized × rice starch	0.585	0.471	0.416	0.352
P value	0.8183	1.0000	0.9996	1.0000

Values with different letters (a-c) within the same column are significantly different at $P < 0.05$.

of frequency. The clearest trend in the Tan δ values was observed at the frequency set of 6.27 rad/s. However, the results elucidated that the effect of the applied starch source on the loss tangent of the reformed cheeses samples was insignificant. That could be ascribed essentially to the convergent ability of all starches to restrict water mobility in their containing gel systems. These phenomena agreed with the results of [25]. On the other hand, the native starches led to reduce the Tan δ values of the reformed cheese samples and hence to decrease their flowability when compared to the pregelatinized starches. That could be ascribed to the superior ability of the native starch to restrict the mobility of moisture in the protein matrix throughout strengthening the hydrophobic interactions and weakening the hydrogen bonds.

3.4. Texture Profile Analysis of the Reformed Ras Cheese. Data of Table 5 revealed that the application of starches to reform the trims of Ras cheese led to reduce the hardness of the final samples as compared to control. That could be due to the decrease in the protein content of the final reformed cheese product that occurred through water and

Table 5: Ls means values for starch level (SL), starch source (SS), starch form (SF), SL × SS, SL × SF, and SS × SF on the textural functional properties of the reformed Ras cheese.

Source of variation	Hardness (g)	Cohesiveness	Fracturability (g)	Gumminess (g)	Springiness (mm)	Adhesiveness (mJ)	Sliceability (gf)
Starch level (SL)							
0% (control)	672.24^{a}	0.782^{a}	665.24^{a}	525.93^{a}	7.050^{a}	0.039^{c}	486.34^{a}
2.5%	460.96^{b}	0.570^{b}	445.14^{b}	262.02^{b}	5.376^{b}	0.154^{a}	322.21^{b}
5%	437.02^{c}	0.495^{c}	433.15^{c}	215.41^{c}	5.011^{c}	0.129^{b}	317.82^{c}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Starch source (SS)							
Corn starch	532.70^{a}	0.586^{c}	525.77^{a}	325.85^{b}	5.581^{c}	0.100^{c}	375.43^{a}
Potato starch	513.57^{c}	0.601^{b}	506.15^{c}	322.81^{b}	5.730^{b}	0.115^{a}	375.43^{a}
Rice starch	523.96^{b}	0.661^{a}	511.61^{b}	354.69^{a}	6.126^{a}	0.106^{b}	375.52^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.9662
Starch form (SF)							
Native starch	528.69^{a}	0.541^{b}	513.41^{b}	303.69^{b}	5.362^{b}	0.155^{a}	383.71^{a}
Pregelatinized starch	518.13^{b}	0.690^{a}	515.61^{a}	365.21^{a}	6.263^{a}	0.059^{b}	367.20^{b}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SL × SS							
2.5% × corn starch	474.23	0.553	461.28	261.62	5.075	0.143	317.68
2.5% × potato starch	451.63	0.422	450.78	190.01	4.620	0.120	322.26
2.5% × rice starch	443.82	0.539	430.07	238.76	5.285	0.170	318.18
5% × corn starch	424.64	0.480	423.15	203.74	4.855	0.137	321.76
5% × potato starch	464.84	0.617	444.07	285.67	5.770	0.151	317.61
5% × rice starch	434.80	0.583	425.51	252.48	5.560	0.130	322.61
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.7269
SL × SF							
2.5% × native starch	469.37	0.453	437.84	212.71	4.696	0.221	330.75
2.5% × pregelatinized starch	444.46	0.389	437.16	172.43	4.340	0.206	334.05
5% × native starch	452.56	0.687	452.44	311.32	6.056	0.088	304.90
5% × pregelatinized starch	429.58	0.602	429.14	258.39	5.683	0.052	310.37
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SF × SS							
Native × corn starch	537.90	526.90	0.519	297.69	5.430	0.146	383.71
Native × potato starch	518.94	506.47	0.548	302.58	5.306	0.170	383.71
Native × rice starch	529.236	506.86	0.556	310.81	5.350	0.149	383.72
Pregelatinized × corn starch	527.50	524.63	0.652	354.02	5.733	0.055	367.15
Pregelatinized × potato starch	508.20	505.83	0.653	343.05	6.153	0.060	367.15
Pregelatinized × rice starch	518.69	516.36	0.765	398.57	6.903	0.063	367.32
P value	0.9173	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.9769

Values with different letters (a-c) within the same column are significantly different at $P < 0.05$.

starch addition during making. The applied starch source affected the hardness of cheese significantly, where the corn starch reformed cheeses obtained the highest hardness, followed by the rice starch cheeses and then the potato starch ones. That could be due to the considerably high amylose content of corn starch which is capable for forming relatively strong network [26]. Cheeses made with the pregelatinized starches were characterized with lower hardness degree than those made with the native starches. That could be attributed to the role of the pregelatinization process in weakening the internal molecular hydrogen bonds leading to amylose molecules leaching and hence reducing the moisture holding strength as previously concluded by Ma et al. [19]. Cohesiveness is a parameter for measuring

Table 6: Ls means values for starch level (SL), starch source (SS), starch form (SF), SL × SS, SL × SF, and SS × SF on the meltability and shredability profiles of the reformed Ras cheese.

Source of variation	Melt distance (mm)	Free oil (% of total fat)	Adhered cheese weight (g/ 500 g)	Cheese fines weight (g/ 500 g)	Shredding efficiency (%)
Starch level (SL)					
0% (control)	53.45[a]	23.59[a]	25.65[c]	18.23[a]	91.22[a]
2.5%	38.33[b]	22.88[b]	66.12[a]	9.67[b]	84.84[c]
5%	35.71[c]	21.71[c]	56.71[b]	6.81[c]	87.29[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Starch source (SS)					
Corn starch	40.25[c]	21.65[c]	45.49[c]	12.74[a]	88.35[a]
Potato starch	44.11[a]	23.71[a]	52.78[a]	10.34[c]	87.37[c]
Rice starch	43.13[b]	22.82[b]	50.21[b]	11.63[b]	87.62[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Starch form (SF)					
Native starch	37.26[b]	23.86[a]	58.16[a]	12.23[a]	85.91[b]
Pregelatinized starch	47.73[a]	21.59[b]	40.82[b]	10.90[b]	89.65[a]
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SS × SL					
Corn starch × 2.5%	34.98	20.93	60.44	11.60	85.59
Corn starch × 5%	32.34	20.44	50.38	8.38	88.24
Potato starch × 2.5%	41.07	24.23	70.42	7.27	84.46
Potato starch × 5%	37.81	23.32	62.27	5.51	86.44
Rice starch × 2.5%	38.94	23.49	67.49	10.14	84.47
Rice starch × 5%	37.00	21.38	57.49	6.54	87.19
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SF × SL					
Native starch × 2.5%	30.37	23.97	77.53	10.94	82.30
Native starch × 5%	27.96	24.02	71.32	7.54	84.22
Pregelatinized starch × 2.5%	46.28	21.80	54.71	8.40	87.37
Pregelatinized starch × 5%	43.47	19.40	42.10	6.08	90.36
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SF × SS					
Native × corn starch	37.44	24.56	53.77	13.63	86.51
Native × potato starch	38.89	24.98	63.93	10.76	85.06
Native × rice starch	35.44	22.04	56.80	12.31	86.17
Pregelatinized × corn starch	43.06	18.74	37.21	11.84	90.18
Pregelatinized × potato starch	49.33	22.44	41.62	9.92	89.69
Pregelatinized × rice starch	50.81	23.60	43.62	10.96	89.08
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values with different letters (a-c) within the same column are significantly different at $P < 0.05$.

the ability of cheese to adhere with each other; moreover, to obtain a cheese that slices easily, with minimum matting, a moderate cohesion is desirable. The results of cohesiveness indicated that the starch application led to decrease the cohesiveness of the reformed Ras cheese than the control Ras cheese in a level-dependent manner. That could be due to increasing the porosity of the protein matrix that occurred by the presence of starch. Moreover, the starch source affected the cheese cohesiveness significantly as the corn starch reformed cheeses obtained the lowest cohesiveness, followed by the potato starch cheeses and then the rice starch ones which were the most cohesive ones of the reformed samples. That could be due to the relatively small diameter of the roughly spherical granules of rice starch which had a limited swilling capacity and hence caused the lowest disruption to the reformed cheese protein network. Likewise, the pregelatinized starches helped to maintain the cohesiveness of the reformed cheese samples near to the control Ras cheese. These results were consistent with the results of Butt et al. [27] who concluded that replacing fat with pregelatinized starch in the imitation Mozzarella cheese helped in increasing the cohesiveness. Concerning the fracturability degrees, the added starches led to decrease the fracturability of the reformed cheeses than the control, as the lowest fracturability was for cheeses reformed by 5% starch. That could be due to the emulsifying capacity of the applied starches which caused some structural stabilization to the protein matrix. Moreover, these structural vibes were expected to be like the effect of emulsifying salts but without their adverse effects on the original cheese texture. Amongst the studied starch types, the corn starch led to obtain the most fracture cheese, possibly due to the comparatively low cohesiveness of the cheeses reformed by corn starch. The native starch cheeses were distinguished with lower fracturability than the pregelatinized ones, possibly due to the effect of the pregelatinization process in damaging the semicrystalline regions of starch and hence weakening the structure. The gumminess of cheeses took the same trends as hardness towards the factor of starch level. Moreover, the differences upon the starch source were very little; however, the rice starch cheeses gained the highest significant gumminess in comparison with the other starches. That could be the relatively high cohesiveness caused by the rice starch. Likewise, the pregelatinized starch cheeses were gummier than the native starch ones. The starch addition also decreased the springiness of cheeses because of the reduction of protein and fat. The rice starch cheeses were distinguished by the highest springiness degree of all starch containing reformed cheeses, and their springiness degrees were very close to the control Ras cheese. That could be ascribed essentially to the particle size and morphology of the rice starch granules as previously mentioned. The pregelatinized starch application led to obtain reformed cheeses with higher springiness than when the native starch was applied. Concerning the adhesiveness of cheese, the reformation of cheese trims with starches led to obtain cheeses with higher adhesiveness values than the control cheese. That could be due to the comparatively low moisture and high protein and fat contents of the control which helped with the pressing process in much effective distribution of moisture in the protein matrix of cheese. Likely, the corn starch cheeses were the lowest adhesive ones, followed by those of rice starch, while potato starch cheeses were characterized with the highest adhesiveness degrees of all starch reformed cheese samples. Moreover, the pregelatinized starches caused to decrease the adhesiveness of cheeses when compared to the native ones, possibly due to that pregelatinized starches offer the lowest interactions with protein and hence localize between protein strands and increase the distance between strands leading to enhance moisture distribution and fat emulsification. Regarding cheese sliceability which was defined as the hard cheese ability to be cut cleanly into thin slices, with minimum breakage at edges, the obtained results revealed that starch application led to improve and facilitate the sliceability of the reformed Ras cheese as compared to control as the force required to cut the cheese blocks into sliced was reduced significantly [28]. The obtained results revealed that starch application led to improve and facilitate the sliceability of the reformed Ras cheese as compared to control as the force required to cut the cheese blocks into sliced was

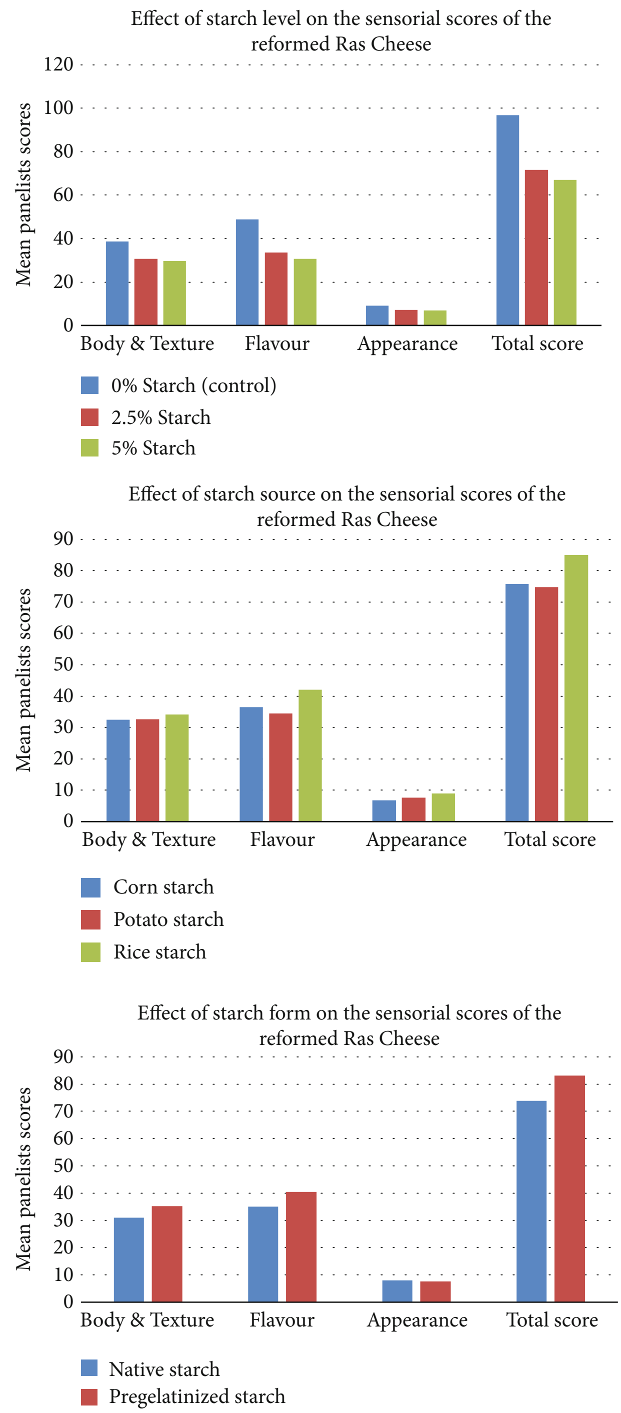

FIGURE 2: Effect of starch level, source, and form on the sensorial scores of the reformed Ras cheese ($\alpha = 0.05$).

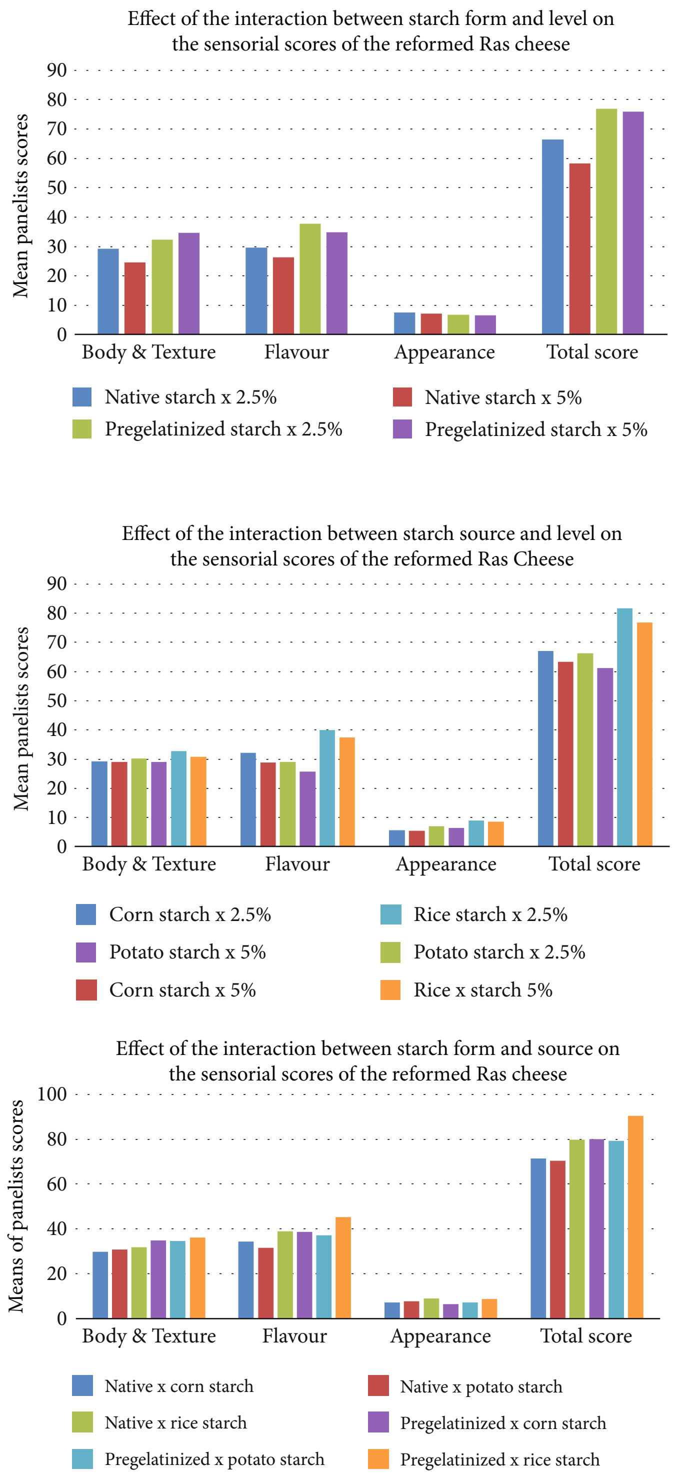

FIGURE 3: Effect of the interaction between the studied factors on the sensorial scores of the reformed Ras cheese ($\alpha = 0.05$).

reduced significantly. That could be ascribed to the role of starches in making the texture more open with much effective water distribution and oil emulsification. The statistical analysis confirmed that all starches improved cheese sliceability regardless of the starch source. The pregelatinized starch cheese samples were more sliceable than those of the native starch.

3.5. Meltability and Shreddability Profiles of the Reformed Ras Cheese. Data of Table 6 elucidated that the melt distance values of cheese samples were decreased by increasing the level of starch added to reform the cheese trims. Amongst the studied starch sources, the potato starch application was associated with the highest melt distance values, while corn starch produced cheeses with considerable low meltability. That could be due to the relatively low hardness degrees of the potato starch cheese samples. Nevertheless, the melt distance was increased significantly in the pregelatinized starch reformed cheese samples as compared to the native starch reformed ones. The free oil contents were decreased by the application of starches, possibly due to the considerable emulsifying capacity of starch as well as the opened structure occurred through processing. The corn starch cheeses showed the lowest free oil contents of all starch containing samples, followed by the rice starch ones, while those of potato starch obtained the highest free oil contents. The native starch cheeses were characterized with higher free oil contents than the pregelatinized ones. These observations were supported by the findings of [6]. With respect to the shreddability of cheese, the results indicated that cheeses made with 5% starch produced the highest adhered cheese weights, while the control produced the lowest amount. Moreover, potato starch caused the cheese to produce the highest adhered cheese weights, while corn starch cheeses were distinguished with the lowest adhesion to the shredder blades. The pregelatinized starch cheeses caused lower adhesion to the blades than the native starch ones. Concerning the lost cheese as fines during shredding, the results indicated that the lost fines were decreased with the increase in added starch levels, possibly due to the decrease in hardness degrees. Likewise, corn starch cheeses were associated with the highest shredding fines, followed by the rice starch cheeses, while those of potato starch came in the latest order producing the lowest significant amounts of cheese fines. Moreover, native starches increased the lost cheese as fines when compared to the pregelatinized ones. Regarding the comprehensive shredding indicator, i.e., the percentage of shredding efficiency, data demonstrated that the control cheese obtained the highest score, while the reformed samples with 5% starch had higher shredding efficiency scores than those with 2.5% starch. The corn starch reformed cheeses gained the highest shredding efficiency of the reformed samples, followed by rice and potato starch cheeses, respectively. Moreover, pregelatinized starches were more effective than native ones in enhancing the overall shreddability of the reformed Ras cheese samples.

3.6. Sensory Evaluation of the Reformed Ras Cheese. As declared in Figures 2 and 3, the reformed Ras cheese samples obtained slightly lower scores than the control Ras cheese in all studied sensorial characteristics. The reformed samples with 2.5% starch level gained relatively higher scores in all criteria compared to the samples of 5% starches. Regarding the body and texture scores, the rice starch cheese samples attracted the attention of the panelists and took the highest preference, possibly due to their moderate hardness as well as their relatively high cohesiveness and springiness, as confirmed by the instrumental texture analysis. Moreover, the applied starch source affected the flavour scores significantly ($\alpha = 0.05$); the rice starch cheese samples gained the highest-ranking scores, whereas the potato starches ones took the lowest degrees. Moreover, the corn starch reformed cheeses suffered from slightly noticeable starchy after taste, especially when the high level was applied. The rice starch cheese samples attained the highest appearance degrees compared to the other starch sources cheeses and were the nearest ones to the control, followed by the potato and corn starch ones. Regarding the total sensorial scores, rice starch cheeses gained the highest degrees, followed by potato and corn starch cheese samples. Cheeses with the pregelatinized starches gained higher body and texture scores than those made with the native form of starches, as the pregelatinized starches offered body very similar to the conventional control cheese. Moreover, the application of pregelatinized starches was associated with higher flavour scores than the native ones. This observation was supported by the previous results of Azaripour and Abbasi [29] who reported that the application of pregelatinized corn starch was associated with increasing the taste acceptability of low protein biscuits. Regarding the appearance scores, the native starch cheeses were more preferable than the pregelatinized starch ones, as the native starch enriched the waxy appearance of the cheese. However, the pregelatinized starches enhanced the overall acceptability of the reformed Ras cheese product.

4. Conclusion

The foregoing results led to conclude that the reformed Ras cheese product may form a new style of cheese economical production which reuses the trim losses of the conventional hard cheese to make a new product apart from processed cheese and similar to the conventional cheese in its rheological and sensorial characteristics. Pregelatinized starches especially rice and corn ones could be used to reform the hard cheese trim losses and enhance the overall acceptability as a safe substitute of Ras cheese.

Data Availability

Data is available upon request to the author.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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