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Research Article
Impact of Different Food Protein Sources in Processed Cheese Sauces Manufacture

[1]Suhila A. Saad, [1]Laila D. EL-Mahdi, [2]R.A. Awad and [2]Z.M.R. Hassan

[1]Food Technology Research Institute (FTRI), Agricultural Research Center, Giza, Egypt
[2]Department of Food Science, Faculty of Agriculture, Ain Shams University, Cairo, Egypt

Abstract
Milk Protein Concentrate (MPC), Total Milk Proteinate (TMP), UF-Retentate Curd (UF-RC), Skim Milk Powder (SMP) and Soy Protein Concentrate (SPC) as a new different sources of proteins were investigated in this study, not only to substitute ras cheese in base blends of cheese sauces but also to successfully produce delicious and favourable cheese sauces with highly acceptable moisture/texture profile, shelf stable and high sensory quality. All blends were adjusted to contain 25% dry matter, 40% F/DM in the finished product of processed cheese sauces. Stabilizing system was added to the final product formulas as a mixture of corn starch and guar gum. All produced cheese sauces treatments were acceptable. Cheese sauce UF-RC treatment showed the highest acceptability. Moreover, cheese sauce samples with MPC and TMP were not significantly different from that with UF-RC. All resultant processed cheese sauces were evaluated when fresh and after one and three months of storage either at 5±2°C or 25±2°C for chemical properties and examined also for pH, oil separation index, viscosity and sensory properties. Three replicates were carried out for each treatment and the data obtained were statistically analyzed at $p \leq 0.05$.

Key words: Processed cheese sauces, MPC, TMP, UF-RC, SMP, SPC, corn starch, guar gum

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Corresponding Author: Suhila A. Saad, Food Technology Research Institute (FTRI), Agricultural Research Center, Giza, Egypt

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cheese sauce is a novel cheese product now-a-days, not only for being an attractive appetizer but also for being perceived as a first course or a side dish and rather as an ingredient entire, meant to stand by itself. Several dishes and foods such as chicken, beef, barbecue or seafood, pizza, macaroni and sandwiches have a unique delicious flavour when cheese sauce was added. Cheese sauce product should exhibit adequate stability in the pouch including good squeezability and emulsion stability (Gamay *et al*., 2011). More uniform particle sizes and flowable end product resulted from the cheese power. Natural cheese may play an increasingly important role in cheese sauces formula for a number of reasons. Cheese which provides a solid base in which a number of ingredients can be incorporated can add texture and viscosity, act as a flavor carrier while, releasing other flavours, contribute dairy notes and enhance visual appeal. (Pszczola, 2000). Nevertheless, most of cheese sauce varieties in the market are including cheese as cheese powder or just cheese flavour. As a result of the ongoing research, today there are several options available for manufacturing cheese sauce that have improved performance and taste. Out of such an approach have come several novel ingredients to replace natural cheese for use in the development of new cheese sauces. The functionality and nutritive value of dairy based ingredients can help to enhance the value of sauces as well as stimulate the development of future products. Milk proteins provide a number of key functions that facilitate successful manufacture of milk products (Morr, 1985). Because of consumer growing interest in especial cheese, cheese processors especially can help lead the way in incorporating soy into their products (Pszczola, 2001). Soy protein providing in significant levels can be combined with a cooked starch-based product (Carpenter *et al*., 2005). Attractive or repulsive interactions between proteins and polysaccharides can be used to create microstructures that give foods novel textural and sensory properties (McClements, 2006). The combination of protein and polysaccharide delivers a range of properties to emulsions, physicochemical stability, storage stability, texture and mouth-feel (Sun *et al*., 2007).

Therefore, in this study different sources of proteins were investigated not only to substitute ras cheese in base blends of cheese sauces but also to successfully produce delicious and favourable cheese sauces formulas with highly acceptable moisture/texture profile, shelf stable and high sensory quality.

MATERIALS AND METHODS

Practical experiments were conducted at Food Technology Research Institute (FTRI), Agricultural Research Center, Giza, Egypt and Food Science Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt, during January-April 2011.

Materials: Ras cheese was purchased from the local market, Cairo, Egypt. Fresh cow's milk from the herd of the High Institute of Agricultural Cooperation, Cairo, Egypt was used in this study. Fresh UF-retentate was procured from Animal Production Research Institute, Agriculture Research Center, Dokki, Egypt. Skim Milk Powder (SMP) used in this study was obtained from Dina farmer, Cairo, Egypt. Milk Protein Concentrate (MPC) was obtained from Master Trade Co., Giza, Egypt. Soy Protein Concentrate (SPC) from Nantong Sun-Green Bio-Tech. Co., China was used. Corn starch was obtained from the starch and glucose company, Cairo, Egypt. Guar gum used in this study was obtained from Gumix International, Inc., Fort Lee, NJ. Butter oil brand name NZ was imported from New Zealand Dairy Board, Wellington, New Zealand and was purchased from the local market, Cairo, Egypt. Calf rennet powder from Chr. Hansen's Laboratories, Denmark, was used as coagulant. Commercial fine grade sodium chloride NaCl was obtained from EL-Nasr Salines Co., Alexandria, Egypt. Commercial emulsifying salt S_9special were obtained from JOHA BK Ladenburg corp., GmbH, Ladenburg, Germany. Nisin used as preservative in this study was produced by Zhejiang silver elephant Bio-Engineering Co., China and was obtained from Amson international trading, Giza-Egypt.

Methods of manufacture

Total milk proteinate preparation: Total Milk Proteinate (TMP) was prepared according to the method described by Morr (1985).

Preparation of UF-Retentate Curd (UF-RC): Soft cheese curd was manufactured using UF-retentate according to the method described by Suhila (2002).

Processed cheese sauce manufacture: Ras cheese blocks were cut into small portions suitable to be fed through the inlet of a shredding machine (Braun mincer, Germany). Shredded cheese was milled in milling machine, (National, Japan). Suitable amounts of ras cheese, different food protein

sources, skim milk powder, butter fat, NaCl, nisin, stabilizing system (corn starch+guar gum) and emulsifying salt were added consecutively in a laboratory style-processing Kettle locally made in Egypt. Control treatment was adjusted to have the same composition without adding food protein sources. Specifications of the cooking machine were previously mentioned by Awad (1996). The ingredients were mixed for about 1 min before processing. The mixture was cooked for 10 min at 85-90°C using indirect heated steam at pressure of 1.5-2.0 kg cm^{-2}. Melted processed cheese sauce was purred into glass jars (150 g) and capped directly after filling. The resultant cheese sauces were cooled at room temperature before storage.

Methods of analyses

Chemical analysis: Cheese sauce samples were tested for moisture, fat, salt and ash contents as mentioned by AOAC (2005). Total Nitrogen (TN) and Soluble Nitrogen (SN) contents were measured using the semi micro-Kjeldal method according to the method described by Ling (1963). Total Volatile Fatty Acids (TVFA) value was determined according to the method described by Koiskowski (1982) and values were expressed as ml of 0.1 N NaOH/100 g cheese sauce.

Physicochemical properties: Values of pH were measured using the electric HANNA instrument pH 213 microprocessor pH meters by inserting the pH combined glass electrode (Electric Instruments limited) directly in the sample. Values of pH were reported to nearest 0.01 units.

Physical properties: Oil Separation Index (OSI) of processed cheese sauces was determined as described by Thomas (1973). Viscosity of processed cheese sauces samples was measured according to Viturawong *et al*. (2008) using a coaxial rotational viscometer, Brookfield Engineering laboratory DV-III ultra-rheometer, at shear rates ranging from 12.411-74.467 sec^{-1}. The measuring device spindle (HA-07) was used with a sample volume of 110 g per run. The apparent viscosity was recorded at all shear rates.

Sensory evaluation: Sensory evaluation was carried out according to the scheme of Meyer (1973). The evaluation was done by regular scoring panel members of Food Science Department, Faculty of Agriculture, Ain Shams University and Dairy Department, Food Technology Research Institute, Agricultural Research Center.

Statistical analysis: Statistical analysis at $p \leq 0.05$ was performed according to SAS (2006) using General Linear Model (GLM). Duncan's multiple rang was used to separate among means of three replicates of samples.

RESULTS AND DISCUSSION

Chemical composition

Total Solids (TS) and Fat/Dry Matter (F/DM) contents: Total solids contents of processed cheese sauces with different protein sources were determined and presented in Table 1. Total solids ranged from 25.96% in processed cheese sauce with MPC to 25.23% in processed cheese sauce with TMP. Control processed cheese sauce showed total solids content of 25.46%.

Fat/dry matter ratios are also presented in Table 1 and showed a range from 40.86% in control processed cheese sauce to 40.00% in processed cheese sauce with MPC. Total solids and fat/dry matter were adapted when the formulas of all blends were prepared before processing to be 25 and 40% consecutively in the resultant processed cheese sauces. The slight differences among all treatments could be due to the slight differences in the ingredients weight when formulating the blends.

Total Nitrogen (TN) content: Total nitrogen values of different processed cheese sauces with different protein sources are shown in Table 1. The data indicated that TN values of processed cheese sauces were 1.43, 1.55, 1.45, 1.24, 0.94 and 1.11 for the control processed cheese sauce and cheese sauces with MPC, TMP, UF-RC, SMP and SPC, respectively. The obtained data showed that processed cheese sauce with MPC has the highest TN content and processed cheese sauce with SMP had the lowest comparing with other sauces. The differences among all resultant sauces could be due to the differences in TN content of ingredients the main source of protein in the formulas.

Ash content: Ash content of processed cheese sauces with different protein sources are also shown in Table 1. Ash content of processed cheese sauces values were 2.85, 2.96,

Table 1: Chemical composition (%) of processed cheese sauces manufactured using different food protein sources

Treatments	Total solids	F/DM	Total nitrogen	Ash	Salt/moisture
Control	25.46	40.86	1.43	2.85	1.27
MPC	25.96	40.00	1.55	2.96	1.09
TMP	25.23	40.46	1.45	2.82	1.06
UF-RC	25.35	40.56	1.24	2.83	1.07
SMP	25.76	40.54	0.94	2.92	1.08
SPC	25.45	40.17	1.11	2.84	1.05

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate

Table 2: pH values of processed cheese sauces manufactured using different food protein sources when fresh and during storage

		One month		Three months	
Treatments	Fresh	5°C	25°C	5°C	25°C
Control	5.75^{Ba}	5.70^{Aab}	5.65^{BCbc}	5.60^{Acd}	5.55^{Ad}
MPC	5.80^{ABa}	5.76^{Aa}	5.73^{Aa}	5.67^{Ab}	5.56^{Ac}
TMP	5.80^{ABa}	5.75^{Aab}	5.70^{ABb}	5.60^{Ac}	5.55^{Ac}
UF-RC	5.85^{Aa}	5.78^{Aab}	5.75^{Ab}	5.65^{Ac}	5.60^{Ac}
SMP	5.81^{ABa}	5.75^{Aa}	5.60^{Cb}	5.66^{Ab}	5.58^{Ab}
SPC	5.78^{ABa}	5.75^{Aa}	5.70^{ABa}	5.60^{Ab}	5.56^{Ab}

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate, ^{A,B,C}Means with the same letter among treatments in the same storage period are not significantly different, ^{a,b,c}Means with the same letter in the same treatment during storage periods are not significantly different

Table 3: Soluble nitrogen content (%) of processed cheese sauces manufactured using different food protein sources when fresh and during storage

		One month		Three months	
Treatments	Fresh	5°C	25°C	5°C	25°C
Control	0.890^{Ab}	0.957^{Aab}	1.019^{Aab}	1.045^{Aab}	1.125^{Aa}
MPC	0.609^{BCd}	0.735^{BCcd}	0.851^{Ad}	0.940^{ABab}	1.072^{ABa}
TMP	0.687^{BCc}	0.825^{ABCbc}	0.920^{Aab}	0.976^{ABab}	1.085^{ABa}
UF-RC	0.769^{ABb}	0.856^{ABb}	0.911^{Ab}	0.943^{ABab}	1.099^{ABa}
SMP	0.542^{Cc}	0.645^{Cc}	0.667^{Bbc}	0.827^{Bb}	1.043^{ABa}
SPC	0.221^{Dc}	0.357^{Dcb}	0.457^{Cb}	0.518^{Cb}	0.956^{Ba}

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate, ^{A,B,C}Means with the same letter among treatments in the same storage period are not significantly different, ^{a,b,c}Means with the same letter in the same treatment during storage periods are not significantly different

2.82, 2.83, 2.92 and 2.84% for the control processed cheese sauce and cheese sauces with MPC, TMP, UF-RC, SMP and SPC consecutively. The results indicated that processed cheese sauce with MPC had ash content being the highest, while processed cheese sauce with TMP had ash content being the lowest among all treatments. The differences in ash contents among all treatments including the control could be due to the differences in ash content of different ingredients used as a cheese substitute when formulating the blends.

Salt/moisture content: Table 1 illustrates the salt/moisture content of processed cheese sauces with different base blends. Salt/moisture ratio was 1.27 in the control processed cheese sauce while it was 1.09, 1.06, 1.07, 1.08 and 1.05 in processed cheese sauces with MPC, TMP, UF-RC, SMP and SPC, respectively. The highest salt/moisture content of the control processed cheese sauce could be related to the amount of ras cheese in the base formula since it contains the greater amount of ras cheese. Ras cheese used to formulate cheese sauces blends is the main source of salt due to that its manufacture process include a salting step which may contribute an amount of salt in the final product and that increased with increasing the amount of added ras cheese.

pH values: pH values of different processed cheese sauces with different protein sources are stated in Table 2. From the data in the Table 2 it is clear that, there were no great differences among all resultant processed cheese sauces with different base blends. The values of the pH were in close range among all sauce treatments with different cheese base replacements. The pH values ranged from 5.85 in cheese sauce with UF-RC to 5.78 in cheese sauce with SPC. Control cheese sauce possessed a slightly lower pH value 5.75 comparing with other sauces. The differences in pH values of processed cheese sauces are mainly due to the different raw materials used in formulating the base blends. Ras cheese has lower pH value than that of other raw materials or other protein sources and therefore, a lower pH value in the blend with higher added ratio of ras cheese. This could be explaining the lower pH value in control cheese sauce since it contains greater ras cheese amount in the base blend.

During storage pH values of all treatments decreased by extending the storage period up to three months. The treatments stored at room temperature (25±2°C) were more affected and showed a greater decrease in pH values than that stored in the refrigerator (5±2°C). These changes in pH values during storage could be due to the hydrolysis of polymerized phosphate present in the emulsifying salts and their interaction with protein. The hydrolysis could be more extensive at room temperature which may cause more reduction in pH values of all treatments. These results agree with those of Awad (2003), El-Mahdi *et al*. (2014) and Saad *et al*. (2015).

Soluble Nitrogen (SN) content: Soluble nitrogen content of processed cheese sauces with different protein sources when fresh and during storage at (5±2°C) and (25±2°C) for three months are presented in Table 3. Soluble nitrogen content of processed cheese sauces made using ras cheese, MPC, TMP, UF-RC, SMP and SPC were 0.890, 0.609, 0.687, 0.769, 0.542 and 0.221% in order. These data indicated that control treatment with ras cheese showed the highest soluble nitrogen content, while, cheese sauce with SPC showed the significantly lowest content. These could be due to that, Ras cheese may had a higher soluble nitrogen content than other raw materials used. Hassan *et al*. (2007) mentioned that soluble nitrogen content decreased in processed cheese treatments by increasing the soy flour ratio in the base blend. Moreover, using SPC in formulating the cheese sauce produced a product with lowest soluble nitrogen content due to the protein forms in SPC which may be mostly in higher molecular weight. Bachmann (2001) mentioned that soy proteins are much larger in molecular size than milk proteins, possess complex quaternary structure and unlike casein,

Table 4: Total volatile fatty acids values (TVFA[n]) of processed cheese sauces manufactured using different food protein sources when fresh and during storage

		One month		Three months	
Treatments	Fresh	5°C	25°C	5°C	25°C
Control	14.67^{Ad}	16.78^{Ac}	17.61^{Ac}	24.64^{Ab}	29.30^{Aa}
MPC	8.56^{Ce}	10.44^{Cd}	12.42^{Cc}	16.20^{CDb}	19.69^{Da}
TMP	10.31^{CBc}	11.89^{CBc}	14.06^{CBb}	15.44^{Db}	21.07^{CaD}
UF-RC	11.08^{Be}	12.96^{Bd}	14.79^{Bc}	18.97^{Bb}	26.99^{Ba}
SMP	10.07^{CBd}	11.48^{CBd}	13.29^{CBc}	17.49^{Bb}	21.62^{Ca}
SPC	10.34^{CBd}	10.64^{Cd}	13.52^{CBc}	17.92^{CDb}	20.82^{CDa}

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate, [n]mL 0.1 N NaOH/100 g cheese, ^{A,B,C}Means with the same letter among treatments in the same storage period are not significantly different, ^{a,b,c}Means with the same letter in the same treatment during storage periods are not significantly different

Table 5: Oil separation index of processed cheese sauces manufactured using different food protein sources when fresh and during storage

		One month		Three months	
Treatments	Fresh	5°C	25°C	5°C	25°C
Control	17.87^{Aa}	12.92^{ABb}	10.50^{CBc}	8.39^{Ad}	6.45^{Be}
MPC	15.90^{Ba}	12.09^{Bb}	10.73^{CBcb}	9.37^{Bc}	6.75^{Bd}
TMP	16.78^{ABa}	11.93^{Bb}	9.30^{Cc}	7.73^{Bcd}	6.36^{Bd}
UF-RC	17.01^{ABa}	13.11^{ABb}	9.83^{CBc}	7.69^{Bd}	6.04^{Bd}
SMP	17.96^{Aa}	13.77^{ABb}	11.35^{Bc}	9.50^{Bd}	7.23^{Be}
SPC	12.26^{Ce}	14.44^{Ad}	24.45^{Ac}	35.45^{Bb}	41.59^{Aa}

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate, ^{A,B,C}Means with the same letter among treatments in the same storage period are not significantly different, ^{a,b,c}Means with the same letter in the same treatment during storage periods are not significantly different

they are not a phosphoprotein. In the other cheese sauce treatments where MPC, TMP, UF-RC and SMP were used as sources of protein a lower soluble nitrogen values obtained comparing with the control, since all of them are in the native milk protein form with negligible protein hydrolysis and thus lower the soluble nitrogen content.

Soluble nitrogen content gradually increased during storage in all cheese sauce treatments including the control especially when stored at room temperature. The increase occurred in soluble nitrogen content may be due to the enzymatic activity of heat resistant proteinases which could be more active at room temperature. The results agree with Awad *et al*. (2003), Hassan *et al*. (2007), El-Mahdi *et al*. (2014) and Hassan *et al*. (2015).

Total Volatile Fatty Acids (TVFA): Changes in total volatile fatty acids values of processed cheese sauces with different protein sources are shown in Table 4. Control cheese sauce treatment of ras cheese had total volatile fatty acids value of 14.67 while cheese sauces of MPC, TMP, UF-RC, SMP and SPC presented total volatile fatty acids values of 8.56, 10.31, 11.08, 10.07 and 10.34 mL NaOH 0.1 N/100 g cheese sauce in order. The data showed that control cheese sauce with ras cheese as a base blend has higher total volatile fatty acids value than that of other cheese sauces with different protein sources in the base blends. Among cheese sauces with protein sources, cheese sauce with UF-RC showed the highest total volatile fatty acids value meanwhile that with MPC had the lowest. Values of total volatile fatty acids in cheese generally and processed cheese sauces particularly are related mainly to the amount, type and statues of fat in the product. Fat hydrolysis could be occurred before in ras cheese during ripening due to its manufacture process, while other protein sources have no fat hydrolysis. Moreover, in all sauces formulas most of the fat amount has been added as fresh butter oil. This could be the reason of higher total volatile fatty acids value in control sauce.

Total volatile fatty acids values changed during storage period and increased in all processed cheese sauces including the control. The increase in total volatile fatty acids values differed from one sauce to another. After three months of storage, processed cheese sauce with UF-RC continued to show the highest value of total volatile fatty acids among all sauces with other protein sources at both degrees of storage being highest at room temperature. These results are in agreement with Othman *et al*. (2005), Hassan *et al*. (2015) and Saad *et al*. (2015).

Oil Separation Index (OSI): Oil separation index values of processed cheese sauces with different protein sources in base blends are recorded in Table 5. The recorded data were 17.87, 15.90, 16.78, 17.01, 17.96 and 12.26 for control, MPC, TMP, UF-RC, SMP and SPC, respectively. It is clear that, the differences among all cheese sauces were significant when compared to each other. Among all treatments processed cheese sauce with SMP had the highest oil separation index value while that with SPC had the lowest. The lower values of oil separation in cheese sauces could be related to the high stability of the emulsion and good fat emulsification in the matrix. Cheese sauce treatment with SPC was different from the other treatments including the control, it was the only one manufactured using a plant protein while others were manufactured using milk proteins.

During storage period of cheese sauces treatments, there were a different trend among all stored samples. The treatment of SPC showed gradual increase in oil separation index values being higher at the higher storage temperature. On the other hand, all other treatments with milk protein sources including the control showed a decrease in oil separation index values up to the end of the storage period.

These results are in agreement with Saad *et al*. (2015). The UF-retentate curd treatment showed the lowest oil separation index value among all treatments up to the end of the storage period. As mentioned above processed cheese sauce contain SPC was the only one with plant protein while other sauces were contain milk proteins. This could be due to SPC is a plant protein not contain casein and not had the ability to retain fat inside as a reason of fat separation especially when the storage period and the temperature were increased (Bachmann, 2001; Hassan *et al*., 2007). Otherwise, milk proteins containing casein that has ability to make a matrix and has ability to make interactions with stabilizing system due to more ability to retain fat in the emulsion and reduce oil separation index values during storage (Heyman *et al*., 2010).

Viscosity: Differences in viscosity values of processed cheese sauces with different protein sources in the base blends at different shear rates are illustrated in Fig. 1. From the Table 5 it can be observed that, the use of different protein sources in formulating processed cheese sauces blends had affected the viscosity of the resultant products. The flow behaviour data of the viscosity at different shear rates revealed that the viscosity were decreased in all treatments by increasing the shear rates through changing the viscometer speed to higher levels. At shear rate 37.233 sec^{-1} the viscosity values were 1600, 4933, 2000, 3067, 1733 and 6800 cP for control processed cheese sauce and sauces with MPC, TMP, UF-RC, SMP and SPC, respectively. Viscosity values of fresh sauce samples cleared that cheese sauce treatment with SPC had the highest viscosity at all shear rates comparing with all other treatments, while treatment with MPC had the highest viscosity comparing with treatments with added milk protein sources including the control. On the other hand, control treatment with ras cheese showed the lowest viscosity values among all cheese sauce treatments. The lower viscosity value in control cheese sauce could be due to the type and nature of protein in the base formula since the stabilizing system added was the same in all treatments. The proteins of ras cheese might be slightly hydrolyzed during ripening and therefore give a lower viscosity. There were no hydrolysis in proteins forms of other protein sources added in cheese sauces formulas which may explain the higher viscosity values in all of them than the control. The differences in viscosity values among sauce treatments with protein sources were related to the protein state and ratio and soluble matters in the source of added protein. For example, higher viscosity values in treatment with MPC could be due to that milk proteins are a colloidal material and may play a role as thickening agents to bind more water than soluble material, while lower viscosity in treatment with skim milk powder could be due to the higher lactose and ash content which being soluble matters and thus could lower the viscosity. Noisuwan *et al*. (2008) mentioned that the addition of MPC increased the viscosity values than the addition of SMP in the past with starch and these could be due to the diffusion of lactose present in SMP into the starch granules which affected their swelling behaviour and lower the viscosity.

After three months of storage processed cheese sauces with different protein sources in base blend samples were exhibited different viscosity values when stored in the refrigerator from that stored at room temperature. In control processed cheese sauce sample and that with TMP and SPC viscosity increased to higher values at refrigerator and being more higher at room temperature. Meanwhile, in processed cheese sauce with UF-RC and that with SMP viscosity changed to decrease and being lower at room temperature. The increase in viscosity values could be revert to the interaction between milk protein and the stabilizing system meanwhile, the decrease could be due to the presence of lactose and also could be due to the hydrolysis in proteins. Considine *et al*. (2011) mentioned that no clear trend in viscosity is evident when starch is added to the casein, in some instances viscosity increased and in others it decreased. Moreover, the role of ions and lactose within milk protein must be also considered as they can influence the final properties of the protein-starch mixture.

Sensory evaluation: Sensory evaluation of processed cheese sauces with different protein sources in base blends are reported in Table 6. Fresh samples of control, MPC, TMP, UF-RC, SMP and SPC processed cheese sauces scored 18, 18.5, 19, 19, 18 and 17 points for outer appearance. These scores proved that sauces with TMP and UF-RC possessed the highest points and were the most bright and shiny comparing with all other sauces. Cheese sauce sample with SPC scored the lowest points for outer appearance and was less preferable to the panelists. Sample with SPC can be described to be as a pasty like with dull yellow colour, less shiny than other samples. For the inner appearance which was expressed by "Body and texture" the samples of processed cheese sauces with MPC, TMP, UF-RC, SMP, SPC or the control scored 37, 38, 38.5, 38.5, 37.5 and 36 points, respectively. These data proved that cheese sauce with TMP and UF-RC showed the best body and texture. The body of cheese sauce samples with TMP and UF-RC were very smooth, more homogenous and flowable than other treatments. Cheese sauce treatments of control and SMP exhibited a less viscous, more thin body with high flow ability and can be used as cheese dips. Processed cheese sauce with SPC had an inner appearance with no flow ability,

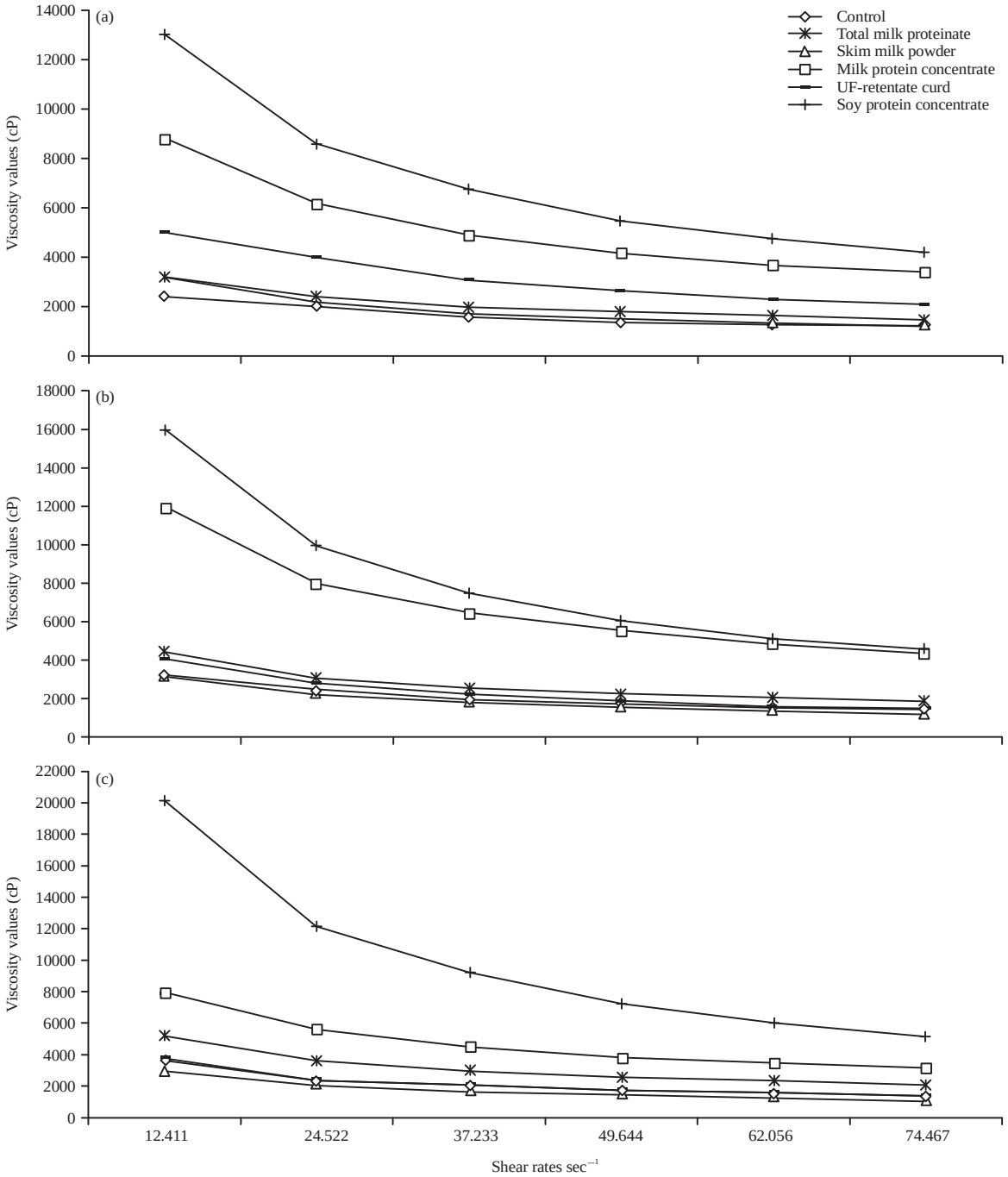

Fig. 1(a-c): Viscosity values (cP) of processed cheese sauces manufactured using different food protein sources when fresh and after three months of storage, (a) Fresh, (b) 3 months at 5°C and (c) 3 months at 25°C

so it was not convenient to be a sauce or a dips, it was more like a paste. Sensory scores of aroma and flavour of processed cheese sauces with different protein sources in base blends exhibited that the sauce of UF-RC scored the highest with balanced and attractive flavour followed by the sauce with TMP. Sauce with SMP had a slight sweet taste which may be attributed to the natural presence of lactose with high percentage in skim milk added to formulate the base blend of the sauce. The control processed cheese sauce had a flavour of mature ras cheese being less favourable for panelists. Sauce of SPC had an oily and beany flavour that was not attractive and less preferable to panelists. The total scores of sensory quality attributes for cheese sauces with different protein sources were 92.0 points for control sample compared

Table 6: Sensory evaluation of processed cheese sauces manufactured using different food protein sources when fresh and during storage

Storage			Treatments					
Period	Temperature	Character assessed	Control	MPC	TMP	UF-RC	SMP	SPC
Fresh		O.A. (20)	18.0^{Ba}	18.5^{ABa}	19.0^{Aa}	19.0^{Aa}	18.0^{Ba}	17.0^{Ca}
		B and T (40)	37.0^{ABa}	38.0^{Aa}	38.5^{Aa}	38.5^{Aa}	37.5^{ABa}	36.0^{Ba}
		A and F (40)	37.0^{BCa}	38.0^{ABa}	38.5^{ABa}	39.0^{Aa}	37.5^{ABCa}	36.0^{Ca}
		T (100)	92.0^{ABa}	94.5^{Aa}	96.0^{Aa}	96.5^{Aa}	93.0^{ABa}	89.0^{Ba}
	5°C	O.A. (20)	18.0^{Ba}	18.5^{ABa}	19.0^{Aa}	19.0^{Aa}	18.5^{ABa}	17.0^{Ca}
		B and T (40)	37.0^{ABa}	38.0^{Aa}	37.5^{ABab}	38.0^{Aa}	37.0^{ABab}	36.0^{Ba}
		A and F (40)	37.0^{Ba}	38.0^{ABa}	38.5^{ABa}	39.0^{Aa}	37.0^{Bab}	36.0^{Cab}
1 Month		T (100)	92.0^{ABa}	94.5^{Aa}	95.0^{Aab}	96.0^{Aa}	92.5^{ABa}	89.0^{Bab}
	25°C	O.A. (20)	17.0^{Bb}	18.0^{Aab}	18.5^{Aa}	18.5^{Aab}	18.0^{Aa}	16.5^{Ba}
		B and T (40)	36.5^{ABab}	37.5^{Aab}	36.5^{ABbc}	37.5^{Aab}	36.5^{ABab}	35.5^{Bab}
		A and F (40)	36.5^{BCab}	37.5^{ABab}	38.0^{ABa}	38.5^{Aa}	36.5^{BCab}	35.0^{Cab}
		T (100)	90.0^{ABab}	93.0^{Aab}	93.0^{Aab}	94.5^{Aab}	91.0^{ABab}	87.0^{Bab}
3 Months	5°C	O.A. (20)	16.5^{Cb}	17.5^{ABbc}	17.5^{ABb}	18.0^{Abc}	17.0^{BCb}	15.0^{Db}
		B and T (40)	36.0^{ABab}	37.0^{Aab}	36.0^{ABab}	37.0^{Aab}	36.0^{ABab}	35.0^{Bab}
		A and F (40)	36.0^{Bab}	37.0^{ABab}	37.0^{ABab}	38.0^{Aab}	36.0^{Bab}	34.0^{Cb}
		T (100)	88.5^{Aa}	91.5^{Aab}	90.5^{Abc}	93.0^{Aab}	89.00^{Aab}	84.0^{Bbc}
	25°C	O.A. (20)	15.5^{Bc}	17.0^{Ac}	17.0^{Ab}	17.5^{Ac}	16.0^{Bc}	14.0^{Cc}
		B and T (40)	35.0^{ABb}	36.0^{Ab}	35.0^{ABbc}	36.0^{Ab}	35.5^{ABb}	34.0^{Bb}
		A and F (40)	35.0^{Ab}	36.0^{Ab}	36.0^{Ab}	36.5^{Ab}	35.5^{Ab}	32.0^{Bc}
		T (100)	85.5^{Ab}	89.0^{Ab}	88.0^{Ac}	90.0^{Ab}	87.0^{Ab}	80.0^{Bc}

MPC: Milk protein concentrate, TMP: Total milk proteinate, UF-RC: UF-retentate curd, SMP: Skim milk powder, SPC: Soy protein concentrate, O.A: Outer appearance, B and T: Body and texture, A and F: Aroma and flavour, T: Total score, ^{A,B,C}Means with the same letter among treatments in the same storage period are not significantly different, ^{a,b,c}Means with the same letter in the same treatment during storage periods are not significantly different

to 94.5, 96.0, 96.5, 93.0 and 89.0 points for treatments with MPC, TMP, UF-RC, SMP and SPC, respectively. These scores indicated that all cheese sauces were acceptable but cheese sauce with UF-RC showed the highest acceptability. Cheese sauce samples with MPC and TMP were not significantly different from that with UF-RC. On the other hand, cheese sauce sample with SPC scored the lowest and was the least preferable to the panelists.

Sensory evaluation of cheese sauces with different protein sources were affected by extending storage period and temperature. As can be seen from the data presented in Table 6, there were slight decrease in quality parameters and total scores of sauces samples after one month of storage being more affected in stored samples at higher temperature (room temperature). Prolongation of the storage period for three months led to more decrease in sensory quality attributes and the cheese sauce became less acceptable than fresh samples. Cheese sauces stored at higher temperature (25±2°C) were less preferable to panelists than that stored at refrigerator (5±2°C). It can be also noticed that, control processed cheese sauce showed a more mature undesirable flavour (Schar and Bosset, 2002) and processed cheese sauce with soy protein concentrate exhibited more oily beany flavour (Hassan *et al*., 2007), while the processed cheese sauce with UF-RC was still the most preferable sauce with no undesirable flavour (EL-Shabrawy *et al*., 2002).

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