Influence of Incorporation of Different Dried Dairy Ingredients and Inulin on the Physicochemical Properties of Non-fat Set Yoghurt

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Abstract

This study was carried out to investigate the possibility of manufacturing non-fat set yogurt with acceptable quality from reconstituted skim milk powder (SMP) 10% T.S, enriched by adding one of the four dried dairy ingredients namely; skim milk powder, milk protein concentrate (MPC), whey protein concentrate (WPC) or sodium caseinate (NaCn) to achieve a concentrations of 1.5, 3.0, and 4.5%, respectively in the final mixes. A control sample was prepared without any additives. The other twelve mixes were fortified with % 1 (wt/wt) Inulin. Physiochemical properties of yoghurts were evaluated during cold storage for 14 d. The results showed that increasing the added ratios of different dried dairy ingredients and inulin led to the increase in total solids, protein, soluble nitrogen, acidity, and ash content, whereas the fat percentage did not affect. Enrichment of non-fat yoghurt with different dried dairy ingredients and inulin caused a decrease in the pH values. There was a negative correlation between syneresis and the added percentage of dried dairy ingredients and inulin. During storage, the total solids content, protein, soluble nitrogen, fat, ash, acidity and syneresis were increased in contrast with pH level. This study suggests that the using mixes of the different dried dairy ingredients in appropriate ratios along with inulin seems as a useful and interesting approach for manufacture of non-fat set yogurt.

INTRODUCTION

Over the past few years, a consumer has become more aware of maintaining good health through dieting and thus tends towards functional foods that offer additional benefits beyond those offered by traditional foods. Increased consumer interest in healthy food products is due to a variety of factors, including increased awareness of the link between diet and health, meeting nutritional needs and reducing the risk of disease.

Another potential growth area includes value-added food products such as low and non-fat varieties, and those supplemented with functional ingredients, including dairy based proteins and dietary fibers that provide specific health and technological benefits beyond basic nutrition.

Consumers are encouraged to consume non-fat dairy products to ensure good overall health and reduce the risk of several types of diseases such as obesity, hypertension, stroke and coronary heart disease. Non-fat dairy products are a major promise for the expansion of the dairy industry, especially in specific sectors such as yogurt and cheese. However, the formulation of these products represents a number of challenges in the dairy industry, as fat has multiple properties that positively affect the texture, appearance and flavor. Non-fat dairy products have a number of defects: very hard, elasticity, coarse consistency, and poor flavor.

It is common to use skimmed milk powder (SMP) to enrich the milk base, but an excessive amount of SMP may lead to a taste of powder in the product. Moreover, the development of excess acidity of the product, as a result of the high lactose content of the powder, is still the limiting factor for the use of SMP in enrichment purposes, which may cause many defects in the finished products.

Other milk powders such as milk protein concentrate (MPC), whey protein concentrate (WPC), and sodium caseinate (NaCn), have many functional properties including emulsification, foaming, water absorption, viscosity, gelation, and heat stability (Guzman-Gonzalez *et al*. 1999; Bhullar *et al*. 2002; Puvanenthiran *et al*. 2002; Augustin *et al*. 2003; Remeuf *et al*. 2003; Sodini *et al*. 2005; Damin *et al*. 2009). The functional properties of these milk powders have promoted their use as alternatives to SMP for enrichment purposes in low and reduced-fat yogurt and cheese varieties (Henriques *et al*. 2013; Karam *et al*. 2013).

An alternative approach to enhance the sensory properties of low and reduced-fat dairy products is to use fat replacers. The soluble fiber has been widely used to replace fat in dairy products. Among the many soluble fibers, oligosaccharides especially inulin. The inulins belong to a class of dietary fibers known as fructans. Chemically, inulin is a carbohydrate built up from β-(2, 1) - linked fructosyl residues mostly ending with a glucose residue (Kalyani Nair *et al*. 2010; Dhingra *et al*. 2012; Miremadi & Shah, 2012; Arora *et al*. 2015; Chaito *et al*. 2016)

MATERIALS AND METHODS

Four dried dairy ingredients were used: skim milk powder (SMP) (Aktiebolaget Västgöta Mjölkförädlin, Odengatan 6- Sweden.), Milk protein concentrates (MPC) (Westland Milk Products Hokitika - New Zealand), whey protein concentrate (WPC) (Davisco Foods International, Le Sueur, Minnesota, USA.) ,sodium caseinate (NaCn) (Foodchem International Corporation, China). and the inulin Frutafit® HD: Highly dispersible native powdered inulin of medium average chain length (8-13 monomers) properties was imported from Sensus (BrenntagQuímica, SA, Barcelona, Spain) The composition of the dried dairy and non-dairy ingredients used in this study is shown in Table 1.

Thermophilic Yoghurt Culture was provided by (YC-X11, Chr. Hansen, Inc., Milwaukee, Wis., U.S.A. For the preparation of yoghurt, *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* were used as starter cultures.

Table 1: Specifications * of different dried dairy ingredients and inulin

Constituents (%)	Dried dairy ingredients and inulin				
	SMP	MPC	WPC	NaCn	Inulin
Protein	≥34	≥70	81.4±1.0	≥90	0
Fat	≤1.25	1.4	5.4±1.0	≤2	0
Lactose	≤53	16.2	8.0±1.5	≤1	carbohydrates≤97%
Ash	≤8	8.2	2.6±0.3	≤6	0.2
Moisture	≤4	<5	4.7±0.3	≤6	3

* Specifications obtained from the manufacturers.

Yoghurt manufacture

Yogurt base mix was made by reconstituting low heat skim milk powder to a final concentration of 10% total solids. The reconstituted skim milk was divided into thirteen equal batches. The first batch was left without any additives to serve as a control. The other twelve batches were enriched by adding one of the four dried dairy ingredients; SMP, MPC, WPC and NaCn to achieve a concentrations of 1.5, 3.0, and 4.5%, respectively in the final mixes. Additionally, appropriate amount of Inulin was added to enriched mixes to obtain a constant ratio of 1% (wt/wt) in the final mixes. Each mix was blended thoroughly with a hand blender until the complete dispersion of all additives. The mixes were cooled to 5°C, and kept in a refrigerator overnight to complete hydration of the dried ingredients before use. The yoghurt mixes were heated in a water bath at 90°C for 10 min, rapidly cooled to 42°C, inoculated with 1.5 % (w/w) activated yogurt starter culture. The inoculated milks were poured into 250-mL plastic cups with lids and incubated at 42°C until complete coagulation (approximately 3,5 h). After incubation, yogurts were cooled down at room temperature, transferred and kept in a refrigerator at 5±°C for 14 d. The analyses were carried out within 24 h of completing the yoghurt fermentation. The physicochemical analyses were carried out after 1, 7 and 14 days of storage. Yoghurts were made in three replicated batches on three consecutive weeks.

Physiochemical analysis:

Chemical analysis in yogurt samples include total solids (TS), total nitrogen (TN), soluble nitrogen (SN), fat, ash content and titratable acidity (TA) were determined according to AOAC (2010). Moreover, pH value of yogurt was measured using adigital pH-meter (Orionmodel410 A, Boston, MA, USA). Syneresis of yogurt was determined using the drainage whey (mL/100 mL yoghurt) as described by Tarakci and Kucukoner (2003); Achanta *et al.* (2007). All measurements were conducted in triplicate.

Statistical analysis:

The data obtained in the present study was analyzed by ANOVA. For all analysis, when a significant difference ($p < 0.05$) was detected in some variable, the data means test was applied to evaluate the difference between the samples. The results were analyzed with the aid of the software Statistical Analysis System for Windows (SAS, 2008).

RESULTS AND DISCUSSION

Chemical composition:

The results of the chemical composition of non-fat set yogurt and its formulae containing different percentages of different dried dairy ingredients and inulin during storage period are presented in Tables (2 and 3).

Total solids, protein, and soluble nitrogen contents:

Table 2 shows that, the content of total solids increased significantly ($p <0.05$) by increasing the added percentages of the different dried dairy ingredients in the formulated yogurts. The highest content of the total solids was in yogurt sample enriched with 4.5% NaCn (Aziznia *et al*. 2008; Unal and akalin, 2013). During the storage period, the total solid content of all yogurts has also increased (Table 2). Increased total solids can be due to the moisture loss during storage period. These results are in agreement with Salariya *et al*. (2010).

It has been previously reported that increased total solids resulted with the increase in viscosity and prevent syneresis of non-fat yogurt made from high milk protein powder (Mistry and Hassan, 1992).

On the other hand, the presence of inulin may contribute to the increase of total solids content in the experimental yogurt formulations. Debon *et al*. (2010) found that the increase in inulin and oligofructose supplementations increased the total solids content of the prebiotic fermented milk.

Table 2: Total solids (T.S), protein, and soluble nitrogen (S.N) contents of non-fat set yogurt supplemented with different dried dairy ingredients and inulin during storage period (14-d) at refrigerator temperature

Formulations	T.S%	Protein%	S.N%

	1	7	14	1	7	14	1	7	14
Control*	10.23^{j}	10.59^{g}	11.03^{i}	3.48^{m}	3.53^{m}	3.55^{m}	0.0436^{h}	0.0493^{f}	0.0526^{f}
SMP (1.5%) + Inulin (1%)	11.54^{h}	11.86^{e}	12.17^{g}	3.90^{l}	3.94^{l}	3.98^{l}	0.0466^{fgh}	0.0530^{def}	0.0583^{e}
SMP (3.0%) + Inulin (1%)	12.69^{f}	13.11^{c}	13.43^{e}	4.37^{k}	4.40^{k}	4.45^{k}	0.0466^{fgh}	0.0546^{cdef}	0.0600^{de}
SMP (4.5%) + Inulin (1%)	13.97^{c}	14.32^{b}	14.80^{b}	4.89^{g}	4.90^{g}	4.94^{g}	0.0526^{cde}	0.0560^{cde}	0.0613^{cde}
MPC (1.5%) + Inulin (1%)	11.60^{gh}	11.93^{de}	12.31^{f}	4.51^{j}	4.57^{j}	4.61^{j}	0.0460^{hg}	0.0520^{ef}	0.0593^{de}
MPC (3.0%) + Inulin (1%)	12.87^{e}	13.15^{c}	13.47^{de}	5.47^{f}	5.50^{f}	5.54^{f}	0.0510^{de}	0.0576^{cd}	0.0656^{abc}
MPC (4.5%) + Inulin (1%)	14.17^{a}	14.54^{a}	14.92^{a}	6.38^{c}	6.43^{c}	6.49^{c}	0.0600^{a}	0.0676^{a}	0.0700^{a}
WPC (1.5%) + Inulin (1%)	11.43^{i}	11.70^{f}	12.04^{h}	4.59^{i}	4.63^{i}	4.67^{i}	0.0426^{h}	0.0510^{ef}	0.0583^{e}
WPC (3.0%) + Inulin (1%)	12.81^{e}	13.19^{c}	13.52^{d}	5.73^{e}	5.75^{e}	5.79^{e}	0.0493^{efg}	0.0556^{cde}	0.0596^{de}
WPC (4.5%) + Inulin (1%)	14.07^{b}	14.43^{ab}	14.64^{c}	6.91^{b}	6.97^{b}	6.98^{b}	0.0556^{bc}	0.0633^{ab}	0.0683^{ab}
NaCn (1.5%) + Inulin (1%)	11.63^{g}	12.04^{d}	12.32^{f}	4.70^{h}	4.75^{h}	4.80^{h}	0.0503^{def}	0.0583^{bcd}	0.0643^{bcd}
NaCn (3.0%) + Inulin (1%)	13.01^{d}	13.22^{c}	13.45^{de}	5.97^{d}	6.02^{d}	6.08^{d}	0.0536^{cd}	0.0586^{bc}	0.0630^{bcde}
NaCn (4.5%) + Inulin (1%)	14.21^{a}	14.55^{a}	14.83^{b}	7.30^{a}	7.33^{a}	7.36^{a}	0.0593^{ab}	0.0656^{a}	0.0710^{a}

*Control: Non -fat set yogurt made from reconstituted skim milk powder without any additives.
- Values are means of three replicates.
- Numbers with different letters within the same column are significantly different (P < 0.05).

All formulated yogurts had significantly (P <0.05) higher protein content than that of control (Table 2). Dried dairy ingredients used in this study were not greatly different from each other when considering their own protein content except for SMP, which had lower protein content than the other three dried dairy ingredients (Table 1). Yogurt sample formulated with 4.5% NaCn had the highest protein content of 7.30%, while control sample had the lowest protein content of 3.48%. The high protein content in the added NaCn (90% protein) was the main reason for NaCn yogurts having higher protein contents than the other three categories of yogurt. Similarly, the reason for the lower protein content of the control and SMP yogurts was the protein source used, which was SMP (34% protein). The protein contents of formulated yogurts increased significantly (p < 0.05) by increasing the added percentages of the various dried dairy ingredients (Dave and Shah, 1998; Isleten and Karagul-Yuceer, 2008; Akalin *et al*. 2012; Unal and Akalin, 2013; Bruzantin *et al*. 2016). Protein content increased slightly in all yogurt samples during storage (Table 2) (Salariya *et al*. 2010).

Protein is one of the main solid constituents in yogurt. The presence of protein is essential for good body and texture of yogurt products. The need for proteins is the main reason for the addition of dried dairy ingredients to yogurt formulations (Sodini *et al*. 2005). The main reason for the addition of non-fat milk solids in yogurt formulations is to add milk protein. Increased levels of protein resulted in higher values in hardness, WHC and viscosity for yogurts (Berber *et al*. 2015).

On the other hand, inulin can also form part of the protein structural network by complexity with protein aggregates (Kip *et al*. 2006).

The soluble nitrogen percentage significantly (P <0.05) increased in enriched yogurts than that of the control by increasing the added percentage of various dried dairy ingredients. The highest percentage of soluble nitrogen was in yogurt sample enriched with 4.5% MPC, followed by 4.5% NaCn. There was also an increase in soluble nitrogen in the experimental yogurts during the storage period (Table 2).

Fat and ash contents:

Table 3 shows that, there were no great differences in fat content between control and yogurts supplemented with various dried dairy ingredients and inulin because they are all made from reconstituted skim milk powder. However, control yogurt had 0.1% fat content, while yogurt sample enriched with 4.5% WPC had 0.3% fat content. The reason for this difference can be attributed to the WPC used in the formulation, which contains around 5.4% of fat (Table 1).

Table 3: Fat and ash contents of non-fat set yogurt supplemented with different dried dairy ingredients and inulin during storage period (14-d) at refrigerator temperature

Formulations	Fat %			Ash %		
	1	7	14	1	7	14
Control*	0.10^{d}	0.10^{c}	0.10^{e}	0.81^{j}	0.81^{g}	0.85^{g}
SMP (1.5%) + Inulin (1%)	0.10^{d}	0.10^{c}	0.10^{e}	0.90^{g}	0.91^{e}	0.92^{ef}
SMP (3.0%) + Inulin (1%)	0.10^{d}	0.10^{c}	0.10^{e}	1.00^{d}	0.99^{d}	1.03^{c}
SMP (4.5%) + Inulin (1%)	0.10^{d}	0.13^{c}	0.20^{bc}	1.09^{b}	1.10^{b}	1.11^{ab}
MPC (1.5%) + Inulin (1%)	0.10^{d}	0.10^{c}	0.10^{e}	0.91^{fg}	0.91^{e}	0.91^{ef}
MPC (3.0%) + Inulin (1%)	0.10^{d}	0.13^{c}	0.20^{bc}	1.02^{c}	1.03^{c}	1.04^{c}
MPC (4.5%) + Inulin (1%)	0.16^{bc}	0.20^{b}	0.20^{bc}	1.12^{a}	1.14^{a}	1.13^{a}
WPC (1.5%) + Inulin (1%)	0.13^{cd}	0.20^{b}	0.16^{cd}	0.84^{i}	0.85^{f}	0.88^{f}
WPC (3.0%) + Inulin (1%)	0.20^{b}	0.26^{a}	0.30^{a}	0.88^{h}	0.89^{e}	0.90^{ef}
WPC (4.5%) + Inulin (1%)	0.30^{a}	0.30^{a}	0.33^{a}	0.92^{f}	0.92^{e}	0.94^{e}
NaCn (1.5%) + Inulin (1%)	0.10^{d}	0.10^{c}	0.13^{de}	0.87^{h}	0.90^{e}	0.91^{ef}
NaCn (3.0%) + Inulin (1%)	0.13^{cd}	0.20^{b}	0.20^{bc}	0.96^{d}	0.97^{d}	0.99^{d}
NaCn (4.5%) + Inulin (1%)	0.16^{bc}	0.20^{b}	0.23^{b}	1.03^{c}	1.05^{c}	1.09^{b}

*Control: Non -fat set yogurt made from reconstituted skim milk powder without any additives.
- Values are means of three replicates.
- Numbers with different letters within the same column are significantly different (P < 0.05).

There was a slight increase in fat percentages between the formulations with increasing the added rates. The fat percentage of all yogurt samples slightly increased with the duration of the storage period (Table 3). The code of federal regulations (2013) requires that yogurt products should have levels of 0% to 0.5%, 0.5% to 2% and not less than 3.25% to be considered as non-fat, low-fat and full-fat yogurt, respectively.

The same Table shows that, the ash content increased significantly (P <0.05) by adding various dried dairy ingredients in yogurt formulations compared with that of the control. The ash content increased in yogurt formulations with increased added ratios of various dried dairy ingredients. The ash content of yogurt enriched with 4.5% MPC was 1.12% and significantly higher (P < 0.05) than any of the other yogurt formulations. This may be due to the high ash content of MPC (8.2%) compared with other dried dairy ingredients (Table 1). The ash content of all yogurt samples increased slightly during the storage period (Table 3).

pH-values and titratable acidity

Table 4 shows the changes in pH-values and titratable acidity of non-fat set yogurt supplemented with various dried dairy ingredients and inulin during storage period. After complete coagulation, pH-values of all yogurt samples were approximately 4.6 and yogurt samples enriched with WPC were the fastest response (Antunes *et al*. 2004). The control sample had the highest pH-value, while yogurt enriched with 4.5% WPC had the lowest one. The pH-values were significantly decreased (P <0.05) with increased ratios of various dried dairy ingredients. However, the pH-values were lower in yogurts fortified with WPC when compared with NaCn. This may be due to whey protein, which generally has less buffering than casein. A similar trend was observed by Amatayakul *et al*. (2006). They suggest that milks with low casein to whey protein ratios have low buffering capacity. This finding is parallel to the results of the current study that yogurts fortified with NaCn showed higher pH-values (P < 0.05). This can be described by the different buffering capacity between caseins and whey proteins.

Table 4: pH-values and Titratable acidity (T.A) of non-fat set yogurt supplemented with different dried dairy ingredients and inulin during storage period (14-d) at refrigerator temperature

Formulations	pH- Values			T.A%		
	1	7	14	1	7	14

Control*	4.57^{a}	4.39^{a}	4.24^{abc}	0.89^{g}	1.08^{g}	1.17^{g}
SMP (1.5%) + Inulin (1%)	4.53^{bcd}	4.32^{cde}	4.20^{bcd}	0.93^{efg}	1.06^{g}	1.21^{fg}
SMP (3.0%) + Inulin (1%)	4.50^{efg}	4.32^{cde}	4.14^{ef}	1.00^{bcd}	1.20^{abcd}	1.24^{ef}
SMP (4.5%) + Inulin (1%)	4.47^{hg}	4.30^{de}	4.10^{f}	1.04^{ab}	1.23^{a}	1.35^{ab}
MPC (1.5%) + Inulin (1%)	4.56^{ab}	4.38^{ab}	4.25^{ab}	0.90^{fg}	1.11^{efg}	1.26^{def}
MPC (3.0%) + Inulin (1%)	4.53^{ecd}	4.33^{cd}	4.20^{cd}	0.94^{ef}	1.15^{cdef}	1.30^{bcd}
MPC (4.5%) + Inulin (1%)	4.50^{efd}	4.29^{e}	4.15^{e}	0.99^{cd}	1.17^{cde}	1.35^{ab}
WPC (1.5%) + Inulin (1%)	4.51^{cdef}	4.36^{abc}	4.28^{a}	0.94^{ef}	1.10^{fg}	1.25^{ef}
WPC (3.0%) + Inulin (1%)	4.46^{hg}	4.32^{cde}	4.22^{bc}	0.96^{de}	1.15^{def}	1.22^{f}
WPC (4.5%) + Inulin (1%)	4.44^{h}	4.29^{e}	4.17^{de}	1.03^{abc}	1.19^{abcd}	1.32^{bc}
NaCn (1.5%) + Inulin (1%)	4.55^{ab}	4.36^{abc}	4.23^{bc}	0.96^{de}	1.17^{bcde}	1.24^{ef}
NaCn (3.0%) + Inulin (1%)	4.51^{def}	4.34^{bcd}	4.20^{cd}	1.00^{bcd}	1.21^{abc}	1.29^{cde}
NaCn (4.5%) + Inulin (1%)	4.48^{fg}	4.30^{de}	4.16^{de}	1.07^{a}	1.23^{ab}	1.38^{a}

- Control*: Non- fat set yogurt made from reconstituted skim milk powder without any additives
- Values are means of three replicates.
- Numbers with different letters within the same column are significantly different ($P < 0.05$).

The pH-values for all yogurt samples decreased gradually during storage period. There was a noticeable decrease in pH values for yogurt on day 14 (Table 4). However, the pH values were more stable and slightly higher in yogurt sample enriched with 1.5% WPC than that of the control over 14 d of storage period. Due to buffering capacity of WPC yogurt samples had a stable pH-value during the storage period (Puvanenthiran *et al*. 2002). Similarly, Isleten and Karagul-Yuceer (2008) stated that non-fat yogurt containing WPI showed a significant decline in pH by the 12th day of storage. They also observed a higher pH-value in yogurt with NaCn than in the yogurt with WPI.

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The percentage of the titratable acidity (T.A %) increased significantly ($P < 0.05$) in the enriched yogurts than that of the control (Table 4). This may be due to increased lactose content that has increased the activity of lactic acid bacteria or because some additives may have a positive effect on bacteria. It is also may be due to the increase in total solid contents particularly protein. The titratable acidity (T.A %) increased significantly ($P < 0.05$) with increasing the added percentage of various dried dairy ingredients. The highest value of titratable acidity was observed in yogurt sample enriched with 4.5% NaCn. Yeganehzad *et al*. (2007) and Delikanli & Ozcan (2014) reported that the increase in acidity and decrease of pH in whey-protein-based yogurt might result from the increased concentration of milk solids.

In general, the titratable acidity was also increased with advanced the period of storage (Table 4). The decrease in pH and the increase in titratable acidity during the storage period were expected as a result of the acidity of lactic acid bacteria due to milk protein stimulating the growth of yogurt starter culture. That phenomenon is commonly known and it is a result of acidifying microflora activity (Sady *et al*. 2007 and Delikanli & Ozcan, 2014).

On the other hand, it was reported that the use of inulin as a fat replacer in low-fat yogurt manufacturing did not significantly affect the pH-values and titratable acidity (Guven *et al*. 2005; Guggisberg *et al*. 2009 and Modzelewska-Kapituła & Kłębukowska, 2009). However, Aryana *et al*. (2007) reported that chain length of inulin (small, medium or long) affects the pH-values of yogurt. Gustaw *et al*. (2011) also reported that yogurts obtained with the 1% inulin exhibited lower pH-values than the control samples throughout the storage period.

Syneresis:

Table 5 show the syneresis of non-fat set yogurt supplemented with the various dried dairy ingredients and inulin during the storage period. Control yogurt consistently offered the highest syneresis compared to other formulated samples. A significant decrease ($P < 0.05$) was observed in the capability of yogurt on the expulsion of whey by increasing the percentage of addition of the various dried dairy ingredients. There was a negative correlation between syneresis and total solid content. The resulting matrices appeared relatively more compact (denser) in the formulated yogurts after complete coagulation, which could be due to that the formulated yogurts containing more protein and total solids beside inulin as a texturizer. The whey extruding rate was the lowest in yogurt sample enriched with 4.5% WPC. Similar results have been reported by Isleten and Karagul-Yuceer (2006) and Akalin *et al*. (2012), who observed the lowest syneresis in yogurt fortified with WPI among all milk ingredient fortifiers.

Whey proteins contain intramolecular disulfide bonds that stabilize their structure. β -Lactoglobulin contains a sulfhydryl group that becomes active upon denaturation of protein by heat and can subsequently form sulfhydryl-disulfide interactions with itself and other proteins. With these properties, whey proteins affect the structure and rheological properties of coagulated milk gels including yogurt and cheese (Fox *et al*. 2000). As the casein to whey ratio decreases, the gel network becomes finer, the cross-link more dense and pores smaller, resulting in a decreased amount of syneresis (Puvanenthiran *et al*. 2002). Some researchers believe that the more open gel structure formed with a low casein content will make the aggregate network more sensitive to syneresis (González-Martínez *et al*. 2002). Some studies describe WPC-enriched matrix as a very fine network containing a lot of very small pores (Remeuf *et al*. 2003 and Saint-Eve *et al*. 2006). Others described it as a more compact flocculated protein matrix with more obvious micelle chains and larger pore and whey protein aggregates (Krzeminski *et al*. 2011).

Table 5: Syneresis (Wheying- off) of non-fat set yogurt supplemented with different dried dairy ingredients and inulin during storage period (14-d) at refrigerator temperature

Formulations	Syneresis (%)		
	1	7	14
Control*	43.6^{a}	47.3^{a}	52.0^{a}
SMP (1.5%) + Inulin (1%)	40.0^{b}	44.6^{a}	47.3^{b}
SMP (3.0%) + Inulin (1%)	36.3^{cde}	41.6^{b}	47.0^{b}
SMP (4.5%) + Inulin (1%)	34.3^{de}	37.6^{cd}	41.3^{de}
MPC (1.5%) + Inulin (1%)	38.3^{bc}	41.0^{b}	44.6^{cb}
MPC (3.0%) + Inulin (1%)	35.0^{de}	39.3^{bc}	41.6^{de}
MPC (4.5%) + Inulin (1%)	31.0^{f}	32.6^{f}	36.3^{fg}
WPC (1.5%) + Inulin (1%)	34.0^{e}	35.6^{de}	40.3^{e}
WPC (3.0%) + Inulin (1%)	29.6^{fg}	33.6^{ef}	37.3^{f}
WPC (4.5%) + Inulin (1%)	23.3^{h}	26.0^{g}	30.6^{h}
NaCn (1.5%) + Inulin (1%)	36.6^{cd}	40.6^{b}	44.0^{cd}
NaCn (3.0%) + Inulin (1%)	31.3^{f}	37.0^{cd}	40.3^{e}
NaCn (4.5%) + Inulin (1%)	27.3^{g}	31.6^{f}	34.0^{g}

- Control*: Non- fat set yogurt made from reconstituted skim milk powder without any additives
- Values are means of three replicates.
- Numbers with different letters within the same column are significantly different ($P < 0.05$).

There was an increase in the rate of separation of whey in all yogurt samples, especially in control with the progress of the storage period (Table 5). These results are consistent with the results of Pimentel *et al*. (2012) and Aslam *et al*. (2015).

On the other hand, according to Guven *et al*. (2005), the addition of inulin at more than 1% increased whey separation from yogurt and consistency. However, Aryana *et al*.

(2007) reported that fat-free plain yogurts containing inulin had less syneresis than the control and had a better body and texture than other yogurts.

CONCLUSION

It could be concluded that, the addition of dried dairy ingredients (SMP, MPC, WPC and NaCn) to non-fat set yogurt greatly affected physio-chemical properties of these product. Fortification by inulin with enrichment by the dried dairy ingredients might play a beneficial role in improving the quality of non-fat set yogurt and could be used to develop functional dairy products. The type and ratios of dried dairy ingredients enrichment not had the same consequences on the characteristics of the final products. Addition of the dried dairy ingredients seems to be highly dependent on the composition of the powders employed and appears definitely appropriate for non-fat set yogurt production. Finally, using mixes of the different dried dairy ingredients in appropriate ratios along with inulin seems as a useful and interesting approach for manufacture of non-fat set yogurt.

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