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INCORPORATION OF BARLEY WHOLE MEAL IN SOME DAIRY AND FOOD PRODUCTS

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ABSTRACT

The effect of incorporation of barley whole meal (BWM) whether in ice milk (IM) as skim milk powder (SMP) substitute, in tomato soup (ST) as modified starch substitute and in Egyptian kishk (EK) as wheat flour substitute on their properties was studied. The obtained results reveal that, the substitution with BWM was associated with increases in the fiber, β-glucan, K and Mg contents in all products studied. Whereas, the protein and ash contents increased in ST samples. The freezing point of IM mixes heightened and the specific gravity lowered by BWM addition instead of SMP. In spite of the stabilizer (CMC) level, the overrun % decreased by substitution of SMP with BWM but the melting resistance increased. Rheologically, the 50% replacement SMP with BWM achieved remarkable increase in the rheological response of IM samples especially in the presence of 0.1% CMC. At the same time, the replacing of modified starch by 200% of BWM in ST samples resulted in increasing the shear stress value and led to a mix behavior of thixotropy and rheopectic in ST samples. Although the partial or fully replacement of wheat flour with BWM led to reduction in the thixotropy area in EK samples. Organoleptically, IM and EK with 50% BWM and ST with 200% BWM substituted gained the highest sensory scores especially in the absence of CMC in IM samples.

INTRODUCTION

Ice-milk, tomato soup and Egyptian kishk are conventional foods consumed in Egypt. Ice-milk is the most popular frozen dairy product consumed nearly by all levels of society, especially children. Tomato soup is a staple in the diet and it can increase appetite by stimulating the secretion of saliva and also assist peristalsis of the stomach to facilitate food intake, whereas kishk is a popular diet in Egypt.

The recently local shortage in milk production, wheat and consequently the increasing cost of dairy products, such as skim milk powder, as well as the relatively higher price of modified starch and wheat flour encourage the effort done for the substitution of them with available lower-priced and healthy-beneficial materials such as barley whole meal.

At the same time, barley is a nutritious cereal grain that offers consumers many bioactive compounds that can help improve their health because it is a major source of fiber and nutrients in the human diet. β-glucan, a cell wall component of cereal grains and the major fiber constituents in barley have been shown to lower plasma cholesterol, reduce glycemic index and reduce the risk of colon cancer **(Cavallero *et al* 2002).** Its efficiency in reducing the risk of coronary heart diseases has recently been recognized by Food and Drug Administration **(FDA, 2005).** Increase fiber consumption promotes general health and prevents disease. The beneficial effects of fiber have been ascribed to its ability to control hyperglycemia (high blood sugar) improve glucose tolerance and reduce serum lipids and cholesterol levels associated with cardiovascular disease in both normal and hyperlipidemia individuals. The health benefits of β-glucan have been attributed primarily to its ability to increase the viscosity of intestinal digesta **(Jenkins *et al* 1980; Toma and Curtis, 1986; Cavallero *et al* 2002).** Therefore, it's important to implicate barley grains in several potential new applications as a whole meal for it is value-added products.

For that in view, the present study was carried out to evaluate the impact of the supplementation

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with barley whole meal as potential substitute on the properties of the final products meanly, ice milk, tomato soup and Egyptian kishk.

MATERIALS AND METHODS

Materials

Barley (*Hordium vulgare L.*) whole meal (BWM) was obtained from barley research section, Field Crops Research Institute, Agric. Research Center, Giza, Egypt. The chemical composition of barley whole meal was as follows, 9.1% moisture, 15.3% crude protein ,4.2% crude fat, 2.6% ash, 17.9% crude fiber, 5.6% β-glucan and from 100 the 50.9% carbohydrate (calculated by the difference). Fresh cow's milk (3.63 % fat, 8.8% solids not fat (SNF), 3.23% Protein and 4.83% lactose) was obtained from Dina Farm at the 80th Km of Cairo –Alex. Desert High- way. Fresh cream (50% fat and 5.5% SNF) was obtained from the dairy farm at Fac. of Agric. Ain Shams Univ. Skim milk powder (SMP with total solids of 96%) made in USA was obtained from Misr for Milk and Food Co., Cairo, Egypt. Commercial grade cane sugar was purchased from Sugar and Integrated Industries Co., Giza, Egypt. Carboxy methyl cellulose (CMC) made by BDH chemicals Ltd poole; England, and vanillia made by Boehringer Manheim GMB, Germany were obtained from local market. The ingredients of tomato soup and Egyptian kishk (modified starch, wheat flour, fresh tomato, onion, carrots, garlic, dry spices, salt, vegetable oil, chicken soup (Maggi), milk, and butter milk) were purchased from local market in Cairo, Egypt.

Products preparations

Ice milk (IM)

Ice milk base mix 4% fat and 12% SNF and 15% sucrose was prepared (**Arbuckle, 1986)**. SMP which usually used to supply the required milk SNF was substituted with BWM at a level of nil (control), 50 or 100%. CMC was added at a level of nil, 0.1 or 0.2 %, **(Table 1).** All mixes were heat treated at 85ºC for 5 min. then cooled to 5 ºC. The mixes were aged at the same temperature for 4 h. After ageing, 0.01% vanilla was added and the mixes were frozen in horizontal batch apparatus (Tyalor, Model 1039 USA). The resultant ice milk was filled into PVC cups and hardened at -25°C for 24 h. before analyses. Three replicates were carried out for each batch.

Tomato soup (ST)

Tomato soup samples were prepared according to **Lyly et *al* (2004)** with some modification by replacing modified starch, which is conventionally used as thickening agent, with BWM at a level of nil (control), 50, and 100%. Furthermore a special batch was made using the BWM in amount double of modified starch (200%). The recipe of ST is given in **Table (2)**. In a heavy bottom pot, the vegetable oil was added and heated over a medium flame then the remaining ingredients were added and simmered slowly for 30 min. and cooled to the room temperature (25±2°C). Then soup was well blended using electric blender for 3 min. Finally, the water with thickening agent was heated and the blended mixture was added to it with gently stirring until thickening. Three replicates were carried out for each batch.

Egyptian kishk (EK)

The Egyptian kishk samples were prepared by replacing wheat flour, which is conventionally used as thickening agent, with BWM at a level of nil (control), 50 and 100%. The recipe of EK samples is given in **Table (2)**. In a heavy bottom pot, the chicken broth and milk were poured over thickening agent, according to the treatment, and then it was stirred to blend. After that cooking and stirring constantly were carried out over low flame to reach the thickness of thin custard pudding. Kishk was placed in shallow serving dish to cool, and then onion was fried until nicely brown and drained on absorbent paper and cooled. Finally, latter fried onion was decoratively sprinkled over kishk. Three replicates were carried out for each batch.

Analytical methods

Physico-chemical analyses

The prepared products, IM, ST and EK, were analyzed for β- glucan contents according to **Mc Cleary and Codd (1991).** Protein, crude fiber, ash and minerals (K, Mg) were determined as described by **A.O.A.C, (2007).**

The prepared mixes of ice milk were analyzed for their titratable acidity, pH value as reported by **Ling, (1963).** Specific gravity as described by **Winton, (1958)** at 20°C and freezing point of mix

Table 1. Ice milk formulas (gm/Kg mix) as affected by the substitution level of skim milk powder (SMP) with barley whole meal (BWM)

Ingredients	SMP substitution level (%) with BWM						
	0	50			100		
	control***	*	**	***	*	**	***
Cream (50% fat, 5.5 SNF)	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Cow's milk (3.63% fat, 8.8% SNF)	793	795	794	793	795	794	793
SMP (total solids %96)	48.84	24.42	24.42	24.42	-	-	-
BWM	-	24.42	24.42	24.42	48.84	48.84	48.84
Sucrose	150	150	150	150	150	150	150
CMC	2	-	1	2	-	1	2

* Without CMC, ** with 0.1% CMC and *** with 0.2% CMC

Table 2. Tomato soup and Egyptian kishk recipe as affected by the substitution level of modified starch and wheat flour with barely whole meal (BWM)

Ingredients	wheat flour or modified starch level substitution with BWM			
	control	50%	100%	200%
	Tomato soup			
	ST	ST1	ST2	ST3
Modified starch[a]	20	10	-	-
Tomato[a]	500	500	500	500
Carrots[a]	100	100	100	100
Onion[a]	50	50	50	50
Vegetable oil[b]	50	50	50	50
Garlic[a]	5	5	5	5
Salt[a]	5	5	5	5
Spices[a]	1	1	1	1
Water[b]	150	150	150	150
BWM[a]	-	10	20	40
	Egyptian kishk			
	EK	EK1	EK2	
Wheat flour[a]	50	25	-	
Milk[b]	250	250	250	
Chicken soup[b]	500	500	500	
Onion[a]	100	100	100	
Butter milk [a]	10	10	10	
BWM[a]	-	25	50	

a = gm b = ml

ST: tomato soup with modified starch
ST1: tomato soup with 50% BWM
ST2: tomato soup with 100% BWM
ST3: tomato soup with 200% BWM

EK: Egyptian kishk with wheat flour
EK1: Egyptian kishk with 50% BWM
EK2: Egyptian kishk with 100% BWM

as described by **Pearson, (1973)** .The final products were tested for overrun according to **Anderson *et al* (1983**) and melting resistance according to **Sommer, (1951).**

Rheological analysis

Shear stress responses of the tested samples at different shear rate values were obtained using a coaxial rotational viscometer (Rheotest, type RV2, Pruefgreat, Medingen, Germany). The measuring device (S2 with IM mixes& ST samples; and H with EK samples) were used with a sample volume 30 ml per run according to **Ibarz and Barbosa –Canovas, (2002**). The shearing data were analyzed by two rheological models as follows:

Power law model: $\tau = K \cdot \gamma^{n-1}$ **(1)**

Hershcel Bulkely model: $\tau = \tau_0 + K.\gamma^{n-1}$ **(2)**

Where:

τ = Shear stress (Dynes/cm^2)

γ= Shear rate (S^{-1})

K= consistency coefficient (Dyne. S/cm^2)

n= Flow behaviour index

τ_0 = Yield stress value (Dynes/cm^2)

Organoleptic evaluation

Ten panelists randomly were selected from the staff members of the Food Science Dept., Fac. of Agric., Ain Shams univ. Cairo, Egypt to evaluate the organoleptic properties of each batch of IM samples according to **Arbuckle, (1986)** as well as ST and EK samples according to **Lyly *et al* (2004).**

Statistical analysis

The data obtained were exposed to proper statistical analysis (ANOVA) according to statistical analyses system user's guide **SPSS, (1998)**.

RESULTS AND DISCUSSION

Physico-chemical properties of Ice-milk mixes and Ice-milk resultant

As indicate from the data presented in **Table (3),** the increase of substitution level of SMP with BWM in ice milk mixes was associated with significant reduction in the total solids and the ash content of the resultant mixes. That could be attributed to the relative high moisture and low ash contents possessed of the BWM *versus* SMP. Moreover, the full replacement of SMP caused a significant increasement in the titratable acidity and hence decreasement in pH values of the ice milk mixes, although the partial substitution did not affect this criterion. Further, the proportional increase in the BWM level was correlated with significant increase in the levels of β-glucan, fiber, Mg and K. Physically, the proportional replacement of SMP with BWM led significantly to gradual increase in the freezing point and decrease in specific gravity (without control) of the ice milk mixes.That could be ascribed to the decreasement in both total solids and ash contents as the level of BWM raised. **Fayed & Kamaly, (1993)** mentioned that the freezing point of ice milk was heightened by increasing the milk solids not fat which include lactose and mineral matters. It is worthy to mention that the difference in the CMC levels did not result in any significant differences in all criteria of the ice milk mixes.

As indicated from the data given in **Table (4)**, the proportional SMP replacement with BWM was associated with significant gradual increase in the specific gravity of the resultant ice milk. This phenomenon was clearly reflected on the overrun% of the product, where, it was significantly changed by the partial substitution of SMP with BWM while it was significantly harmed due to the total replacement of SMP with BWM. Regarding the melting resistance of ice milk, the presence of BWM led to delate the product to melt, especially, during the first 15 minutes. The melting loss percent at any experimental time tended to decrease gradually as the level of BWM added was increased. At the end of melting test time (45 min.), 97-99% of the ice milk had melted with two exceptions of those containing full replacement of SMP with BWM and CMC whether at level of 0.1 or 0.2 %. Similar observations were found in ice cream stabilized with starch **(Mahran, 1965)**, in ice milk fortified with cooked wheat (beliela) **(Fayed & Kamaly, 1993)** and ice cream made using water extract of barley as skim milk substitute **(Abd El-Rahman, 2003).**

Chemical properties of tomato soup and Egyptian kishk

Data given in **Table (5)** reveal that, increasing barley whole meal (BWM) replacement level from 50 to 200% in tomato soup (ST) samples significantly increased the protein content. That might be due to the low protein content in starch when compared with BWM. In contrast at Egyptian kishk (EK)

Table 3. Physico-chemical properties of ice milk mixes as affected by the substitution level of skim milk powder with barley whole meal (BWM)

Property	SMP substitution level (%) with BWM						
	0	50			100		
	control***	*	**	***	*	**	***
Total solids %	31.43[a]	30.49[b]	30.48[b]	30.50[b]	29.03[c]	29.09[c]	29.12[c]
Titratable acidity %	0.29[b]	0.30[b]	0.30[b]	0.31[b]	0.35[a]	0.35[a]	0.37[a]
pH value	6.65	6.62	6.62	6.61	6.60	6.60	6.58
Specific gravity	1.165[a]	1.130[b]	1.136[b]	1.146[b]	1.097[c]	1.109[c]	1.114[c]
Ash%	1.20[a]	1.12[b]	1.12[b]	1.12[b]	1.03[c]	1.03[c]	1.03[c]
Freezing point (°C)	-3.1[c]	-2.6[b]	-2.6[b]	-2.5[b]	-2.2[a]	-2.2[a]	-2.3[a]
β-glucan %	0.00	0.14[b]	0.14[b]	0.14[b]	0.28[a]	0.28[a]	0.28[a]
Fiber %	0.00	0.44[b]	0.44[b]	0.44[b]	0.88[a]	0.88[a]	0.88[a]
Mg (ppm)	250[c]	298[b]	298[b]	298[b]	346[a]	346[a]	346[a]
K (ppm)	1570[c]	1770[b]	1770[b]	1770[b]	1980[a]	1980[a]	1980[a]

* Without CMC, ** with 0.1% CMC and *** with 0.2% CMC
Means with the same superscript letter within the same parameter are not significantly different (p > 0.05).

Table 4. Physico-chemical properties of ice milk as affected by the substitution level of skim milk powder (SMP) with barley whole meal (BWM)

Property	**SMP substitution level (%) with BWM**						
	0	**50**			**100**		
	control***	*****	******	*******	*****	******	*******
Specific gravity	0.673[c]	0.695[b]	0.702[b]	0.713[b]	0.799[a]	0.816[a]	0.847[a]
Overrun %	73.11[a]	62.59[b]	61.82[b]	60.73[b]	37.30[c]	35.91[c]	31.52[c]
Melting loss (%) at 30°C							
After 15 min	41.66[a]	27.94[b]	26.00[b]	23.02[c]	25.99[c]	24.94[c]	21.39[c]
After 30 min	86.34[a]	75.02[b]	74.77[b]	74.05[b]	69.95[c]	69.37[c]	69.37[c]
After 45 min	99.66[a]	99.00[a]	98.88[a]	98.27[a]	97.61[a]	94.66[b]	92.88[b]

* Without CMC, ** with 0.1% CMC and *** with 0.2% CMC
Means with the same superscript letter within the same parameter are not significantly different (p > 0.05).

Table 5. Chemical properties of tomato soup and Egyptian kishk as affected by the substitution level of thickening agent with barley whole meal (BWM)

Samples	Parameters					
	Protein (Nx6.25)	Crude fiber (%)	β-glucan (%)	Ash (%)	Minerals (ppm)	
					K	Mg
Tomato soup						
ST	1.22^{cd}	0.17^{d}	0.03^{d}	1.56^{d}	1828^{d}	306^{d}
ST1	1.34c	0.39^{c}	0.15^{c}	1.86^{c}	4852^{c}	367^{c}
ST2	1.63^{b}	0.73^{b}	0.28^{b}	2.46^{b}	9043^{b}	415^{b}
ST3	2.24^{a}	1.19^{a}	0.47^{a}	3.61^{a}	9875^{a}	505^{a}
Egyptian kishk						
EK	2.5^{a}	0.30^{c}	0.09^{c}	0.64^{c}	574^{c}	268^{c}
EK1	2.4^{a}	1.03^{b}	0.39^{b}	0.83^{b}	870^{b}	302^{b}
EK2	2.1^{b}	1.49^{a}	0.58^{a}	1.11^{a}	919^{a}	388^{a}

Means with the same superscript letter within the same parameter are not significantly different ($p > 0.05$).

ST: tomato soup with modified starch
ST1: tomato soup with 50% BWM
ST2: tomato soup with 100% BWM
ST3: tomato soup with 200% BWM

EK: Egyptian kishk with wheat flour
EK1: Egyptian kishk with 50% BWM
EK2: Egyptian kishk with 100% BWM

samples there are no significant difference between EK and EK1 in the protein content percentage but there are a significant decrease in protein content between EK and EK2. That might be due to the high content of protein in wheat flour when compared with BWM, that as stated by (**Pando *et al* 2002).**

Crude fiber percentage show significantly difference among samples with increment percentage reached to 600% in ST3 when compared to ST sample and 396.7% in EK2 when compared with EK sample. Starch and wheat flour samples have relatively very low content of crude fiber due to removal of bran or the outer kernel layers. Several studies (**Gabrovska *et al* 2002; Lovis, 2003; Malik *et al* 2002; Ragaee *et al* 2001**) showed that whole grains contain higher concentration of dietary fiber compared to wheat flours and would enhance dietary fiber intake. The results obtained justify using BWM in food products as source of crude fiber.

The enrichment in β-glucan concentration in the different ST and EK samples were successfully achieved as shown by chemical composition reported in **Table** (**5).** β-glucan content percentage was increased significantly with increasing the application of BWM from 50 to 200% in ST samples and from 50 to 100% in EK samples. Increasing in β-glucan content percentage take the same trend as crude fiber hence. In general, whole grain contained higher levels of minerals compared to starch and wheat flours due to the presence of the outer kernel layers where minerals are concentrated. It was clear from **Table** (**5)** that potassium and magnesium concentrations were statistically influenced by increasing level of BWM in ST and EK samples. The concentrations of K in ST3 and EK2 were 5.4 and 1.6 times higher than ST and EK respectively .In the same time, the concentrations of Mg in ST3 and EK2 were 1.7 and 1.4 times higher than ST and EK respectively. As the same trend, ash content percentage of ST3 was 2.3 times higher than ST and it was 1.7 times higher in EK2 than EK. These results are due to the BWM replacement in all prepared samples.

Rheological properties

Flow curves of ice milk mixes

Fig. (1 and 2) respectively show the flow curves and dynamic viscosity of the tested ice milk mixes. The mix samples showed a non Newtonian shear thinning rheological behavior. Shear stress values of ascending and descending shearing cycles were very similar; so that no thixotropy behavior could be observed.

As seen, replacement of 50% of the skim milk powder with barley whole meal has increased the values of shear stress response of the sample. On the other side, increasing the percent ratio of CMC in the mix from 0.1% to 0.2% did not remarkably enhanced the shear stress response of the tested samples. However, remarkable increase in the shear stress and dynamic viscosity values have been achieved by the full replacement of skim milk powder with barley whole meal, even in the presence of 0.2%CMC.

The reason for the enhancement in rheological response of ice milk mixes with the addition of barley meal could be referred to the gelatinization of barley starch in the heated mixes and the viscous properties of the water soluble barley ß-glucan binding free water in the ice milk mixes, **(Lyly *et al* 2004; Burkus and Temelli, 2005 and Lazaridou *et al* 2008)**. The results indicate that the presence of barley whole meal in the mix has enhanced the rheological response of the samples more than the enhancement achieved by the presence of CMC.

According to **Bayarri *et al* (2008)**; both the type of dispersing media and the CMC concentration clearly affect the viscoelastic behavior of the product. **Cancela *et al* (2005),** reported that the presence of sugars with CMC in an aqueous solution has increased the viscosity values. The main components of BWM are starch, proteins and β-glucan. The role of starch in stabilizing the viscosity of ice cream and other dairy products has been discussed by **Early, 1992; Patmore *et al* 2003 and Soukovlis *et al* (2008)**. Addition of starch has enhanced the viscosity of the products through its ability to swell upon heating of the ice milk mixes and to gel forming a dense network and significantly reinforcing the shear thinning behavior of ice milk and dairy desserts by gelation phenomena. On other side, the role of protein in the rheological behavior of ice cream has been explained by **Arbukle, 1986**; **Yu *et al* (2004)** as well as **Camacho *et al* (2005)**. The protein not present at interface (air bubble films) contribute to viscosity enhancement, especially in the presence of other polysaccharides which contribute to a more dense structure and aggregation of the proteins generating more stable disulfide bridges resulting in the formation of a three- dimensional network.

The role of ß-glucan as thickening agents for ice milk is also reported by **Uzomah and Ahiligwo, 1999** as well as **Lyly *et al* 2004.** They also reported the stabilizer in ice milk may be blends of two or more stabilizers and each one differs in its effect on mix viscosity and texture.

Flow parameters of the ice milk mixes

Table (**6)** gives the Rheological parameters of the ice milk samples calculated according to the rheological models given in equation 1 and 2. As seen, flow behavior index (n value) of the tested ice milk mixes was in the range of 0.60 to 0.79 indicating the low deviation of the ice milk mixes from the ideal Newtonian –behavior, with the lower values belonging to ice milk samples substituted with 50% barley whole meal and 0.2% CMC. The consistency coefficient (k)-values were increased by 50%substitution of skim milk powder with BWM as well as by increasing the CMC percent. The K-values of the mix samples with 100% BWM substitution appears to be lower than those of mix samples with only 50%substitution,but it is not to true because k-value is always combined with the corresponding n-value in designing handling and processing equipment. The values of the apparent viscosity (measured at 50sec^{-1}) showed that the mix samples with fully replacement of skim milk powder with BWM had higher viscosity values than those of only 50% substitution, which confirm the fact that increasing BWM content and CMC percent in the mix resulting in increasing the viscosity values of the obtained mixes. Data obtained from Hershel- Bulkely equation showed that the ice mixes had very minor yield stress values ranging between 0.38325 to 1.76 Dynes/cm^2 and higher values of τ_0 belongs to mix samples with barley whole meal substitution and containing 0.2%CMC. The improvement in the Rheological parameters of the ice milk mix in the presence of CMC is well known from the literature (**Aqualon, 2005**). The obtained rheological parameters of ice milk mixes agree with those of **Marcotte, 2001; Patmore *et al* 2003; Cancela, 2005; and Soukovlis *et al* 2008.** They reported that τ_0– values of ice cream mixes ranges between 0 and 0.8 Pa (according to CMC concentration) and the presence of a yield stress value is seen to be a good measure of gel formation. The reported n-value of ice milk mixes by the

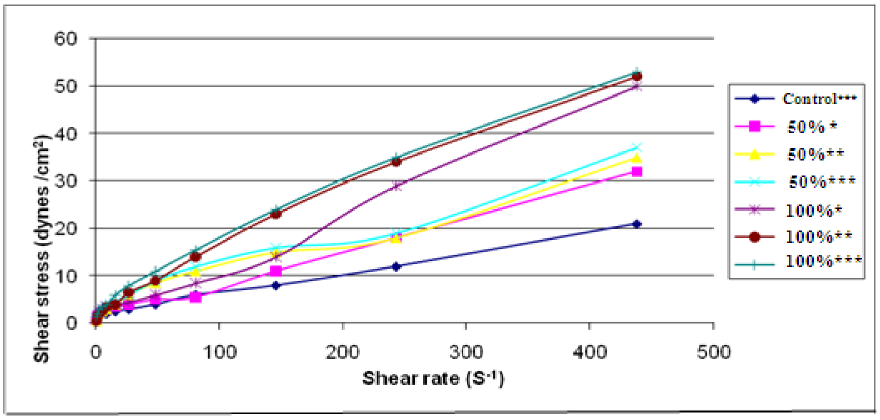

Fig. 1. Flow curves of ice milk mixes as affected by the substitution level of SMP with barley whole meal (BWM)
50 and 100% are substitution level of SMP with BWM
*** Without CMC, ** with 0.1% CMC and *** with 0.2% CMC**

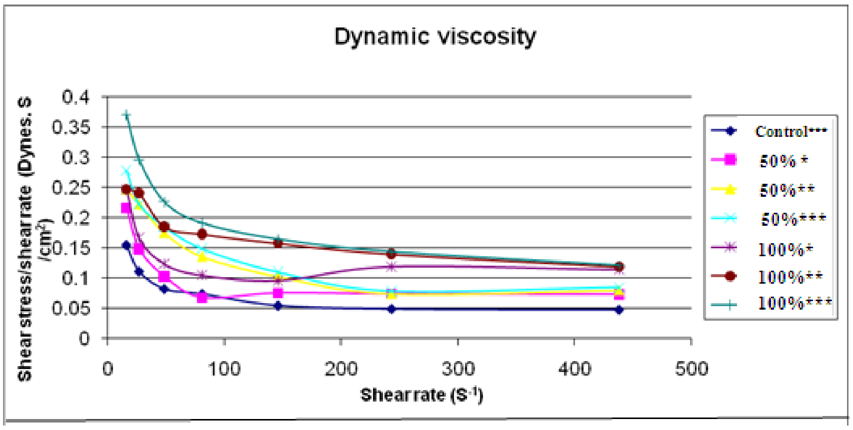

Fig. 2. Dynamic viscosity of ice milk mixes obtained at different shear rate as affected by the substitution level of SMP with barley whole meal (BWM)
50 and 100% are substitution level of SMP with BWM
*** Without CMC, ** with 0.1% CMC and *** with 0.2% CMC**

Table 6. Rheological parameters of ice milk samples as affected by the substitution level of SMP with barley whole meal (BWM)

SMP substitution level (%) with BWM	Mix samples	Power law equation				Herschel-Bulkly equation			
		n	K (Dyne. S/cm²)	ηa (poise)	R^2	n	k(Dyne. S/cm²)	τo(Dynes /cm²)	R^2
0	Control***	0.6408	0.3675	0.0902	0.9818	0.4343	0.2644	0.6412	0.9919
50	*	0.6797	0.4062	0.1160	0.9291	0.3906	0.4357	0.3833	0.9369
	**	0.6034	0.7751	0.1643	0.9815	0.6124	0.1082	1.5346	0.9588
	***	0.5989	0.8411	0.1752	0.9824	0.6381	0.0942	1.6619	0.9677
100	*	0.7905	0.3329	0.1467	0.9522	0.4086	0.5241	0.1103	0.9542
	**	0.7761	0.4699	0.1957	0.9980	0.5004	0.3202	0.7889	0.9949
	***	0.6677	0.8758	0.2387	0.9962	0.6289	0.1303	1.7631	0.9936

*Without CMC, ** with 0.1% CMC and *** with 0.2% CMC
K= consistency coefficient, n= flow behavior, τ_0 = yield stress , η_{50} = apparent viscosity

aforementioned authors was in the range of 0.516 to 0.95. K-values were increased by increasing concentration of starch and CMC, while n-values were decreased, which agree with the results given in **Table (4)** of the present work.

The results obtained in the present work could assist the use of barley meal as functional and bioactive ingredient in ice milk mixes. The published data on the use of barley meal in ice mixes or other dairy products are very rarely in the literature, but results publish by **Gee *et al* (2007)** as well as **Lazaridou *et al* (2008)**, showed that the use of barley ß-glucan has improved the viscosity of yoghurt and skim milk gels.

Flow curves of tomato soup and Egyptian kishk

Figs. (3) and (4) show respectively the flow curves and the dynamic viscosity data of the tested tomato soup (ST) and Egyptian kishk (EK) samples. As seen, the relationship between shear rate and shear stress values is not linear indicating non-Newtonian behavior of the ST and EK samples. The flow curves in **Fig. (3)** are based on the ascending shear stress values obtained during the shearing cycles of the tested samples. For ST1 and ST2 samples, shear stress values were decreased as the starch was partially (50%) or fully replaced by barley whole meal (BWM). However, increasing the added ratio of BWM to 200% in ST3 sample resulted in a dramatical increase in the obtained shear stress and dynamic viscosity values exceeding those obtained for the reference sample (ST) containing starch only. Similar behavior was also observed for EK1 and EK2 samples, where the partial or fully replacement of wheat flour by BWM resulted in decrease in the obtained shear stress and dynamic viscosity values. These results could be explained as follows: the presence of starch in soup and wheat flour in Egyptian kishk is widely applied to modify and control the texture and water binding in soup and Egyptian kishk, due to the gelatinization and retrogradation of starch in heated aqueous media (**Ibanoglu and Ibanoglu, 1999, Achayuthakan and Suphantharika, 2008)**). Replacing the amount of starch by 50% or by 100% of BWM did not give the required gelatinization effect in the soup samples, due to the lower percent of starch and gluten in the added BWM, resulting in lower gelatinization effect in the soup product. On the other side, replacing modified starch by 200% of BWM in the soup samples resulted in increasing the obtained shear stress value due to the effect of starch and β-glucan content of barley on increasing the viscosity of the soup samples. It is well known that barley β-glucans are water soluble, linear and high molecular weight polysaccharides which gives viscous and shear thickening solutions even at low concentrations, and soups is one possible product category where β-glucan can be used as thickening agent **(Lyly, *et al* 2004** as well as **Burkus and Temelli, 2005).**

Flow parameters of tomato soup and Egyptian kishk

The flow curves of tomato soup (ST) and Egyptian kishk (EK) samples were analyzed according to the Power law (equation 1) and Herschel-Bulkely law (equation 2) as common rheological models for non-Newtonian fluids and the results are given in **Table (7).** Also, the apparent viscosity values at a shear rate 50 s^{-1} were calculated and given in **Table (7)**. This shear rate is chosen as it has been shown to correlate with sensory sliminess and thickness in mouth **Lyly *et al*** (**2004).** The results showed that the Power law model was more suitable than Herschel-Bulkely law to represent the shearing data of ST and EK samples, based on the R^2 values given in **Table (7)**. As seen, the n value of both ST and EK samples were in the range of 0.24 to 0.41 indicating the pseudoplasticity of the tested samples. As expected, the ST3 sample prepared by 200% replacement of starch with BWM showed the highest consistency coefficient (K-value) of 175.4 Dynes.sn/cm^2, the highest apparent viscosity (9.70 poise) and the highest yield stress value (253.7 Dynes/cm^2), while the lowest K-value was obtained for the soup samples prepared by 50% replacement of starch with BWM. The same trend was obtained for kishk samples, where the replacement of wheat flour with BWM leads to 33 and 38% reduction in the consistency coefficient and apparent viscosity values, respectively.

The non-Newtonian behavior of the soup samples was reported in several works. **Ibanoglu and Ibanoglu, (1998)** reported K values for Turkish soups thickened with wheat flour in the range of 500 Dynes.s^n/cm^2, which agree with values obtained here for kishk samples. There are no published data on the rheology of Egyptian kishk, but rheological measurements carried out on similar cereal-based products, **Ibanoglu and Ibanoglu, (1999)**, found that replacement of wheat flour in the recipe with other ingredients (rice flour, lentil flour or yogurt) led to reduction in the viscosity

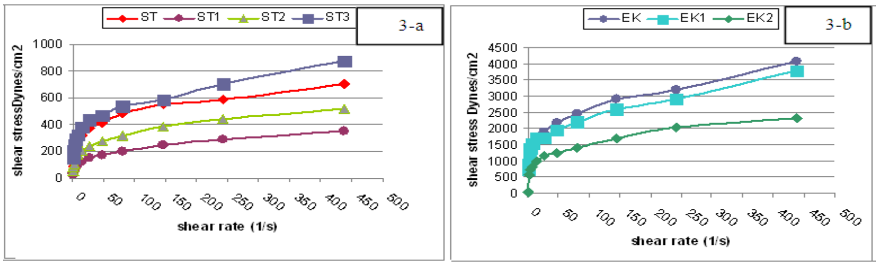

Fig. 3. Flow curves of tomato soup (3-a) and Egyptian kishk (3-b) as affected by the substitution level of thickening agent with barley whole meal (BWM).

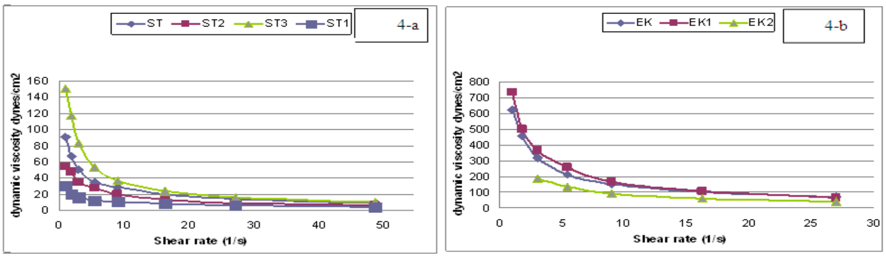

Fig. 4. Dynamic viscosity of tomato soup (4-a) and Egyptian kishk (4-b) at different shear rate as affected by the substitution level of thickening agent with barley whole meal (BWM)

ST: tomato soup with modified starch
ST1: tomato soup with 50% BWM
ST2: tomato soup with 100% BWM
ST3: tomato soup with 200% BWM

EK: Egyptian kishk with wheat flour
EK1: Egyptian kishk with 50% BWM
EK2: Egyptian kishk with 100% BWM

Table 7. Rheological parameters of tomato soup and Egyptian kishk samples as affected by the substitution level of thickening agent with barley whole meal (BWM)

Samples	Power law equation				Herschel-Bulkly equation				Thixotropy areas Dynes.S/cm^2
	η_{50} poise	K Dynes. s^n /cm^2	n	R^2	τ_0 Dynes /cm^2	K Dynes. s^n /cm^2	n	R^2	
Tomato soup									
ST	7.76	106.7	0.33	0.97	172.3	13.85	0.66	0.78	47230.78
ST1	3.27	32.88	0.41	0.98	57.7	6.81	0.67	0.85	11687.26
ST2	5.58	71.0	0.35	0.97	121.9	15.9	0.56	0.96	22614.04
ST3	9.70	175.4	0.26	0.98	253.7	19.1	0.59	0.95	27129.62
Egyptian kishk									
EK	41.36	665.1	0.29	0.99	774	72.9	0.68	0.90	158585.85
EK1	40.72	796.3	0.24	0.98	911	235.1	0.39	0.99	103932.58
EK2	25.64	445.9	0.27	0.99	680.4	29.8	0.71	0.91	135324.68

K= consistency coefficient, n= flow behavior, τ_0 = yield stress ,η_{50} = apparent viscosity

ST: tomato soup with modified starch
ST1: tomato soup with 50% BWM
ST2: tomato soup with 100% BWM
ST3: tomato soup with 200% BWM

EK: Egyptian kishk with wheat flour
EK1: Egyptian kishk with 50% BWM
EK2: Egyptian kishk with 100% BWM

values of the obtained product, which agree with the results of EK1 and EK2 samples obtained in the present work.

In conclusion, it could be stated that replacement of starch with BWM (50,100%substituted level) in ST1, ST2, EK1 and EK2 samples led to weakening of the consistency of the product, but increasing the replacement of BWM to the level of 200% in ST3 sample has enhanced the consistency and could be beneficial for viscosity and health aspects due to its β-glucan content,where, β-glucan was found to enhance the glycemic and insulin response **Lyly *et al* (2004)**.

Effect of barley whole meal on the thixotropy of tomato soup and Egyptian kishk

Thixotropy loops of the tested ST and EK samples were calculated from ascending and descending flow curves, as seen in **Figs. (5-a and 5-b)** and the calculated thixotropy areas were given in **Table (7).** As seen, partial or full replacement of starch with BWM has reduced the thixotropy area of the ST1 and ST2 samples. However, increasing the replacement level of BWM in the ST3 recipe to 200% led to a mixed behaviour of thixotropy and rheopectic as seen in the ST3 sample, may be due to the increasing level of β-glucan in soup sample. Such mixed thixotropic and rheopectic behavior will enhance the mouth feeling of the product. The obtained thixotropy data agree with those reported by **Dewar and Joyce, (2006)** as well as **Dolz *et al* (2007)**. They stated that thixotropy of mixture of starch with other polysaccharide proved complex and the behavior could be toggled between thixotropy and rheopexy by changing certain variables. For EK samples, it was clear that partial or full replacement of wheat flour with BWM led to reduction in the thixotropy area. Since wheat flour is the main component in the Egyptian kishk formula, it is expected that replacement of the wheat flour with BWM (containing lower gluten content) will led to weakness in the consistency and thixotropy due to the missing interaction between starch and gluten gels in the substituted kishk samples.

Organoleptic evaluation

Ice milk

The panel score displaying in **Table (8)** revealed that, the partial replacement of SMP with BWM led to slight improvement in the ice milk flavour while those of made with the full replacement with BWM gained significant lower flavor score regardless the level of CMC added. The mealy flavour was the main taste effect in this respect. Likewise, slight enhancement in the consistency score was recorded when 50% of SMP was substituted with BWM without CMC, while that of 50 % BWM with exhibited body and texture score as good as that of the control. Significant reduction was observed in the score of this criterion by increasing the SMP substitution level with BWM to 100 %. The toughie body was the pronounced defect observed in 100 % BWM samples. That was directly reflected on the melting properties, where they gained the lower score in this criterion. The color of ice milk was not affected the partial replacement while it significantly decreased by the full replacement of SMP with BWM.

The overall organoleptic score indicated that, there is no significant difference between the ice milk with 50% replacement of SMP with BWM and the control in all sensory properties that with CMC level did not exceed 0.1%.

Tomato soup and Egyptian kishk

As presented in **Table (9)** the replacement of starch or wheat flour in ST1, ST3 and EK1 by barely whole meal (BWM), according to the treatment, was improved all attributes of mentioned samples significantly compared with the reference samples, except the texture attribute in case of ST1 and odor attribute in case of ST3 were significantly decreased compared with ST sample. Whereas, the replacement of starch by BWM in ST2 sample was significantly decreased values of most attributes of tomato soup when compared with ST. Also, there are significant decreases in the texture and powderness of EK2 values compared with EK sample whereas there were no significant differences between EK2 and EK in flavour, odor, color, sharpness and overall acceptability values. From the obtained results the 100% replacement was not acceptable to panels in general but also it did not refuse.

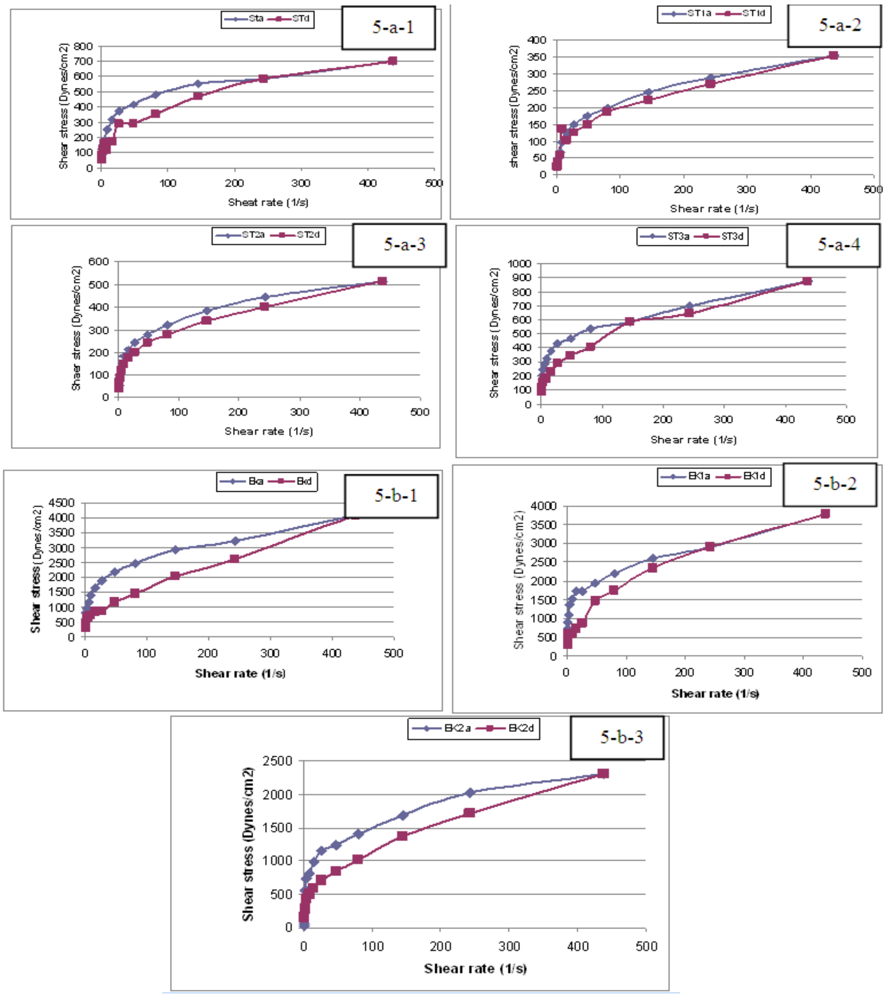

Fig. 5. Thixotropy loops of tomato soup (5- a- 1, 2, 3, 4) and Egyptian kishk (5-b-1,2,3) as affected by the substitution level of thickening agent with barley whole meal (BWM)

ST: tomato soup with modified starch
ST1: tomato soup with 50% BWM
ST2: tomato soup with 100% BWM
ST3: tomato soup with 200% BWM

EK: Egyptian kishk with wheat flour
EK1: Egyptian kishk with 50% BWM
EK2: Egyptian kishk with 100% BWM

Table 8. Organoleptic evaluation of ice milk as affected by the substitution level of SMP with barley whole meal (BWM)

Property	SMP substitution level (%) with BWM						
	0	50			100		
	control***	*	**	***	*	**	***
Flavour (45)	44^a	45^a	45^a	45^a	40^b	40^b	40^b
Body and texture (30)	28^a	29^a	28^a	27^a	23^b	22^b	20^b
Melting properties (15)	14^a	14^a	14^a	14^a	13^{ab}	12^b	10^c
Colour (10)	10^a	9.0^a	9.0^a	9.0^a	8.0^b	8.0^b	8.0^b
Total	96	97	96	95	84	82	78

*Without CMC, ** with 0.1% CMC and *** with 0.2% CMC.

Means with the same superscript letter within the same parameter are not significantly different ($p > 0.05$).

Table 9. Organoleptic evaluation of tomato soup and Egyptian kishk as affected by the substitution level of thickening agent with barley whole meal (BWM)

Samples*	Attributes						
	Flavour (20)	Odor (10)	Color (10)	Texture (20)	Powderness (20)	Sharpness (10)	Overall acceptability (10)
Tomato soup							
ST	18^b	9^b	10^a	19^a	17^b	8^b	9^{ab}
ST1	20^a	10^a	10^a	15^c	20^a	10^a	10^a
ST2	18^b	7^c	10^a	17^b	17^b	10^a	8^b
ST3	20^a	7^c	10^a	20^a	20^a	10^a	10^a
Egyptian kishk							
EK	17^b	7^b	8^{ab}	17^b	17^b	8^b	7^b
EK1	20^a	10^a	9^a	19^a	20^a	10^a	9^a
EK2	18^b	8^b	7^b	15^c	15^c	7^b	7^b

Means with the same superscript letter within the same parameter are not significantly different ($p > 0.05$).
* Sample abbreviations as seen in **Fig. (5).**

Conclusion

The foregoing results led to conclude that, it could be successfully gain BWM, with its healthy benefits, as a substitute with suitable levels being 50% of SMP or wheat flour in IM or EK making respectively and 200% of modified starch in ST recipe. Also, there was no need for using CMC in the manufacture of IM product with BWM.

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