Minufiya J. Agric. Res. Vol. 28 No. 2: 455 - 468 (2003)

THE INFLUENCE OF CORN STARCH AND WAXY CORN STARCH ON THE QUALITY OF ICE MILK

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(Received: Feb., 25, 2003)

ABSTRACT: Nine treatments of ice milk were made. One was served as control (T). Four of them were made by substituting non-fat dry milk and stabilizer with corn starch (CS) at the rate of (A)15%, (B) 30%, (C) 45% and (D) 60% respectively. The other four treatments were made by replacing non-fat dry milk and stabilizer with waxy corn starch (WCS) at the rate of (E) 15%, (F) 30%, (G) 45% and (H) 60% respectively. Ice milk was stored for 4 weeks. Samples from the ice milk mixtures, fresh ice milk and during its storage period were taken for the chemical, physical and sensory investigations. The obtained results revealed that no marked differences in the specific gravity and weight per gallon of mixes containing corn starch and waxy corn starch. Titratable acidity of ice milk mix. decreased as the corn starch and waxy corn starch content of the mix. Increasing. Replacement of non-fat dry milk with either corn starch or waxy corn starch caused significant increase in ice mix. Viscosity and waxy corn starch was more effective. The melting resistance of resultant ice milk increased as the corn starch and waxy corn starch content of the mixes increasing . Increasing the replacing rate of corn starch above 45% caused a significant reduction in overrun of ice milk while, the replacing of waxy corn starch above 30 % caused a significant reduction in overrun of ice milk. Substitution of non-fat dry milk with CS and WCS up to 45% did not affect the scores of organoleptic properties of ice milk.

Key Words: Ice milk, Waxy corn starch, Corn starch, Rheological properties.

INTRODUCTION

Milk desserts are becoming very popular products. There made from milk, sucrose, flavouring and colouring, thickeners, stabilizers and jellifying agents. Ice cream is one of food in which ice crystal growth leads to significant deterioration, although complex polysaccharides are added to ice-cream formulation to enhance smooth texture (Goff *et al.*, 1989).

The main reason for using starch and its derivatives as additives in food preparation is to retain water and to increase the product viscosity.

Starch acts to provide the desired mouth-feel and body, while the synergistic effect of stabilizers increases significantly the viscosity of desserts (Descamps *et al.*, 1986). Mleko (1997) described desserts containing whey protein concentrate and low concentration of gelling agent without deterioration in its texture properties. Native starch granules and modified ones are often used in the production of salad dressings, mayonnaises or processed cheese (Smietana *et al.*, 1998; Tamime *et al.*, 1999; Walkowski *et al.*, 1997). Stabilizers are hydrocolloids used in ice cream to increase the viscosity of the mix, control growth of lactose and ice crystals, and retard melt down (Moore & Chales, 1981). In ice cream water binding by the hydrocolloids helps prevents ice crystal growth caused by temperature variations upon storage and also provides a slow melt down.

The objective of this study were to evaluate the possibility of producing a good quality ice milk by partial replacing non-fat dry milk with corn starch and waxy corn starch and without the use of stabilizers.

MATERIALS and METHODS

Ingredients:

Buffaloe's milk was obtained from the Faculty of Agriculture Minufiya, Shibin El-Kom, Egypt. Waxy corn starch (WCS) was supplied from Roquette (Fréres Society, France), corn starch (CS) was supplied from Sigma (St., Louis, Mo. USA), Non-fat dry milk (Ecoval N.V. Paris, France), Cream was obtained by separating fresh buffalo's milk, sucrose and vanilla were obtained from the local market and the emulsifier/ stabiliser, Palsgaard 5936 were obtained from (Grinsked , Denmark).

Manufacture of ice milk:

Control ice milk was prepared from mixtures of cream, non-fat dry milk (NFDM), sugar and palsagaard 5936 stabilizer /emulsifier in order to contain 4% fat, 13% milk solids not fat, 15% sugar and 0.5% stabilizer/ emulsifier. Four experimental ice milk were prepared by replacing 15,30,45 and 60% of the non-fat dry milk with corn starch in the above formulation. Another, four experimental ice milk were prepared with the replacement of 15,30,45 and 60 % of the non-fat dry milk (NFDM) with waxy corn starch. In all the experimental ice milk, the stabilizer/ emulsifier was not added.

Ice milk was made according to Khader *et al.*, (1992). Ice milk mixes were heated at 71°C for 30 min. and then cooled to 20°C. All mixes were aged overnight at 4°C. Vanilla was added prior to freezing, mixes were frozen in a batch- freezer (Catlaviga, Bologna, Italy). The frozen ice milk was packed in plastic cubs and hardened at –20°C for one day. Frozen ice milk was stored at 20 ± 2 °C for four weeks. The experiment was triplicated.

I- Physical and Chemical properties:

The prepared mixes were analysed for titratable acidity and pH value (Ling, 1963), specific gravity (Winton, 1958), weight per gallon (Burke, 1947). The resultant ice milks were tested for specific gravity (Winton, 1958), weight per gallon (Burke, 1947) overrun (Arbuckle, 1986), melting resistance (Arndt and Wehling, 1989) and pH value (Ling, 1963).

II- Rheological properties:

The prepared mixes were analysed before freezing for viscosity using a coaxial cylinder viscometer (Bohlin V88, Sweden) attached to a workstation loaded with the V88 viscometer. The measuring system (C30), which permits a gap of 1.5 mm between the two cylinders, was filled with ice milk mix. Measurement of viscosity was carried out at 25 ±1°C. viscosity was measured at shear rate ranging from 24 to 150 s^{-1}.

III-Sensory evaluation :

The ice milk was scored for Body and Texture, Flavour and melting quality by Fifteen panellists every one week up to four weeks which was the end of the storage period according to the score sheets described by Badawi *et al.* (2002).

IV- Statistical analysis:

Factorial design 2 factors x 3 replicates and the completely Randomized Design were used to analyze all the data, and Student Newman Keuls test was followed to make the multiple comparisons (Steel and Torrie, 1980) using Costat program. Significant differences were determined at $P \leq 0.05$.

RESULTS and DISCUSSION

1-The use of corn starch

a) Mixes properties

Viscosity:

The viscosity values of different ice milk mixes are presented in Table (1). The replacement of non-fat dry milk with corn starch resulted in an increase in the viscosity of the mix. Increasing the shear rate significantly reduced the apparent viscosity which might be explained by the shearing deformation of the ice milk mix. Increasing the rate of replacement of NFDM with corn starch increased the viscosity of the mix, which may be due to the gel formation and to water hydration, as starch influenced the viscosity of mix. differently. The increase in viscosity on cooling may result in a phenomenon called retrogradation, associated with the amylose fraction being a linear polymer / amylose, has the stablility to form junction zones and re-associate, by the established intermolecular hydrogen bonds. These gel are elastic but they do tend to exhibit syneresis and are not stable to freeze- thaw cycling. These results were in agreement with those of Clark and Ross- Murphy (1987) who reported that the gel network to develop on cooling by the formation of ordered junction zones on amylose double helices.

Table (1) Changes in the Viscosity of ice milk mix as affected by replacement of non-fat dry milk with corn starch.

Shear Rate (s^{-1})	Percent replacement of NFDM with corn starch (%)				
	0.0	15	30	45	60
23.12	190.40	202.40	250.40	266.19	273.30
32.14	188.30	207.30	248.30	258.70	267.60
41.42	180.40	200.30	228.40	237.50	250.40
50.58	165.30	195.40	225.10	225.10	230.40
69.21	155.20	183.30	184.40	189.40	228.40
78.66	140.40	170.40	182.50	184.50	225.30
92.70	134.20	152.30	175.10	177.60	224.10
106.5	120.10	145.40	154.60	156.60	161.20
125.2	110.00	131.30	151.70	154.70	160.00
149.1	90.00	120.00	142.00	143.70	145.40

-Specific gravity and Weight per gallon of mixes:

Table (2) shows that the average specific gravity of control ice milk mix. was 1.1119 and that with 15%, 30%, 45% and 60% replacement of non-fat dry milk with corn starch had average specific gravity of 1.1126, 1.1134, 1.1165 and 1.1194 respectively. It is also seen that the weight per gallon of mixes were closely related to their specific gravity. The foregoing results indicated that the use of corn starch with different levels up to 45 % in mixes did not have significant effect ($P > 0.05$) on either specific gravity or weight per gallon of mixes. These results agree with those reported by (Khader *et al.*, 1992 and Magdoub *et al.*, 1992)

-Titratable acidity

Titratable acidity of the control mix. was 0.23%, while it was 0.21, 0.20, 0.20 and 0.18% for mixes containing 15, 30, 45 and 60% replacement of non-fat dry milk with corn starch respectively. It is obvious that acidity decreased with increasing the rate of replacement of non-fat dry milk. These results as a results of the decreased protein, and salt content which contribute to the acidity of milk.

b)-Ice milk properties:

-Specific gravity and Weight / gallon:

The specific gravity and weight per gallon of ice milk had similar trends of variation to that of the mixes. Table (2) shows that the increased by replacing non-fat dry milk with corn starch and that this increase was proportional to the rate of replacement.

Table (2) Effect of corn starch on ice milk properties mix and ice milk. (Average of 3 replicates)

Properties	Percent replacement of NFDM with CS				
	0.0	15	30	45	60
	ice milk mixes				
	T	A	B	C	D
Specific gravity	1.1119	1.1126	1.1134	1.1165	1.1194
Weight per gallon	4.2097	4.2123	4.2153	4.2271	4.2380
Titratable acidity (%)	0.23	0.21	0.20	0.20	0.18
resultant ice milk					
Specific gravity	1.1163	1.0774	1.1559	1.1845	1.2048
Weight per gallon	4.2263	4.1680	4.3762	4.4845	4.5613
Overrun (%)	57.69	58.65	55.45	43.37	41.59
Melting resistance: Loss % at 30°C					
after 60 min	28.4	28.1	25.3	23.9	18.8
after 70 min	47.7	38.3	33.1	32.1	31.3
after 90 min	23.9	33.6	41.6	44.0	49.9

NFDM: non-fat dry milk
CS: Corn starch
T : Ice milk made with non-fat dry milk only
A,B,C,D : Ice milk treatments made by substituting non-fat dry milk with corn starch at the rate of 15, 30, 45,60 %, respectively.

-Overrun (%):

The overrun have opposite trend of specific gravity and weight per gallon, as it decreased slightly by replacing corn starch for non-fat dry milk Table (2). The overrun of ice milk with 15% replacement non-fat dry milk with corn starch was higher than that of the control. Increasing the rate of replacement above 45% reduced slightly the overrun of the resultant ice milk. The decrease in overrun of ice milk may be attributed to the increase in the viscosity and freezing point of mixes containing corn starch, which would inhibit the incorporation of air in the mix during freezing.

-Melting resistance:

The replacement of non-fat dry milk with corn starch decreased the rate of melting after 60 min and the next 30 min, which means increasing the melting resistance of ice milk (Table, 2). There was a negative correlation between the rate of melting and the percentage of replacement. Thus replacing 15% of non-fat dry milk with corn starch exhibited a rate of melting close to the control. While ice cream that made with 60% replacement showed the lowest rate of melting. These results might be due to the increase in mixes viscosity. Another reason for the increase in melting resistance may be due to the decrease in lactose content which causes an increase in the freezing point of ice milk

Organoleptic properties :

The effect of replacing non-fat dry milk with corn starch on the scores for the organoleptic properties of ice milk is shown in Figure (1).

Ice milk from treatments (A) achieved comparable score to the control for both flavour and body & texture. Ice cream from treatments (D) was given the lowest score. On the other hand, score for melting quality decreased by increasing the rate of replacement of non-fat dry milk with corn starch. It is seen from these data that increasing rate of corn starch content up to 45% did not affect the flavour of ice milk. As the replacement of non-fat dry milk with corn starch (CS) increased more than 45% the flavour scores decreased.

Concerning the effect of rate of corn starch on body and texture of ice milk, the results in Figure (1) show that increasing corn starch up to 45% did not affect the body and texture of ice milk.

Increasing the rate of replacement above 45% corn starch caused a significant decrease in texture score. From the foregoing results, it could be concluded that the use of corn starch up to 45% in replacement of non-fat dry milk did not affect significantly ($P > 0.05$) the organoleptic properties of ice milk.

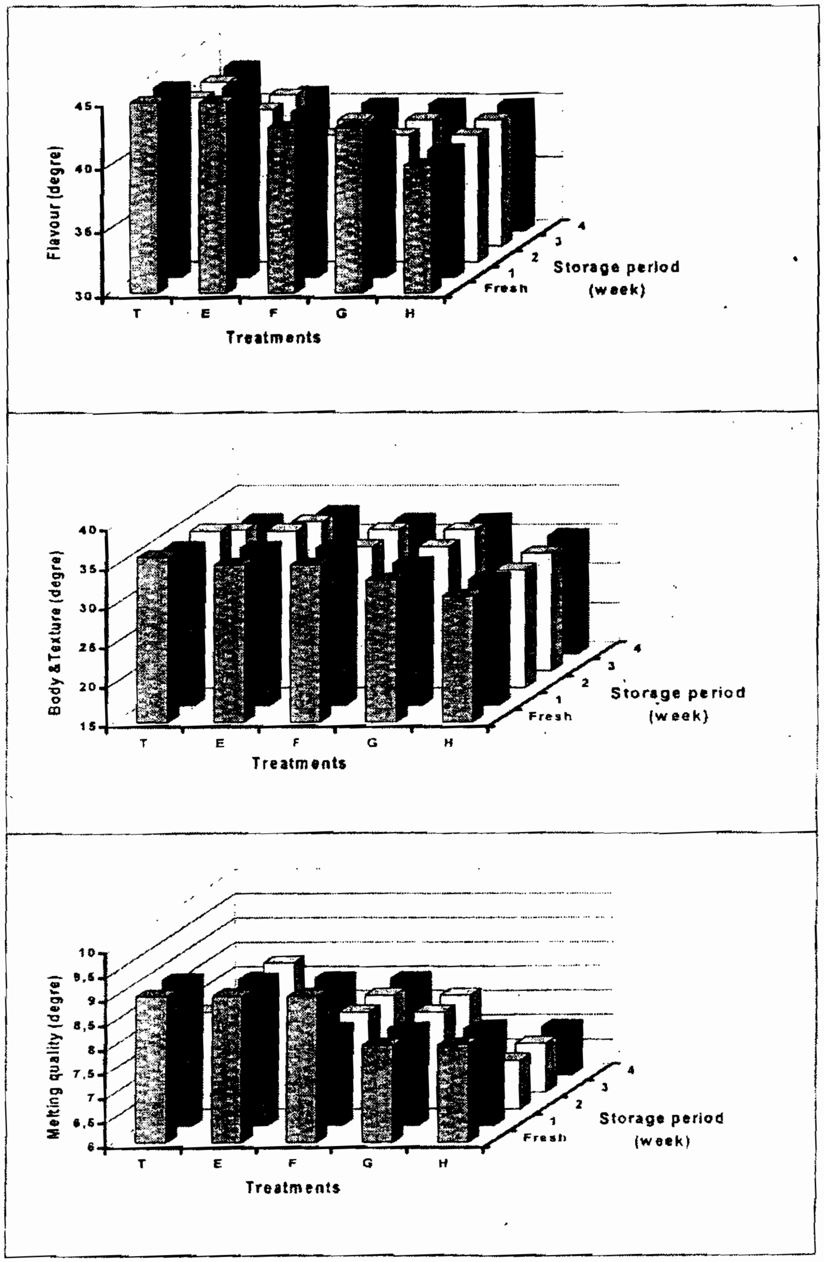

Fig . 1: Scores of organoleptic of ice milk made with corn starch

II- The use of waxy corn starch (WCS):

a) Mixes properties:

-Viscosity:

The viscosity of different ice milk mixes are presented in Table (3). The replacement of non-fat dry milk with waxy corn starch increased the ice milk mixes viscosity. It can be seen that increasing shear rate significantly reduced the apparent viscosity. This might be explained by the deformation of mix, due to shearing. Increasing percentage added waxy corn starch replacing in the mixes increased its viscosity. This increase was probably due to the gel formation and to water hydration. The concentration and type of starch influenced viscosity differently. These results were agree with those reported by (Chedid and Kokini, 1992). Schmidt and Smith (1992), found that waxy corn starch have a (98% amylopectin), which being a branched molecule does not have the same ability to form junction zones and therefore causes viscosity increases without leading to retrogradation.

Table (3) Apparent viscosity at 25°C of ice milk mix containing different percentages of waxy corn starch as a function of the shear rate.

Shear Rate (S^{-1})	Percent replacement of NFDM with Waxy corn starch				
	0.0	15	30	45	60
23.12	226.40	255.10	290.80	335.10	440.10
32.14	218.70	251.10	286.00	328.20	404.40
41.42	210.50	249.00	288.40	293.80	397.60
50.58	205.10	243.00	250.20	281.10	331.40
69.21	187.20	231.20	235.80	262.40	301.60
78.66	160.00	201.52	216.90	240.10	281.70
92.70	147.10	190.96	206.00	224.50	265.20
106.5	136.60	185.30	200.30	213.00	242.70
125.2	124.70	172.81	190.35	208.60	210.40
149.1	103.70	170.00	185.12	196.50	201.50

-Specific gravity and weight per gallon of ice milk mix.

Table (4) shows that the average specific gravity of control mix. was 1.1119 while for that 15, 35, 40 and 60% waxy corn starch replacement they were 1.1122, 1.1130,1.1154 and 1.1179 respectively. It is also seen that the weight per gallon of mixes was closely related to their specific gravity.

The foregoing results indicate that the use of waxy corn starch with different levels in mixes had no marked effect on both specific gravity and weight per gallon of the mixes.

-Titratable acidity

The average titratable acidity of the control mix. was 0.23% but decreased to 0.23, 0.22, 0.21 and 0.20% for mixes with 15, 30, 45 and 60% replacement of non-fat dry milk with waxy corn starch respectively.

b)-Ice milk properties:

Specific gravity and weight per gallon:

Table (4) shows that the specific gravity of the resultant ice milk increased from 1.1163 for control treatments to 1.1269, 1.1299, 1.1342 and 1.1487 for treatments with 15, 30, 45, 60% waxy corn starch respectively. The specific gravity and weight per gallon of ice milk had similar trends of variation as they increased Table (4) by increasing replacement of non-fat dry milk with waxy corn starch. This increase was proportional to the rate of replacement.

-Overrun:

The corresponding figures for overrun decreased from 57.69% for control treatment to 58.40, 56.05, 46.72 and 43.10% for ice milk with 15,30,45 and 60% replacement with waxy corn starch in the same order. The overrun had an opposite trend of variation to specific gravity and weight per gallon. The overrun decreased slightly by replacing waxy corn starch for non-fat dry milk Table (4). Replacement of 15% of non-fat dry milk with waxy corn starch showed slightly higher overrun compared to control. Increasing the rate of replacement above 45% reduced slightly the overrun of the resultant ice milk. These results were probably due to the increase in viscosity that inhibited the incorporation of air in the mix. during freezing. The viscosity of milk proteins/ polysaccharides gels was multiplied by a factor of 2 to 10 in comparison with pure polysaccharides in water gels (Schmidt and Smith, 1992).

-Melting resistance:

From the data presented in table (4) it could be observed that the increase of waxy corn starch tended to decrease the melting resistance of ice cream as shown after one hour of exposure at 30°C. Replacement of non-fat dry milk with waxy corn starch, the rate of melting after 60 min and the next 30 min, which means increasing the melting resistance of ice milk (Table 4). There was negative correlation between the rate of melting and the rate of replacement. The replacing of 15% exhibited the highest rate of melting after 60 min. while ice milk that made with the 60% replacement of non-fat dry milk showed the lowest rate of melting. These results might be due to the increase in mixes viscosity.

Table (4) Effect of waxy corn starch on properties of ice milk mixes and ice milk (Average of 3 replicates).

Property	Percent replacement of NFDM with WCS				
	0.0	15	30	45	60
	ice milk mixes				
	T	E	F	G	H
Specific gravity	1.1119	1.1122	1.1130	1.1154	1.1179
Weight per gallon	4.2097	4.2108	4.2138	4.2229	4.2324
Titratable acidity (%)	0.23	0.23	0.22	0.21	0.20
Resultant ice milk					
Specific gravity	1.1163	1.1269	1.1299	1.1342	1.1487
Weight per gallon	4.2263	4.2656	4.2778	4.2940	4.3849
Overrun (%)	57.69	58.40	56.05	46.72	43.10
Melting resistance: Loss % at 30°C					
after 60 min	28.4	30.6	27.5	26.9	21.0
after 70 min	47.7	42.0	42.4	39.2	38.7
after 90 min	23.9	27.4	30.0	33.9	40.3

FDM: Non-fat dry milk.
WCS: Waxy corn starch.
T : Ice milk made with non-fat dry milk only.
E,F,G,H : Ice milk treatments made without stabilizer by substituting non-fat dry milk with waxy corn starch at the rate of 15, 30, 45,60 %, respectively.

-Organoleptic properties of ice milk:

The effect of waxy corn starch on the flavour of ice milk during storage at –20C is shown in Figure (2). It is seen from these data that increasing waxy corn starch did not affect the flavour of fresh ice milk. As the waxy corn starch content increased more than 45%, flavour scores decreased.

Concerning the effect of waxy corn starch on body and texture of ice milk, the results in Figure (2) show that increasing waxy corn starch content up to 45% did not affect the body and texture of fresh ice milk. As the waxy corn starch increased over 45% replacement the body and texture scores decreased. On the other hand, score of melting quality decreased by increasing the rate of replacement of non-fat dry milk with waxy corn starch.

In conclusion it is possible to make a good quality ice milk by replacing non-fat dry milk up to 45% with either corn starch (CS) or waxy corn starch (WCS) and stabilizers without significant effects on ice milk quality.

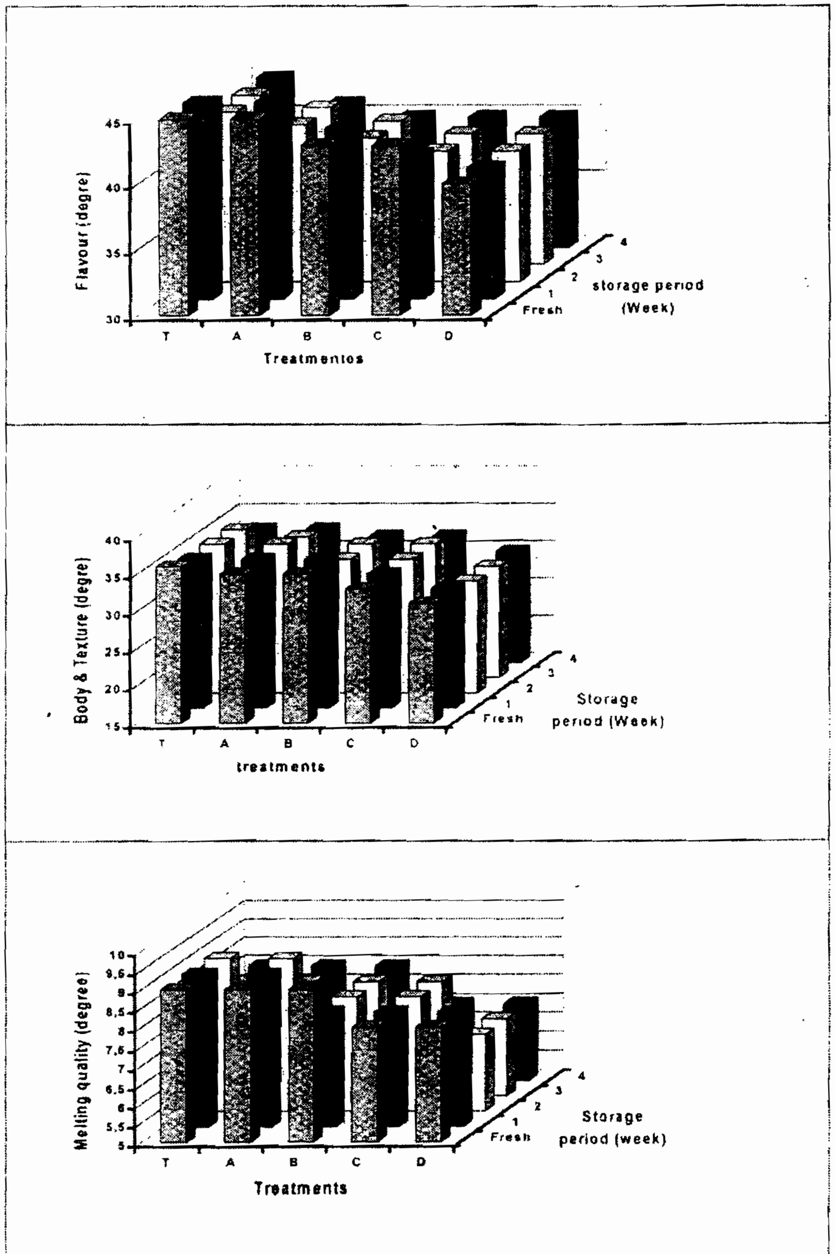

Fig . 2 : Scores of organoleptic of ice milk made with waxy corn starch.

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تأثير نشا الذرة العادي ونشا الذرة الصمغي على صفات المثلوج اللبني

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الملخص العربي

يهـدف هذا البحث إلى دراسة تأثير استبدال اللبن الفرز المجفف المستخدم في صناعة المثلوجات اللبنـية والمثبتات بكل من نشا الذرة العادي ونشا الذرة الصمغي. لذلك فقد تم تحضير ٩ معاملات من المثلوج اللبني واحد منهم صنع باستخدام اللبن الفرز المجفف والمثبت للمقارنة (كنترول) وأربعة منها صـنعت باسـتبدال اللبن الفرز المجفف والمثبت بنشا الذرة العادي بنسب ١٥، ٣٠، ٤٥ و٦٠% على الترتيـب كما صنعت الأربع معاملات الأخرى باستبدال اللبن الفرز المجفف والمثبت بنشا الذرة الصمغي بنسب ١٥، ٣٠، ٤٥ و٦٠% ولقد تم تخزين المثلوج اللبني الناتج لمدة أربعة أسابيع وأخذت عينة كل أسـبوع مـن كـل المعـاملات كمـا تـم تحليل مخاليط المثلوج اللبني للتحليلات الكيماوية والطبيعية والريولوجية والتقييم الحسي. ولقد أوضحت النتائج المتحصل عليها ما يلي:

- لـم يتأثر استبدال اللبن الفرز المجفف والمثبت بكل من نشا الذرة العادي ونشا الذرة الصمغي على الوزن النوعي والوزن للجالون بينما أدت لزيادة اللزوجة وكان نشا الذرة الصمغي أكثر تأثيرا.
- أدى إضـافة نشـا الـذرة العادي أو نشا الذرة الصمغي إلى انخفاض الحموضة وزيادة المقاومة للانصهار.
- أدى زيادة نسبة الاستبدال بواسطة نشا الذرة العادي أعلى من ٤٥% ونشا الذرة الصمغي أعلى من ٣٠% إلى تقليل نسبة الريع.
- لم يؤثر استبدال ٤٥% من اللبن الفرز المجفف والمثبت بواسطة كل من نشا الذرة العادي أو نشا الذرة الصمغي على الخواص الحسية للمثلوج اللبني.