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Quality characteristics of chocolate – containing some fat replacer

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Abstract: Chocolate products are the most important products of candy that popular with a lot, especially children and as a source of energy in addition to its high nutritional value. In chocolate industry, many of ingredients such as cocoa, sugar, cocoa butter, fats, emulsifiers and flavorings play an important role in product quality. This research aims to assess the fatty replacement and its impact on the organoleptic and rheological characteristics of chocolate for the treatment of some problems that arise during marketing thereby increasing the economic returns of these products. Novel functional chocolate spreads were formulated by replacing palm oil in conventional soft chocolate spread by palm olein and cotton seed oil at 25, 50, 75 and 100% levels. Physical, chemical and rheological properties such as particle size distribution, apparent viscosity, flow behavior constants and hysteresis behavior, also sensory evaluation such as smoothness, meltrate, cocoa flavor and milk flovor were measured in soft chocolate samples. Rheological properties indicated that the lower replacement rate 25% of palm olien was closest to the control sample and increasing the ratio of fat replacer had significant advanse effect on rheological properties of investigated chocolate. Sensory evaluation revealed that chocolate made from 25% palm olein was more accepted as conventional chocolate.

1. Introduction

Chocolate is the most frequently craved food (**Hill and Heaten-Brown, 1994**), has an uniquely attractive taste (**Chiva, 1999**) and might even be beneficial for health (**Serafini et al 2003**). The popularity of this food appears to be mainly due to its potential to arouse sensory pleasure and positive emotions (**Macht and Dettmer, 2006**). Chocolate is perceived as a comfort food and has been shown to be craved and consumed during depressive moods (**Macdiarmid and Hetherington, 1995**). Chocolates are complex multiphase systems of particulate (sugar, cocoa, certain milk components) and continuous phases (cocoa butter, milk fat and emulsifiers). During manufacture, refining and conching determine particle size and suspension consistency and viscosity, to yield specific textural and sensory qualities (**Afoakwa et al 2008a**).

The physical properties, rheological behavior and sensory perception of chocolate are influenced largely by its processing technique, particle size distribution and ingredient composition. To enhance chocolate texture, solid particle size distribution and ingredient composition can be manipulated to modify physical properties, rheological behavior and sensorial attributes (**Afoakwa et al 2007**). Particle size distribution and composition have been reported to influence chocolate rheological properties (**Servais et al 2002**). Particle size distribution influences rheology and texture with specific surface area and mean particle size influencing yield stress, plastic viscosity, product spread and hardness (**Afoakwa et**

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al 2008b). Smaller particles improve sensory properties **(Ziegler et al 2001)** but plastic viscosity and yield stress increase due to changes in surface area of particles in contact with fat phase. Particle size optimizations can reduce requirement for viscosity modifiers and improve process control **(Afoakwa et al 2008c)**.

Central to sensory character is continuous phase lipid composition, which influences mouth feel and melting properties. Chocolate triglycerides are dominated by saturated stearic (34%) and palmetic (27%) fatty acids and monounsaturated oleic acid (34%). Chocolates are solid at ambient (20-25°C) and melt at oral temperature (37°C) during consumption giving a smooth suspension of particulate solids in cocoa butter and milk fat **(Beckett, 1999 and Whitefield, 2005)** Differences in the sensory characters of chocolate can be attributed to use of different cocoa types, variations in ingredient proportions, use of milk crumb instead of milk powder, blending techniques and processing methods. Specifications depend on type of chocolate and its intended use **(Jackson, 1999)**.

Some vegetable fats are similar to cocoa butter in triglyceride composition and such cocoa butter equivalents (CBEs) can be added in any proportion to chocolate without causing a significant effect on texture. Cocoa butter replacers (CBRs) such as lauric fats, palm kernel and coconut oils, are used to totally replace cocoa butter **(Talbot, 1999)**. The palm olein is increasingly becoming available in food stores as well **(Gee, 2007)**. The carotenes in palm olein have been demonstrated to have the highest bioavailability among all known plant carotenes. palm olein has been used in many forms to deliver its pro-vitamin (A) carotenes to children at risk. in several cross-continental studies. The findings are consistent: red palm oil administered even in low dose, protects the malnourished child against vitamin A deficiency and the risk of going blind. Moreover, carotenes are known to have several other physiological functions, i.e. antioxidant activity, immune function enhancements and anti-cancer activity **(Sundram, 2005)**. Palm kernel oil (PKO) is regarded as food-grade oil that is of high quality. Its application could be greatly extended if PKO components could be fractionated or modified to have properties that are closer to those of cocoa butter replacers (CBRs), which have a very high value in the confectionary market **(Norulaini et al 2004)**.

This study aims to produce high quality chocolate and reduce the problem of hardness encountered in the consumption of soft chocolate processed with palm oil and full cream milk powder. In addition to investigate new ingredients to avoid the hardness of chocolate by estimating the rheological and sensory properties of novel soft chocolate.

2. Materials and methods

2.1. Materials

Cocoa powder and cocoa mass were obtained from Savola Egypt Co., crystal sugar (sucrose) was purchased from Sugar Egypt Co. The sugar had a moisture of 0.2% with a particle size ranged from 0.2 to 0.75 mm. Skimmed milk powder and full cream milk powder of 26% fat were supplied from Al – GARAS FOOD ingredients Co. Crystal vanillin was supplied from N.A Ibrahim Co. Palm oil (non – lauric specialty oil based on fractionated vegetable fat) was obtained from Loders Croklaan Co. RBD olein (refined ,bleached& deodorized double fractionated palm olein of low melting point) obtained from IFFCO Egypt Co. Hydrogenated cotton seed oil was obtained from Local Egypt Co., Lecithin which had a viscosity of 2000 - 3000 CPS was obtained from Luxe Myer Co., while P.G.P.R (polyglycerol polyricinoleate) numerical references - EEC 476 was obtained from Palsgaard Co.

2.1.1. Preparation of chocolate samples

The following ingredients were used in the manufacture of soft chocolate as previously described by **Melo et al (2009)** and modified using palm oil, skimmed milk powder and P.G.P.R (polyglycerol polyricinoleate).Samples were prepared by replacing part of the palm oil with palm olein and cotton seed oil at levels of 25, 50, 75 and 100%. The quantities of the ingredients that were presented in all the formulations are shown in **Table (1)**.

Table 1. Formulation for soft chocolate by replacing palm oil with palm olein and cotton seed oil

Ingredients %	Control	25 %	50 %	75 %	100 %
Palm oil	20.20	15.15	10.10	5.05	0.00
Sucrose	44.00	44.00	44.00	44.00	44.00
Cocoa mass	4.00	4.00	4.00	4.00	4.00
Cocoa powder	4.00	4.00	4.00	4.00	4.00
Full cream milk powder	20.25	20.25	20.25	20.25	20.25
Palm olein (or) cotton seed oil	0.0	5.05	10.10	15.15	20.20
Skimmed milk powder	6.75	6.75	6.75	6.75	6.75
Vanillin	0.01	0.01	0.01	0.01	0.01
Lecithin	0.7	0.7	0.7	0.7	0.7
P.G.P.R	0.14	0.14	0.14	0.14	0.14

2.2. Methods

2.2.1. Chemical Properties

Moisture and fat contents of the raw materials namely full cream milk powder, skimmed milk powder, cocoa powder and cocoa mass as well as free fatty acids, peroxide value, iodine number and saponification value of palm oil, palm olien and cotton seed oil were determined according to **A.O.A.C.(2000)**.

2.2.2. Physical Properties

2.2.2.1. Melting point

The method given by the **Egyptian Standardization Organization NO.51 (2005)** was applied for measuring the melting point of palm oil, palm olien and cotton seed oil.

2.2.2.2. Particle size distribution:

Particle size was determined with Laser Diffraction Particle Size Analyzer 2000 Ver. 5.31 (Malvern Instrument Ltd., according **Do et al (2007)**.

2.2.3. Rheological Properties

2.2.3.1. Viscosity

Viscoelasticity of soft chocolate was measured at zero time and after 3 &6 months by a rotational type RV(Rheotest 2 – Germany), the investigated samples were introduced into " S_2". The development shear stress values were measured at shear rate from 0.333 to 145.8 S^{-1} as described by **Aeschlimmann and Beckett (2000)**. Apparent viscosity was calculated and given with their corresponding curves, from which the slope of the relation between shear stress and shear rate represented the overall apparent viscosity.

$$\textit{Apparent viscosity } \eta = \frac{\tau}{\gamma} x\ 100$$

Where η = Apparent viscosity in cp
τ = shear stress (dyn / cm^2)
γ = shear rate (S^{-1})

The non-Newtonian behavior index (n) and consistency coefficient (K) were applied and tested according of the formula as given by **Dail and Steffe (1990)**.

$$\tau = K \cdot \gamma^{n}$$

The gab between the ascending and descending shear stress curves that was measured by a digital planimeter "KP- g^2 " reprints hysteresis area in cm^2.

2.2.4. Sensory evaluation

Sensory evaluation of investigated chocolate samples was applied according methods to **Misnow et al (2004)**. Chocolate spreads were evaluated by 10 trained panelists, samples were kept at room temperature (24°C ± 2) for 1 h before evaluation. Samples were served in white plastic cups; water and bread were provided for cleaning the palate between samples. Each panelist was asked to give a number from 1 (Extremely dislike) to 9 (Extremely like) on the hedonic scales for texture attributes: smoothness (sensation on tongue and roof of mouth whilst product is melting), melt rate (rate of disappearance in mouth) and viscosity (perception of thickness / thinness of sample in mouth).

2.2.5. Statistical analysis

Analysis of variance was computed using All PC–Stat Version 1A procedures (SAS, 1996). Differences arrange means were evaluated using Duncan's multiple range test ($P < 0.05$).

3. Results and discussion

3.1. Chemical parameters

Proximate chemical composition of soft chocolate constituents are summarized in **Table (2)**. Moisture content of skimmed milk powder, full cream milk powder, cocoa powder and cocoa mass were 2.97, 2.48, 3.08 and 1.30 %, respectively. The Cocoa mass was found to be higher content of fat reaching 65%.

Table 2. Chemical properties of ingredients used in soft chocolate

Ingredients	% Moisture	Chemical constituents g/100g dry matter	
		% Ash	% Fat
Skimmed milk powder	2.97±0.51	6.49± 0.34	1.1 ± 0.01
Full cream milk powder	2.48±0.53	0.11± 0.01	26.62± 0.58
Cocoa powder	3.08±0.42	4.65± 0.26	11± 0.01
Cocoa mass	1.30±0.12	6.80± 0.35	65.0± 0.01

Data presented in **Table (3)** showed chemical analysis of fat ingredients of palm oil, palm olein and cotton seed oil. The melting point of palm olein gave the highest value (13.33°C) while, for cotton seed oil and palm oil were 12.0 and 9.29°C, respectively. However, the free fatty acid content was equal each other. Date found that no significant differences in peroxide and saponification values between palm oil and cotton seed oil. While, cotton seed oil was the highest one in iodine number (103.4).

3.2. Physical properties of soft chocolate

3.2.1. Particle size distribution

Laser scattering analysis indicated a mono modal particle size distribution (P.S.D) of soft chocolate **(Table 4)**. Data of PSD gave volume histograms (0.84 µm), specific surface area (m^2/g) and mean particle diameter D[4,3] (um). PSD of 25% replacing of palm oil with palm olein was less than control in mean particle size (10.76 um), however replacing with cotton seed oil at the same ratio was similar to control (12.52 um) as seen in **Figs. 1 (a and 1(b)**. **Beckett (1999)** concluded that largest particle size and solids specific surface area were the two key parameters for chocolate manufacture. The former determines chocolate coarseness and textural characters; the latter is associated with requirement of fat for desirable flow properties. From the obtained data, it could be noticed the specific surface area was significantly increased as a function of increasing of fat replacer ratio from 25 to 75% when samples were statistically analyzed at $P \leq 0.05$.

3.2.2. Rheological measurements

3.2.2.1. Apparent viscosity

It seems clearly that tested chocolate samples are of Non Newtonian fluids and when the measured apparent viscosity (cp) is figured against shear rate (S^{-1}) for chocolate formulated either with palm oil or palm olien **(Fig. 2)** the following trends may be concluded. Values of viscosity indicated the presence of a noticeable variation within samples at any given shear rate. For instance, at shear rate 5.4 S^{-1} the apparent viscosity was 33681cp for the control chocolate and 30717 cp for the sample replaced with 25% palm olien **(Table 5)**. The noticeable variation is a function of fat replacement effect **(Afoakwa et al 2007)**.

Table 3. Physiochemical analysis of fat ingredients used in soft chocolate

Ingredients	Melting Point / °C Start	Final	FFA	Peroxide Value	Iodine Number	Saponification Value
Palm oil	8.52 ± 0.56	9.29 ± 0.51	0.04 ± 0.01	0.01±0.002	64.89 ± 2.50	190.88± 4.72
Palm olien	12.54 ± 0.62	13.33 ± 0.58	0.04 ± 0.01	0.05±0.02	63.30 ± 2.48	....
Cotton seed oil	11.0 ± 0.56	12.0 ± 0.51	0.04 ± 0.01	0.01±0.002	103.4± 2.50	191.7± 4.72

Table 4. Particle size distribution of soft chocolate

Treatments	Palm olein			Cotton seed oil		
	mμ	m^2/g	um	mμ	m^2/g	Um
Control	21.00	1.14	12.52	21.00	1.14	12.52
25 % replace	20.26	1.56	10.766	24.01	1.41	12.521
50 % replace	21.48	1.53	11.262	22.18	1.46	11.69
75 % replace	19.79	1.71	10.349	24.00	1.41	12.59
100 % replace	21.55	1.48	11.400	17.56	1.65	9.418

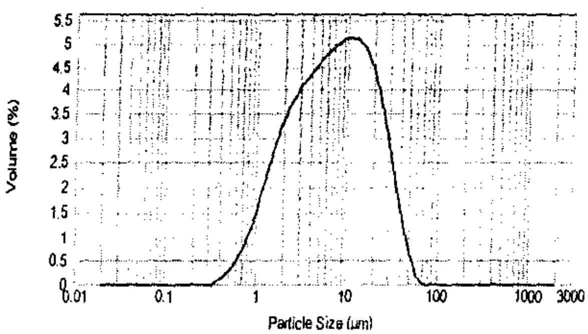

Fig. 1 (a). Particle size distribution of soft chocolate fat replaced with 25% palm olein

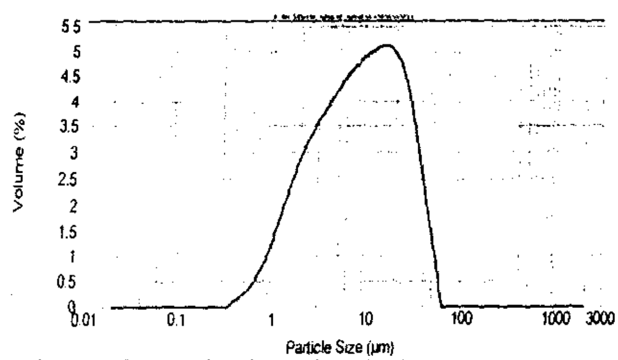

Fig. 1 (b). Particle size distribution of soft chocolate fat replaced with 25% cotton seed oil

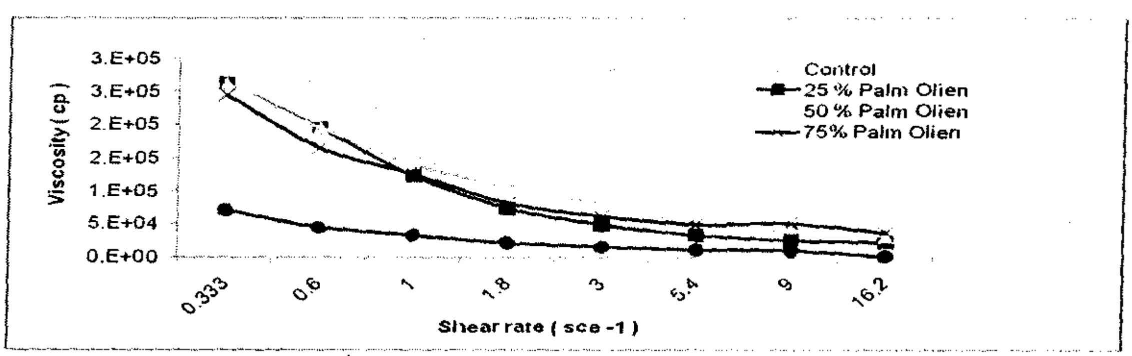

Fig. 2. Apparent viscosity as a function of shear rate of chocolate samples made using palm olien as a replacer for palm oil

Table 5. Apparent viscosity as a function of shear rate of chocolate samples made using palm olien as a replacer for palm oil

Shear Rate	Control	25% Palm Olien	50% Palm Olien	75% Palm Olien	100% Palm Olien
0.333	183514	113604	113604	157297	69910
0.6	113975	130950	77600	106700	43650
1.0	80025	84390	52380	72750	32010
1.8	56583	56583	35567	48500	21017
3.0	43650	43650	27160	37830	15520
5.4	33681	30717	19939	29639	11317
9.0	28453	31363	14550	25543	9700
16.2	19549	35543	15269	2874	719
27.0	24525	29856	15994	24525	77840
48.0	22792	2399	14395	20993	8397
81.0	22037	24880	13862	19549	8175
145.8	19746	19746	13230	15797	7898

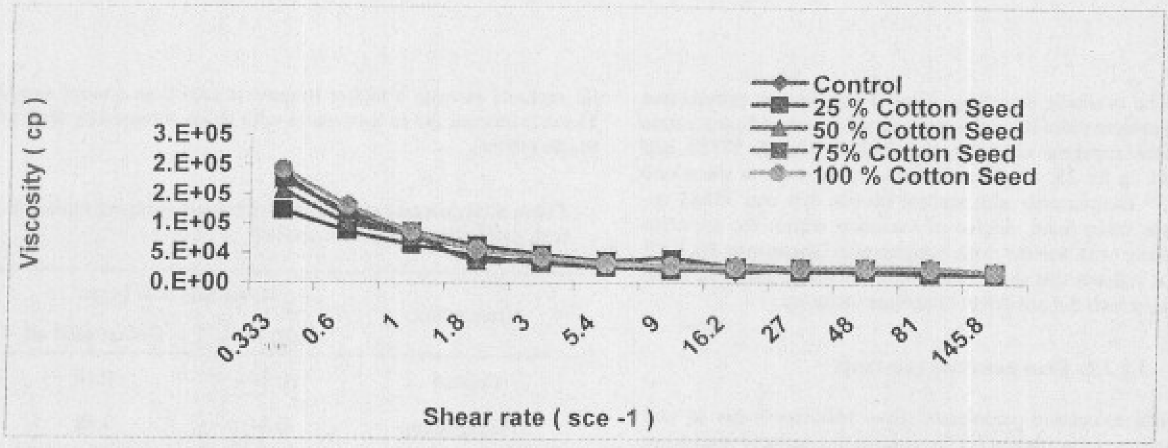

Fig. 3. Apparent viscosity as a function of shear rate of chocolate samples made using cotton seed oil as a replacer for palm oil

Table 6. Apparent viscosity as a function of shear rate of chocolate samples made using cotton seed oil as a replacer for palm oil

Shear Rate	Control	25% C.S.O *	50 % C.S.O	75 % C.S.O	100 % C. S. O
0.333	183514	122342	157297	174775	192252
0.6	113975	87300	101850	121250	130950
1.0	80025	64020	78570	87300	87300
1.8	56583	45267	37183	63050	56583
3.0	43650	32980	40740	47530	43650
5.4	33681	26944	33950	37722	33411
9.0	28453	22957	30070	41586	29747
16.2	19549	24880	30212	28435	28435
27.0	24525	20260	26657	26657	26657
48.0	22792	19193	26391	26391	26991
81.0	22037	16350	24525	24880	26657
145.8	19746	15994	19746	19746	19746

- **C.S.O = Cotton seed oil.**

Table 7. Flow behavior constants (k) and (n) of investigated soft chocolate samples

Samples	Palm olein			Cotton seed oil		
	K(Pas.S)	n	R^2	K (Pas.S)	n	R^2
Control	795.21	0.6509	0.9570	795.21	0.6509	0.9570
25% replacer	783.88	0.6987	0.9732	616.20	0.6763	0.9766
50% replacer	502.12	0.6551	0.9516	716.25	0.7074	0.9657
75% replacer	726.83	0.6586	0.9698	874.57	0.6668	0.9790
100% replacer	264.83	0.6000	0.6662	850.80	0.6645	0.9583

The available data (**Fig. 3** and **Table 6**) also proved that replacement palm oil with cotton seed oil with different ratios showed apparent viscosity was 26944, 33950, 37722 and 33411 cp for 25, 50, 75 and 100% replacement at shear rate 5.4 S^{-1} comparative with control sample that was 33681 cp. On the other hand, degree of variation within the apparent viscosity was narrow with control after shear rate 16.2 S^{-1} and it reflects that there is no significant difference in these ratios, which did not affect chocolate viscosity.

3.2.2.2. Flow behavior constants

The calculated parameters (flow behavior index n) and (consistency coefficient K) for control, fat replacer with palm olein as well as cotton seed oil soft chocolate samples are summarized in **Table (7)**. Correlation coefficient (R^2) for the regression analysis of log shear stress log shear rate data was 0.9516 indicating a strong correlation for the tested parameter within the aforementioned chocolate samples.

The flow behavior index (n) of control and treated chocolate samples were less than 1.0 giving a value ranged from 0.6000 to 0.7074; a pattern which indicating their strong non-Newtonian pseudoplastic behavior. The added level of palm olein caused high reduction in consistency coefficient (K) from 783.88 (25% replacing) to 264.83 (100% replacing) Pas.S in soft chocolate. These results confirm with those reported by (**El-Hadad et al 2011**). On contrary, added level of cotton seed oil caused increase in consistency coefficient from 616.20 to 850.80 Pas. S, respectively.

3.2.2.3. Hysteresis behavior

The hysteresis area of tested soft chocolate samples was given in **Table (8)**, which was based on **Figures (4 and 5)**. Soft chocolate with 25% palm olein showed a hysteresis area of 0.44 cm^2, while 100% replacing showed a decremental trend in hysteresis area to be 0.1 cm^2. However, hysteresis area of soft chocolate with cotton seed oil replacer at 25% was higher than the other treatments (0.48 cm^2). Generally, fat replacer showed a higher hysteresis area than control sample. These evidences are in agreement with those obtained by **Dail and Steffe (1990)**.

Table 8. Hysteresis area of soft chocolate samples replaced with palm olien and cotton seed oil

Treatments	Hysteresis area In cm^2	
	Palm olein	Cotton seed oil
Control	0.10	0.10
25% replacing	0.44	0.48
50% replacing	0.33	0.17
75% replacing	0.17	0.38
100% replacing	0.1	0.34

3.3. Sensory properties

Mean scores of sensory properties of soft chocolate **Table (9)** reveal that 25% replacing is the best acceptable ratio either with palm olien or cotton seed oil. Chocolate which were prepared with replacing palm oil with palm olein at ratio 25% had higher scores of cocoa flavor (9.2) which was found to be significantly higher at $p \leq 0.05$ in comparison with all treatments. Utilization of cotton seed oil as a fat replacer up to 50% resulted chocolate smoothness that was significantly comparable in acceptability compared to the control. As cotton seed oil replacement increased, the chocolate meltrate was less acceptable, as judged by panelists. Finally, a high quality functional chocolate was able to be produced by replacing palm oil with palm olein at 25 % level. These results are in agreement with those mentioned by **El-Hadad et al (2011)** who studed the high quality functional chocolate spread by replacing the butter fat with red palm olein at 20% level.

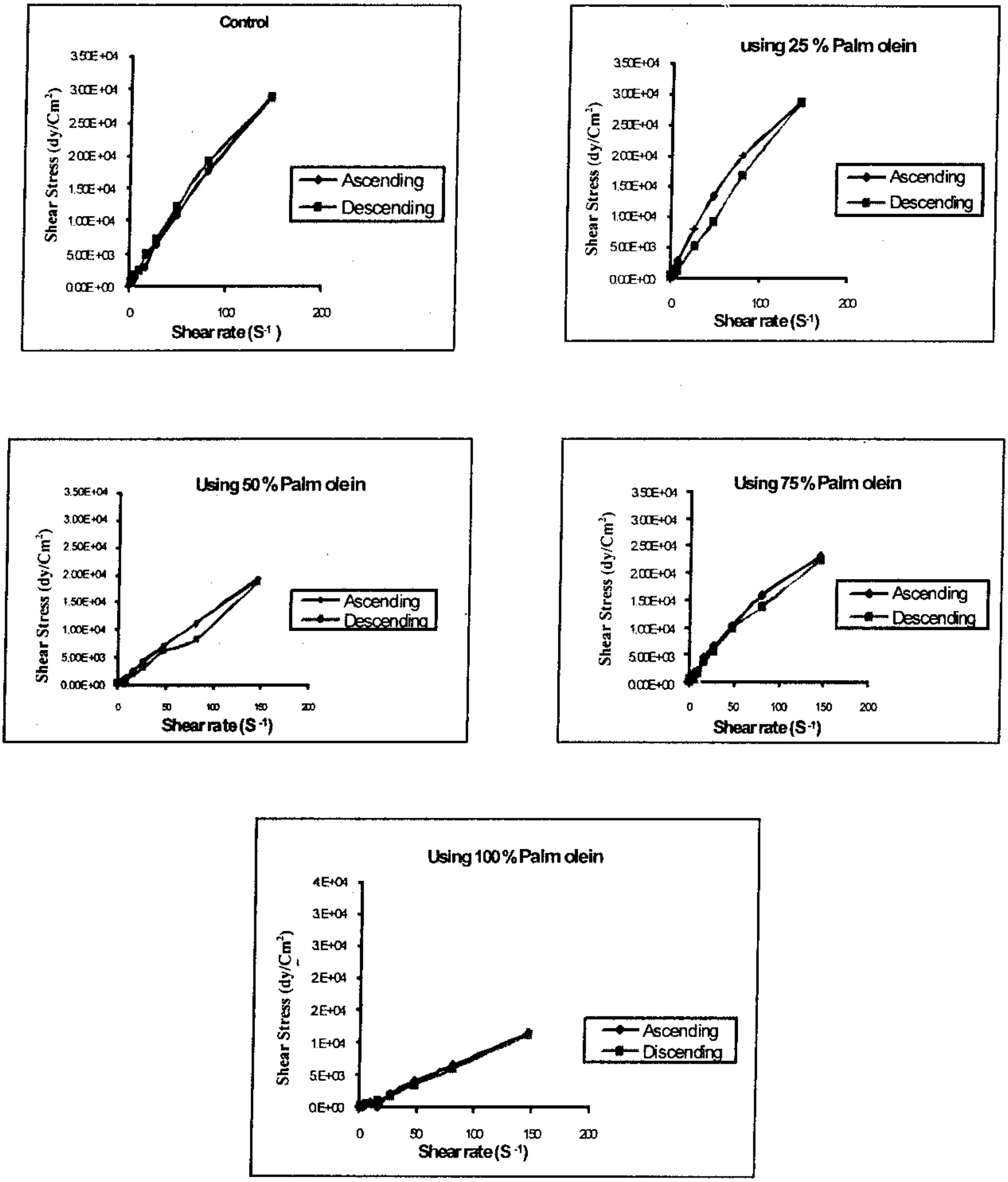

Fig. 4. Hysteresis curves of soft chocolate using different percentages of palm olien

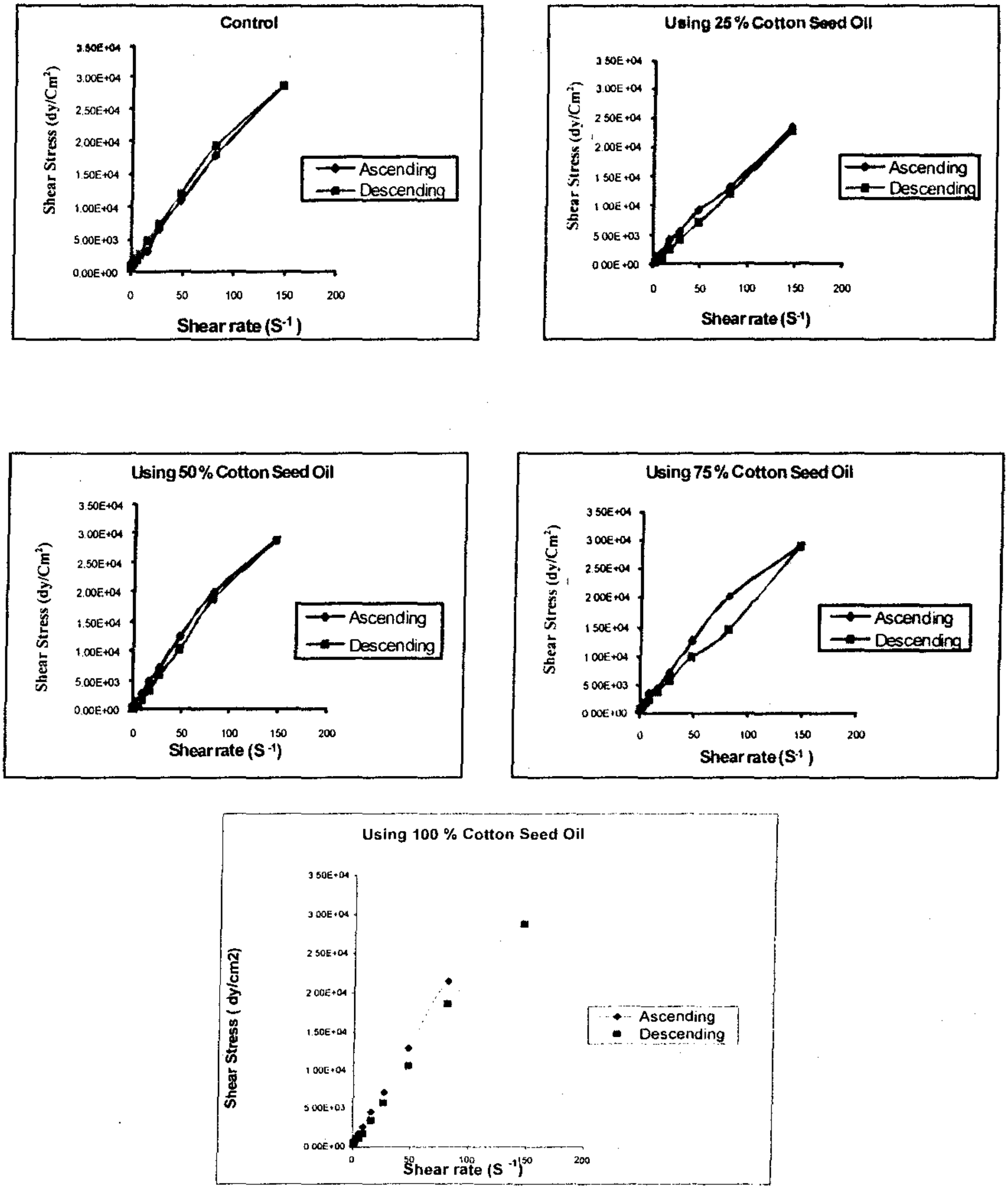

Fig. 5. Hysteresis curves of soft chocolate using different percentages of cotton seed oil

Table 9. Sensory evaluation of the soft chocolate replacement the palm oil with palm olein and cotton seed oil

Treatments	Texture Attributes			Assess Flavor	
	Smoothness	Meltrate	Viscosity	Cocoa Flavor	Milk Flavor
			Palm olein		
Control	9.6 ± .5 [a]	9.7 ± .5 [a]	9.8 ± .4 [a]	9.8 ± .4 [a]	9.7 ± .5 [a]
25 %	9.2 ± .4 [ab]	9.6 ± .5 [a]	9.3 ± .5 [a]	9.2 ± .4 [b]	9.2 ± .4 [b]
50%	8.7 ± .5 [bc]	9.2 ± .4 [a]	9.5 ± .5 [a]	8.8 ± .6 [bc]	8.7 ± .5 [c]
75 %	8.2 ± 1.0 [c]	7.8 ± 1.0 [b]	8.0 ± .9 [b]	8.5 ± .6 [c]	8.4 ± .5 [cd]
100 %	8.2 ± 1.0 [c]	8.3 ± .9 [b]	8.4 ± .7 [b]	7.9 ± .7 [d]	8.2 ± .6 [d]
			Cotton seed oil		
Control	9.6 ± .5 [a]	9.7 ± .5 [a]	9.7 ± .5 [a]	9.7 ± .5 [a]	9.7 ± .5a
25 %	9.0 ± .9 [a]	8.6 ± .5 [a]	8.6 ± .5 [b]	8.2 ± .4 [b]	8.2 ± .4 [b]
50%	8.1 ± .3 [b]	8.2 ± .4 [b]	8.6 ± .5 [b]	7.5 ± .7 [c]	7.6 ± .5 [c]
75 %	7.4 ± .8 [b]	6.8 ± 1.0 [c]	6.6 ± .9 [c]	7.0 ± .8 [cd]	6.7 ± .5 [d]
100 %	7.4 ± 1.173 [b]	7.2 ± .788 [b]	7.0 ± .9 [c]	6.6 ± .5 [d]	6.7 ± .5 [d]

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خواص جــودة الشوكولاتـــه المحتوية على بدائل الدهــون

[١١]

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الموجـــز

تعتبر منتجات الشوكولاته وخاصــة الــشوكولاتة السائلة من أهم منتجات الحلوى التي يقبل عليها الكثير خاصة الأطفال، و تعتبر مصدراً من مصادر الطاقـــة بالإضافة إلى قيمتها الغذائية العالية ويدخل في صناعة الشوكولاتة العديد من المكونات مثل الكاكاو – السكر – زبدة الكاكاو وبعض الدهون والمستحلبات والمـــواد المنكهة، وتلعب هذه المكونات دوراً هاماً في جـــودة المنتج. ويهدف هذا البحث إلى تقييم إستبدال الجـــزء الدهنى وتأثيره على الصفات الحـــسية والريولوجيـــة للشوكولاتة ، بغرض علاج بعض المشاكل التي تنشأ أثناء التسويق مما يزيد من العائد الاقتـــصادي لهـــذه المنتجات. حيث تم تعديل تركيب للشوكولاته وذلك من خلال إستبدال جزء من زيت النخيل بأولين النخيـــل وكذلك زيت بذرة القطن بنسب إســـتبدال ٢٥ ، ٥٠ ، ٧٥ ، ١٠٠ % وتـــم تقـــدير التركيـــب الكيميـــائى والخصائص الطبيعية، الخـــواص الريولوجيـــة مثـــل توزيع حجم الجزيئات واللزوجة ومن ناحية اخرى تم حساب كل من معامل القوام (K)، والاجهاد الظاهرى بالاضافة الى تقدير الاس اللانيوتـــونى (n) لجميـــع العينات حيث كانت النتائج اقل من الواحـــد الـــصحيح وتراوحت ما بين 0.6509 الى 0.7074 وهذا يثبـــت ان سلوك الانسياب للـــشوكولاتة المـــصنعة يتبـــع الــــ Pseudoplastic . وأيضاً الخواص الحسية مثل الذوبان بالفم ، ، نكهـــة الكاكـــاو، نكهـــة الحليـــب لعينـــات الشوكولاته. وبالنسبة للخصائص الريولوجية وجد أن نسب الاستبدال المنخفضة كانت الأقرب الى الكنترول كما وجد أن الزيادة فى إستخدام الدهن لم يكن له تاثير معنوى على الخصائص الريولوجية للشوكولاته. وقد خلصت هذه الدراسة الى أن الشوكولاته المصنعة من ٢٥٪ زيت اولين النخيل بدلاً من زيت النخيل كانـــت هى الأكثر قبولاً.

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