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EFFECT OF DIFFERENT MILK SUBSTITUTES ON RHEOLOGICAL PROPERTIES OF PUDDINGS

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Abstract: *Commercial pudding powders are usually composed of starch, hydrocolloids, colorings and aromas, and are intended to be dissolved in milk. The use of milk substitutes is mandatory for people suffering from lactose intolerance and milk allergies, but these ingredients have an effect on pudding structure and rheological behavior that has been little studied. The aim of the present study was to characterize the rheological behaviour of three commercial pudding powders dissolved in water, rice drink, grapefruit juice, soy drink and milk (reference sample). The three pudding powders, apparently similar in formulation, resulted in final products with large rheological differences that could be ascribed to different types and to quantity of starch present in the formulation. Generally, the properties of rice drink based products were comparable to those of the water systems, while the characteristics of soy drink based puddings were similar to those of the reference sample.*

Keywords: *dairy dessert, milk fat, viscosity*

1. Introduction

Functional food contains some health-promoting compounds beyond traditional nutrients and plays an important role in enhancing human health [1]. In the modern diet, there is a trend towards increased consumption of reduced-fat products [2]. The study of Stussy, M.J., investigated the effect of non-fat chocolate pudding as a fat replacement in brownies and concludes that this modified product has potential for success in the consumer market, offering a healthier alternative to traditionally high-fat brownies [3]. Other studies reported replacement of sugar with stevia (a natural sweetener obtained from the leaf of *Stevia rebaudiana* plant) [4], possibility of using full fat soy flour for replacer for whole milk flour and soybean oil as replacer for cocoa butter in chocolate manufacture [5], guar gum and gum arabic as fat replacers in low-fat Iranian white cheese [6].

Researches of Thomson L.U. et all. examined the effect on the quality of substituting succinylated cheese whey milk protein concentrate in ice cream and instant pudding and concluded that the use of succinylated whey protein concentrate in ice cream increased viscosity and resistance to melting and reduced freezing time and overrun [7]. Ares G. and all. find that addition of a new functional fibre, high-amylose maize starch caused changes in the sensory characteristics in milk puddings, an increase in manual and oral thickness and a decrease in creaminess, melting and sweetness [8].

In a study, Nunes M.C. and all. find that mixed protein – polysaccharide systems, with vegetable proteins and κ-carrageenan or gellan gum – would be good systems to develop vegetable protein desserts [9].

To offer consumers foods that are lower in fat content, several low-calorie and calorie-free fat replacers or fat substitutes have been developed. These ingredients contribute fewer calories to the formulated foods without altering flavour, mouthfeel, viscosity, or other sensory properties [2].

Dairy desserts (milk puddings) are especially consumed by children and elderly people throughout the world. They are generally sold in the powdered or prepacked form and composed of vanilla milk, sugar and thickeners (gum and starch) [10]. Other ingredients such as cacao and fruit aromas are used in formulations to have products with different flavours, affecting consumer acceptability.

Regarding dairy products, many studies have been published dealing with the effect of fat content on rheological behaviour and sensory properties, mainly on flavour and texture perception [11, 12, 13]. However, only a few papers deal with the rheological characterisation of commercial dairy desserts or their corresponding model systems.

The rheology of food products is very important because flow properties define food structure during industrial manufacturing or preparation in the kitchen and this is physiologically important in the mouth, stomach and intestine where the food structure is perceived and digested. In addition, the rheological properties are also important for sensory perception characteristics (e.g. portioning, scooping, dosing, filling) and nutritive characteristics (e.g. release kinetics, satiety). Texturing agents are also important for flavor release because they increase viscosity which in turn impairs perception [14].

The rheological characteristics of dairy desserts mainly depend on the fat content of milk, type and concentration of hydrocolloids and their interactions [15]. The use of two or more gums in the formulation of the product is very widespread in the food industry due essentially to the synergistic effect of combined use [16].

The aim of the present study was to characterize the rheological behaviour of three commercial pudding powders dissolved in water, rice drink, grapefruit juice, soy drink and milk (reference sample).

2. Materials and methods

2.1. Materials

Three commercial puddings with vanilla, caramel and chocolate flavour were purchased from the local market. The declared ingredients list is: corn starch, vanilla flavor (contains milk), color: beta-carotene (vanilla pudding); corn starch, caramel, caramel flavor, colored brown HT and curcumin (caramel pudding); corn starch, low-fat cocoa (11% cocoa butter), ethyl vanillin flavor (chocolate pudding). Its approximate composition is shown in Table 1.

Table 1.
Approximate composition of the comercial pudding sample studied

Raw material	Composition (%)
Water	59.0
Proteins	10.0
Carbohydrates	21.0
Fats	7.2
Flavours, etc.	2.8
Total	100

2.2. Sample preparation

Pudding samples were prepared as follows: 500 ml milk, rice drink, soy-drink or water were used for a bag of pudding (40 g). The contents of a bag of pudding mix with 4 tablespoons of milk or milk substitute. The amount of milk or milk substitute boil, then removed from heat, and the mixture prepared is added. Then it is boiled again on low heat, stirring gently till the composition binds.

The pudding samples were made using cow milk. The cow milk analysis by LACTOSTAR 2005 FUNKE GERBER led to the physical and chemical parameters presented in Tabel 2.

Table 2.
Milk properties

Fat, g/100g	3.30
Protein, g/100 g	3.19
Lactose, g/100 g	4.61
SNF (Solid Non-Fat), g/100 g	8.49
Freezing point, ^{0}C	- 0.5
Minerals, g/100 g	0.02
Conductivity, mS	0.89

Boiling water for rice and soy and non-carbonated grapefruit juice were used.

2.3. Determination of acidity of pudding samples

Acidity analysis of pudding samples was achieved by titration with NaOH in the presence of phenolphthalein as indicator.

2.4. Determination of rheological properties

Viscosity measurements were carried out on the yogurt samples at ambient temperature (25^{0}C), with a Brookfield viscometer (Brookfield Engineering Inc, Model RV- DV II Pro+) at 0.5, 1, 2, 2.5, 4, 5 and 10 rpm with RV spindle (RV3, RV4, RV5, RV6 type). The spindle nos were used in accordance with the sample nature to get all readings within the scale [15].

The samples in 300 mL of beaker with an 8.56 cm diameter (according to the Brookfield requests) were kept in a thermostatically controlled water bath for about 10 min before measurements in order to attain desirable temperature of 25^{0}C.

First measurements were taken 2 min. after the spindle was immersed in each sample, so as to allow thermal equilibrium in the sample, and to eliminate the effect of immediate time dependence.

All data were then taken after 40 s in each sample. Each measurement was duplicated on the sample.

The obtained empirical data were converted using the Mitschka relationships to shear rate and shear stress. The shear rate versus shear stress data were interpreted using the power law expression

$$\sigma = k \cdot \gamma^n \qquad (1)$$

where:

σ – shear stress (N/m^2),

γ is the shear rate (s^{-1}),

n is the flow behaviour index, *k* is the consistency index (Ns^n/m^2).

The values for the flow behaviour index n, were obtained from plots of log shear stress versus log rotational speed; the slope of the line (if the dependence is sufficiently close to a linear one) is simply equal to the flow index of the fluid, *n*.

The shear stress is calculated using the next equation:

$$\tau_i = k_\tau \cdot \alpha_i \cdot C \qquad (2)$$

where:

τ_i – shear stress, (dyne/cm^2)

k_τ = 0.119, this constant is for the spindle nos 2

α_i – torque dial, (%)

C – 7.187 dyne/cm for RV viscometer

The shear rate is calculated using the next equation:

$$\gamma_i = k_\gamma(n) \cdot N_i \qquad (3)$$

where:

γ_i – shear rate, (s^{-1})

k_γ(n) – constant, depends by the value of n

N_i – rotational speed, (rpm).

3. Results and Discussion

The acidity analysis results for pudding samples are presented in Table 3.

Table 3.
Acidity of pudding samples

Sample		Acidity (acidity degrees)
Vanilla pudding with water	VP1	0.81
Vanilla pudding with rice drink	VP2	0.82
Vanilla pudding with grapefruit juice	VP3	3.53
Vanilla pudding with soy drink	VP4	1.98
Vanilla pudding with milk (reference sample)	VP5	1.76
Caramel pudding with water	CP1	0.32
Caramel pudding with rice drink	CP2	0.33
Caramel pudding with grapefruit juice	CP3	3.33
Caramel pudding with soy drink	CP4	1.87
Caramel pudding with milk (reference sample)	CP5	1.67
Chocolate pudding with water	ChP1	0.82
Chocolate pudding with rice drink	ChP2	0.84
Chocolate l pudding with grapefruit juice	ChP3	2.11
Chocolate pudding with soy drink	ChP4	1.87
Chocolate pudding with milk (reference sample)	ChP5	2.09

Vanilla pudding with grapefruit juice has the highest value of acidity, and rice-drink based vanilla pudding has the lowest value.

Puddings sample exhibit a non-Newtonian behaviour, the flow index (*n*) id under 1 for all the samples. The power law model is a suitable one for predicting the rheological parametersthe rheological parameters, the regression coefficient is near 1 ($R^2 > 0.95$) – see table 2.

Consistency index (*K*) values is in the range of 3.62 – 12.93 ($N{\cdot}s^n/m^2$) and flow behaviour index (*n*) values in the range of 0.426 – 0.706.

In a study about rheological behaviour of soy protein-based puddings, Lim H.S. et all found that the *K* and *n* values for soy-protein based puddings were comparable to those of the commercial puddings [17].

Table 3.
Power law parameters for pudding samples

Sample	*n – flow index*	*K – consistency index* ($N{\cdot}s^n/m^2$)	R^2
VP1	0.61	7.57	0.96
VP2	0.581	8.17	0.956
VP3	0.545	8.05	0.957
VP4	0.453	11.7	0.973
VP5	0.431	12.58	0.955
CP1	0.466	10.75	0.967
CP2	0.426	12.93	0.956
CP3	0.448	11.49	0.986
CP4	0.487	9.53	0.957
CP5	0.457	10.64	0.958
ChP1	0.706	5.1	0.969
ChP2	0.644	5.92	0.965
ChP3	0.556	8.36	0.971
ChP4	0.542	3.62	0.996
ChP5	0.535	8.95	0.997

In figure 1 the viscosity of vanilla pudding with water, rice drink, grapefruit juice, soy drink and milk (reference sample) is presented.

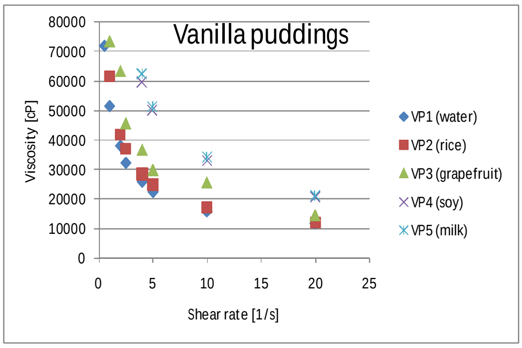

Figure 1. Viscosity profile of vanilla pudding with water (VP1), rice drink (VP2), grapefruit juice (VP3), soy drink (VP4) and milk (VP4)

Generally, the viscosity of rice drink based puddings were comparable to those of the water systems, while the viscosity of soy drink based puddings were similar to those of the reference sample. The grapefruit juice-based pudding has an intermediate behaviour between the two groups. In figures 2 and 3 the viscosity of caramel and chocolate puddings with water, rice drink, grapefruit juice, soy drink and milk (reference sample) are presented.

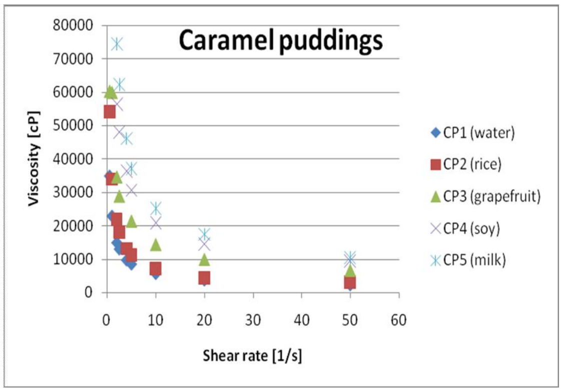

Figure 2. Viscosity profile of caramel pudding with water (VP1), rice drink (VP2), grapefruit juice (VP3), soy drink (VP4) and milk (VP4)

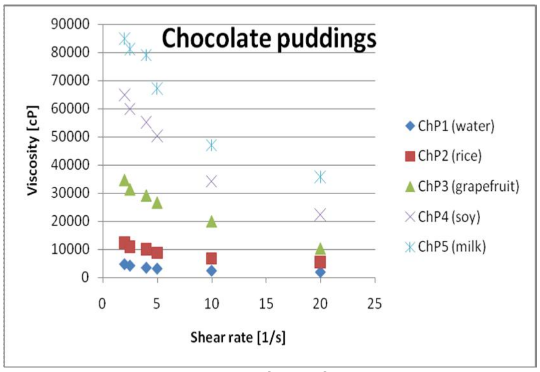

Figure 3. Viscosity profile of chocolate pudding with water (VP1), rice drink (VP2), grapefruit juice (VP3), soy drink (VP4) and milk (VP4)

The influence of the type of pudding on the rheological behaviour is shown in figure 4.

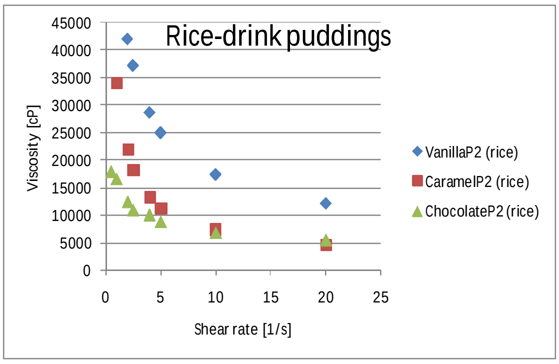

Figure 4. Viscosity profile of rice-drink based vanilla, caramel and chocolate puddings

From the data presented in Figure 4, it is observed that chocolate pudding has the lowest viscosity; caramel pudding next and vanilla pudding has the highest viscosity. This may be due to traces of milk that the composition of this pudding may contain.

4. Conclusion

The pudding is a complex viscous food material due to its nature and composition. Rheological behaviour of pudding is influenced by milk fat.

The rheological behaviour of dairy dessert is among the most crucial factors affecting consumer acceptability of such products.

Generally, the viscosity of rice drink based puddings were comparable to those of the water systems, while the viscosity of soy drink based puddings were similar to those of the reference sample (with milk). The grapefruit juice - based pudding has an intermediate behaviour between the two groups.

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