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Investigating the effect of starch type on the rheological behaviour of Custard

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Abstract

Custard is a starch-based popular dessert with a semi-solid texture. The present study aimed to investigate the changes in rheological properties of custard prepared with waxy and modified waxy corn starch. The results indicated that using waxy and HHP (High Hydrostatic Pressure) starch could increase the flowability index significantly from 0.04 to 0.22 in both waxy corn starch and HHP starch contained samples. All custard samples showed thixotropic behaviour and fitted to the Weltman and Sisko model with R^2 higher than 95 percent. Using waxy and HHP starch both led to a significant change of initial shear stress from 1.64±0.04 in the control sample to 2.98±0.03 and 1.36±0.00 in waxy and HHP custard, respectively.

Keywords: Rheology, Thixotropic behaviour, Starch, Custard

Introduction

Custards are generally milk starch-based desserts, with a typical texture of a semi-solid. They can be explained as a suspension of deformable starch particles dispersed in a continuous medium containing milk fat and proteins as well as a gelling agent (mostly carrageenan) that has high syneresis and phase separation [1]. Starch has a critical role in the properties of the system, including texture, flow behaviour and viscosity, depending on the type and the concentration [2]. There are different methods to modify starch and increase the polymer flexibility with new physicochemical properties [3]. Applying high hydrostatic pressure is a physical modification method that could increase the stability, water absorption and creamy texture of the treated waxy corn starch [4, 5].

There are many research reports on the effect of formulation on the rheological characteristics of custards [1, 6-10].

Thus, this study aimed to determine the rheological properties of custard with different starch types.

Experimental

Materials

waxy corn starch (CAS No: 9005-25-8), sucrose (CAS No: 57-50-1), and κ-Carrageenan (CAS No: 11114-20-8) were provided by Sigma-Aldrich Company (St. Louis, MO, USA). Milk powder from Pegah Khorasan Company and corn starch from Golha Company were bought.

Modified starch preparation

First, a 20% w/w suspension of waxy corn starch is prepared and stirred for 30 minutes at ambient temperature to disperse starch particles in the water, completely. Then the prepared suspensions are transferred to the centrifuge tubes and every tube is subjected to a pressure of 600MPa (High hydrostatic pressure device, model S-FL-065-200-9-W, RIFST, made in Iran) for 20 minutes (pressure increase rate 10 to 20 MPa/s). Then, treated waxy corn starch is frozen in liquid nitrogen and dried for 24 hours at -60◦C and 0.0001 Torr pressure [5].

Sample preparation

The reconstituted milk was rebuilt by mixing the skim milk (0.1%) or whole milk (2.67%) powder in water with a ratio of 11.21g in 89 ml. Afterwards, the prepared suspension was stirred using a magnetic stirrer at 450 rpm for 5 minutes at ambient temperature (about 25◦C), and 4.5g starch, 6.5g sugar and 0.25g κ-Carrageenan powders were added while stirring continued. Then put in a boiling water bath (about 95◦C) for 30 minutes. Finally, the cooked desserts were saturated with vapour and stored at 4◦C for 24 hours before the tests. Table 1 indicates the formulations of prepared custard desserts.

Rheological measurements

The rheological characteristics of the prepared samples were fitted out with a viscometer (Bohlin Model Visco 88, Bohlin Instruments Cirencester, Gloucestershire, UK). During experiments, the temperature was kept at 6◦C by applying a circulating water bath. Then, the data from both time and shear-dependent tests were fitted to the Weltman (1) and Sisko model (2) using MATLAB (R2021b, MathWorks, USA) curve fitting toolbox.

$$\tau = A + B\ln(t) \quad (1)$$

$$\eta = \eta_\infty + k\dot{\gamma}^{n-1} \quad (2)$$

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Results and discussion

Using waxy corn starch could increase the time dependency and initial viscosity while similar HHP samples were weak and had lower viscosity than control.

Table 2 demonstrates the Weltman coefficients that could investigate the time dependency well (R^2=95.29±0.05). Waxy starch led to an increase in both parameters of this model. [6] reported similar results that using more complex starch increases the initial shear stress.

An intensifying shear rate from 14 to 800 s^{-1} indicated a shear-thinning behaviour in all treatments. Waxy and HHP starch both decreased the viscosity. Based on the report of [11], limited changes in HHP treatment is a sign of higher stability of the structure against shear rate. Table 3 shows the measured parameters of the Sisko model that could explain the behaviour of the custard well with R^2 of 99.47±0.00. Adding waxy or HHP starch has led to a significant increase in the flow index which means lower molecular bond breaks and viscosity decreases slowly [12]. The consistency index decreased significantly with changing the starch type.

Conclusion

In the present study, the effects of waxy and HHP starch, on rheological properties of custard were investigated. Using HHP starch could increase the viscosity and shear-thinning behaviour of the dessert and indicated acceptable characteristics. Therefore, the proposed formulations can be used as a stable dessert with diminished syneresis. However, studying the effect of adding hydrocolloids and stabilizers is recommended in order to control the shear-thinning behaviour and the rate of viscosity changes.

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Figures and Graphs

Table1. Formulations of custard dessert based on changing starch and sugar type and fat content

Sample	Starch	Sugar	Milk fat
C	native	Sucrose	Whole
WSF	Waxy	sucrose	Whole
HSF	HHP	Sucrose	Whole

Table2. Measured Weltman model parameters as an explanation for time-dependent behaviour of custard based on formulations at 6̊c.

sample	A (Pa)	- B(-)	R2	RMSE
C	1.64±0.04[a]	0.12±0.00[a]	91.12±0.08[a]	0.025±0.01[a]
WSF	2.98±0.03[b]	0.33±0.01[b]	96.55±0.04[a]	0.05±0.03[a]
HSF	1.36±0.00[c]	0.13±0.00[a]	98.20±0.00[a]	0.021±0.00[a]

Table3. Measured Sisko model parameters as an explanation for shear-dependent behaviour of custard based on formulations at 6̊c.

sample	$\eta\infty$ (Pa.s)	K (Pa.s)	n(-)	R2	RMSE
C	0.08±0.6[a]	119.40±18.66[a]	0.04±0.05[a]	99.17±0.00[a]	0.21±0.11[a]
WSF	0.10±0.00[a]	24.43±1.11[b]	0.22±0.01[b]	99.68±0.00[a]	0.04±0.02[a]
HSF	0.04±0.00[a]	39.17±1.10[b]	0.22±0.00[b]	99.56±0.00[a]	0.09±0.00[a]