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Rheological and Sensory Assessment of Soy-chocolate Drinks as Influenced by Sugar, Cocoa Powder and Fortificants

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Effects of sugar, cocoa powder and fortificants on the rheological and sensory characteristics of soy-chocolate drinks were evaluated. Randomized sensory testing yielded 2 most preferred plain and sweetened sample formulations. Triple fortification of soy- chocolate drinks with 0.15 mg potassium iodide, 2.0 mg ferrous sulphate, 1.6 mg pro- vitamin A (retinol palmitate) / 100g sample was used as recommended by the world health organization [WHO, FAO 2021] and food fortification regulations guidelines (2021). Four soy-chocolate drinks comprising of non-fortified plain (NFPSCD), fortified plain (FPSCD), non-fortified sweetened (NFSSCD) and fortified sweetened (FSSCD) were formulated. The viscosity of soy-chocolate drinks as influenced by sugar, cocoa powder and fortificants reduced (7- 25) significantly *($p< 0.05$)* with increased shear rate and temperature. The

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power law regression analysis indicates that soy-chocolate drink is non- Newtonian since its flow behavior index, n (0.81- 0.97) is less than one. The fortified samples FSSCD (5.9 - 8.4) and FPSCD (7.0 - 7.3) had highest score than the non-fortified samples NFPSCD (5.3 - 5.8) and NFSSCD (5.4 - 5.7) for flavor, color, taste, mouthfeel and general acceptability. Sensory qualities of food formulations are a close representation of preference for target groups when testing for acceptability of food products. It was observed from this study that formulated soy- chocolate drinks are pseudo-plastic.

Keywords: Micronutrient, fortification; soy-chocolate; viscosity; general acceptability; temperature.

1. INTRODUCTION

Soymilk is an aqueous extract of whole soybean (*Glycine max*) seeds which contain 6 % protein, 4% fat, 5% carbohydrate, vitamins, minerals and antioxidants [1-3]. Soymilk, *kunu-zaki*, zobo, coconut milk, and tigernut milk are some of the local aqueous non-alcoholic drinks in Nigeria. Nevertheless, soymilk's ease of production and adaptability are credited to its versatility as a beverage around the world [4]. Cocoa powder is rich in polyphenols (Phytonutrients), commonly referred to as nutraceuticals or phytochemicals, which are used in fortification or supplementation [5].

Soy-chocolate drinks are aqueous blends of liquid soymilk and varying levels of cocoa powder which may be plain or sweetened. These non-alcoholic drinks combine the nutritional and health benefits of soymilk and cocoa powder in a punch. The benefits include high protein contents, predominance of polyunsaturated fatty acids, phytochemicals as well as low lactose and cholesterol contents [1]. Chocolate drinks are popular among adults and children especially those of school age and holds promise as appropriate vehicle in food fortification programmes for addressing micronutrients deficiency (MND). Food fortification is defined as the addition of one or more essential nutrients to a food, for the purpose of addressing a given deficiency in a population. The nutrients of critical concern in MND fortification programmes are iron, iodine and vitamin A.

Sensory evaluation of the soy-chocolate drinks is essential for determining acceptability of the products especially when used as vehicle for triple fortification with iron, iodine and vitamin A while the flow characteristics are essential for determining pumping requirements for scale-up and industrial production operations. Such information is lacking in literature. Hence, this research investigated the rheological and sensory characteristics of soy-chocolate drinks as influenced by sugar, cocoa powder and the triple fortificants.

2. MATERIALS AND METHODS

Soybean (*Glycine max*) (SC- SL01(S1079/6/7) was purchased from Benue Agriculture and Rural Development Agency (BNARDA), sugar, muslin cloth, airtight containers, sample bottles, transparent cups, and blender was bought from wurukum market while cocoa powder [6] was purchased from a supermarket in Makurdi, Benue State. Pro- vitamin A, iron, iodine fortificants were purchased at Emole Nig Ltd Makurdi Benue State, Nigeria.

2.1 Soy-chocolate Drinks Formulation

The soy-chocolate aqueous drink was produced using the method described by Illinois with modifications [7]. Essentially, soybean was sorted and cleaned to remove stones and damaged, deformed seeds. Then the dry soybean was washed and soaked in water overnight (500g in 1 Litre) for 12 hours. It was then rinsed and blanched in 0.5 % sodium bicarbonate for 30 minutes to remove the beany flavor. The soybean seeds were ground in blender and expressed in the ratio of 3:1 (water to beans on a weight basis) to remove the okara or soy pulp. The obtained milk was then boiled and formulated by adding cocoa powder (0.1, 0.2, 0.3, 0.4 %) and sugar (0, 2, 4, 6 %). The milk was then pasteurized at the temperature of 65 ◦C for 15 seconds and subsequently bottled and refrigerated. This yielded 16 experimental groups which were promptly subjected to sensory evaluation. The 2 most preferred plain and sweetened formulations respectively yielded four working samples comprising of non-fortified plain soy-chocolate drink (NFPSCD), fortified plain soy-chocolate drink (FPSCD), non-fortified sweetened soy-chocolate drink (NFSSCD) and fortified sweetened soy-chocolate drink (FSSCD) and were each subjected to triple fortification using 0.15 mg potassium iodide, 2.0 mg ferrous

sulphate and 1.6 mg / 100 g sample pro-vitamin A as recommended by the world health organization [1,8] fortification guide.

2.2 Sensory Evaluation

Sensory evaluation was by descriptive and affective testing [9] on a 9-point Hedonic scale with 9 as like extremely and 1 as dislike extremely. The sensory panelists consisted of 25 judges made up of students and staff of the Benue State University, Makurdi who evaluated the products in terms of flavor, appearance, mouthfeel and overall acceptability.

2.3 Viscosity Measurements

The rheological characteristics of the soy-chocolate drinks were determined using a Brookfield viscometer (model LPDV-II+P) with spindle number 61 as described by Dogan and Kayacier [10]. For each working sample, a 4 × 6 between and within randomized design comprising 4 shear rates (10, 20, 50, 100 rpm) and 6 temperatures (15, 20, 25, 30, 35 and, 40 ℃) which gave 24 experimental groups was employed. Duplicate 10 ml of each sample were allowed to equilibrate at the desired temperatures in an agitated water bath prior to viscometer readings after 2 min of spindle rotation. Data obtained from the viscometry were fitted with the power law rheological model as follows:

$$\mu = m\dot{\gamma}n - 1 \quad (1)$$

Linearization of equation:

$$\ln\mu = \ln m + (n-1)\ln\dot{\gamma} \quad (2)$$

Where μ= viscosity or shear stress of soymilk and cocoa powder-based drink (Ns/m^2); $\dot{\gamma}$ =shear rate (rpm); m= consistency index, n= flow behaviour index.

2.4 Statistical Analysis

Data from the experiment was calculated and analyzed using ANOVA in the Statistical Package for Social Science (SPSS, 2022) Software (SPSS version 12. 0.1 for windows). The Duncan's New Multiple Range Test was used to determine the significant difference between mean values. Least significant difference (LSD) test was used for mean separation at 5% probability level of significance.

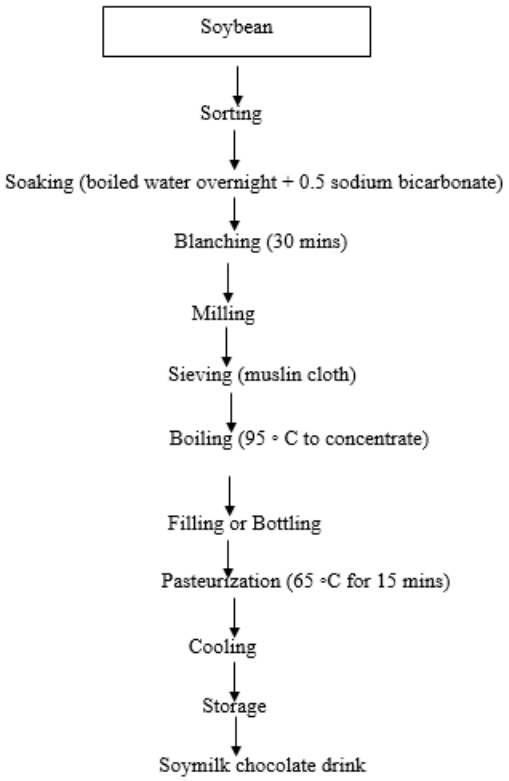

Fig. 1. Flow chart to produce soymilk and cocoa powder based aqueous drinks
Source: Illinois, [7]

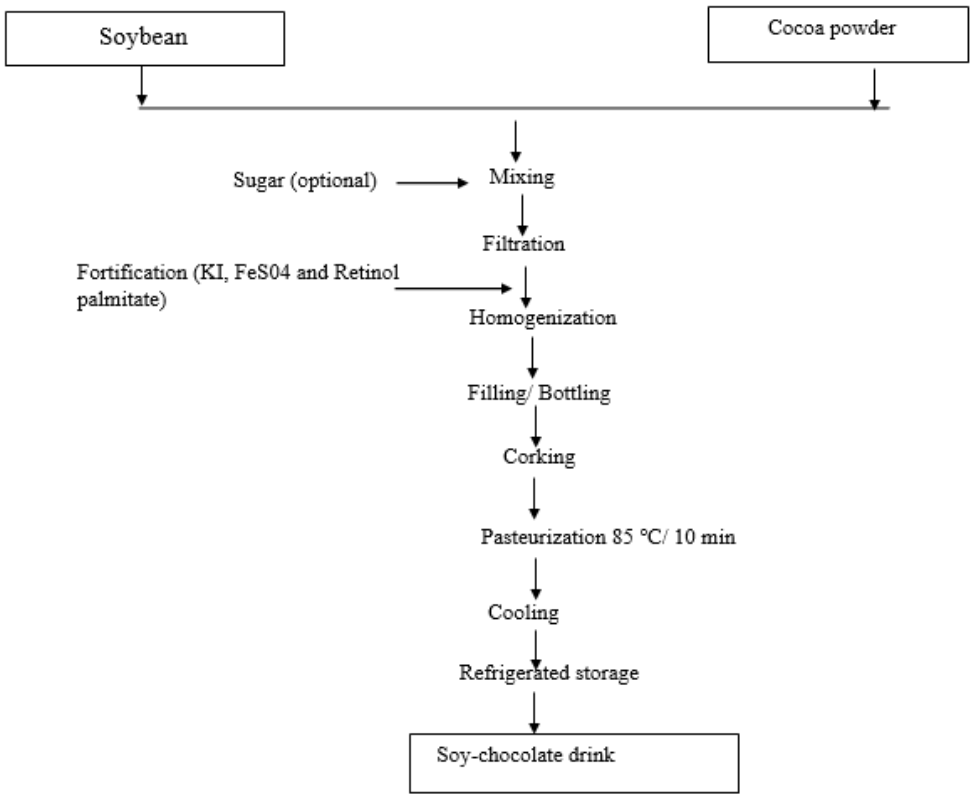

Fig. 2. Flow chart for the production of soy-chocolate drink
Source: Abadi et al., 2023

3. RESULTS AND DISCUSSION

3.1 Effect of Fortification, Cocoa Powder and Sugar on the Sensory Attributes of Soy-Chocolate Drink

The sensory attributes of 6 % sugar, 0.4 % cocoa powder and 0 % sugar, 0.4 % cocoa powder yielded four (4) samples being fortified 6 % sugar, 0.4 % cocoa powder and non-fortified 6 % sugar, 0.4 % cocoa powder as well as fortified 0 % sugar, 0.4 % cocoa powder and non-fortified 0 % sugar, 0.4 % cocoa powder (Table 1) respectively. Sensory qualities of food formulations are important parameter when testing for acceptability of food products. This is a close representation of preference or reference for target groups [11]. The fortified samples FSSCD (5.9- 8.4) and FPSCD (7.0- 7.3) had highest score than the non-fortified samples NFPSCD (5.3- 5.8) and NFSSCD (5.4- 5.7) for flavor, color, taste, mouthfeel and general acceptability. There was significant ($p< 0.05$) difference in overall acceptability of the formulated samples.

3.2 Effect of Temperature on Viscosity of Soy-chocolate Drinks

The viscosity of soy-chocolate drinks as influenced by sugar, fortificants and cocoa powder reduced significantly ($p< 0.05$) with increased shear rate (Fig. 3). The plots of viscosity versus shear rate at varying temperatures clearly indicated that when temperature increased, the energy level of liquid molecules increased (kinetic energy increased) [12]. Therefore, the distance between molecules increased resulting in a decrease in inter-molecular attraction hence reduced viscosities (7- 25). This agrees with [13] for Storage changes in triple fortified tigernut and moringa seed based aqueous drinks. The NFPSCD viscosity ranged from 7 Pa.s to 15 Pa.s and the NFSCD viscosity ranged from 8 Pa.s to 17 Pa.s. The FPSCD viscosity values ranged from 8 Pa.s to 20 Pa.s while FSSCD were 10 Pa.s to 25 Pa.s. As expected, viscosity increased with concentration of solid matter [14]. This implies that for a given consistency and viscosity, the aqueous drinks will have higher nutrients density.

3.3 Power Law Model for Soy-Chocolate Drinks

The power law regression analysis indicates that soy-chocolate drink is non- Newtonian since its flow behavior index, n (0.81- 0.97) is less than one (Table 2). NFSSCD exhibited a more non-Newtonian behavior (0.81) at higher temperature (40 ℃) than other samples. It was observed from this study that formulated soy- chocolate drinks are pseudo-plastic. Power law model for pseudo-plastic fluids require a force (shear stress) before soy-chocolate drink can flow. This was seen with consistency indices values, m (15.15- 50.0). Soy-chocolate drinks exhibited more pseudo-plasticity and increased pumping requirement with increased temperature. Non- Newtonian flow can be interpreted by imagining any fluid to be a mixture of molecules with different sizes and shapes. As the molecules pass by each other because of shear (force), the size, shape and cohesiveness will determine how much force is required to initiate motion. The alignment may be different at each specific rate of shear, and force will be required to maintain motion [15].

Table 1. Sensory Scores of Soy-chocolate Aqueous Drinks as Influenced by Fortificants

Sample	Flavor	Appearance	Mouthfeel	Overall Acceptability
NFPSCD	7.4^{d}±1.4	7.8^{d}±1.1	7.7^{d}±1.4	7.3^{d}±1.5
FPSCD	8.2^{a}±1.2	7.2^{d}±1.0	8.0^{b}±0.7	7.3^{c}±0.7
NFSSCD	8.7^{a}±1.4	7.7^{c}±2.1	6.4^{d}±1.9	8.6^{b}±2.1
FSSCD	8.4^{a}±0.8	5.9^{d}±1.2	7.1^{c}±0.9	7.8^{b}±0.7

Values for sensory attributes are means ± s.d of duplicate determinations. Means with common superscripts are not significantly ($p>0.05$) different within each column

NFPSCD = non fortified plain soy-chocolate drink, FPSCD = fortified plain soy-chocolate drink, NFSSCD = non fortified 0.4% sweetened soy-chocolate drink, FSSCD = fortified 0.4% sweetened soy-chocolate drink

Table 2. Power law regression parameter for influence of shear rate on viscosity of soy-chocolate drink

Sample	Power law	Temperature (℃)					
	Parameter	15	20	25	30	35	40
NFPSCD	Slope	-0.043	-0.086	-0.184	-0.169	-0.165	-0.249
	Y-intercept	2.728	2.792	3.120	2.959	2.906	3.077
	m(Ns/m^2)	15.302	16.314	22.646	19.279	18.284	21.693
	n	0.957	0.914	0.816	0.831	0.835	0.951
	r^2	0.945	0.980	0.986	0.928	0.984	0.964
FPSCD	Slope	-0.107	-0.053	-0.180	-0.094	-0.171	-0.375
	Y-intercept	3.004	2.843	3.266	2.900	3.024	3.774
	m(Ns/m^2)	20.166	17.167	26.206	18.174	20.573	43.554
	n	0.893	0.947	0.820	0.906	0.830	0.925
	r^2	0.972	0.995	0.926	0.982	0.979	0.929
NFSSCD	Slope	-0.052	-0.143	-0.173	-0.121	-0.229	-0.384
	Y-intercept	2.718	2.918	3.259	2.841	3.268	3.857
	m(Ns/m^2)	15.150	18.504	26.024	17.133	26.259	47.323
	n	0.949	0.857	0.828	0.879	0.871	0.916
	r^2	0.959	0.990	0.914	0.982	0.917	0.919
FSSCD	Slope	-0.037	-0.044	-0.143	-0.168	-0.267	-0.346
	Y-intercept	3.025	2.919	3.225	3.134	3.541	3.914
	m(Ns/m^2)	20.594	18.523	25.154	22.966	34.501	50.099
	n	0.963	0.956	0.857	0.832	0.833	0.954
	r^2	0.967	0.948	0.947	0.997	0.932	0.915

m = consistency index (Ns^n/m^2), n = flow behavior index, r^2= regression coefficient,

NFPSCD = non fortified plain soy-chocolate drink, FPSCD = fortified plain soy-chocolate drink, NFSSCD = non fortified 0.4% sweetened soy-chocolate drink, FSSCD = fortified 0.4% sweetened soy-chocolate drink

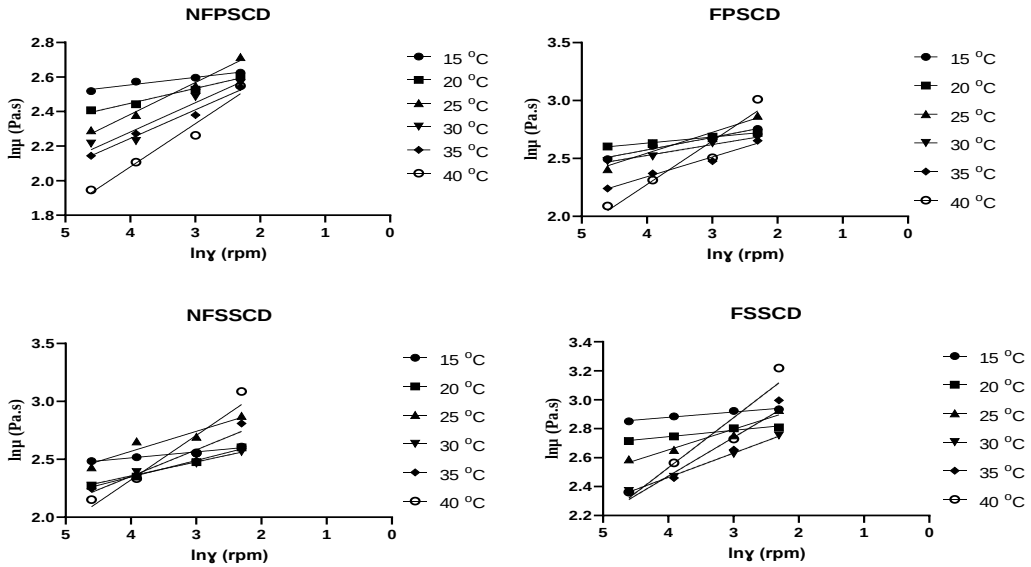

Fig. 3. Effect of temperature on viscosity of soy-chocolate drinks

4. CONCLUSION

Sensory evaluation of the soy-chocolate drinks is essential for determining acceptability of the products especially when used as vehicle for triple fortification with iron, iodine and vitamin A. Acceptable soymilk and cocoa powder blends can be employed for addressing PEM and a vehicle for MND fortification programs.

Soy-chocolate drink can serve as an affordable variety and for wider consumer choice for IDP camps, vulnerable and invalid groups.

The flow characteristics are essential for determining pumping requirements for scale-up and industrial production operations. These data can be employed as a baseline and standardization of soy-chocolate drink products for regulatory agencies and policy makers.

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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