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Effect of the use of starches of three new Ghanaian cassava varieties as a thickener on the physicochemical, rheological and sensory properties of yoghurt

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ABSTRACT

Yoghurt is a popular probiotic food rich in micronutrients but suffers from a thickness loss referred to as syneresis, which is caused by liquid expulsion from the gel during storage. To reduce this adverse sensory effect, the starches of three new cassava varieties, *Abrabopa, AGRA* and *Bankye hemaa,* were used as thickening agents in the production of yoghurt and its physicochemical, functional and sensory properties evaluated. The starches were extracted by wet gravimetric method and initially characterised by assessing their pH, colour, water binding capacity, swelling power, Solubility index and pasting characteristics. Each of these three starch samples were incorporated at a rate of 2.5, 5.0 and 7.5%, to prepare yoghurt, from fully-skimmed, partially-skimmed and whole milk. The pH, viscosity, syneresis, textural and sensory properties of the yoghurt samples stored at 6 ± 1 °C were monitored over 14 days. Whilst there were significant differences ($p < 0.05$) in the swelling power and indices, the water binding capacity of the starch samples were comparable. Their cooked paste viscosity were 512.5 BU (*Bankye hemaa*), 550 BU (*Abrabopa*) and 620 BU (*AGRA*) . When used in preparing the yoghurt, the whole milk yoghurt, with *Abrabopa* starch at 5.0% inclusion, gave the highest consistency (28.7 N.s) and cohesiveness (-2.1 N), whilst fully-skimmed milk yoghurt with *AGRA* starch, at 7.5%, gave the lowest consistency (7.5 N.s) and cohesiveness (-0.4 N). These results correlated well with those of the sensory scores, which gave the best taste, mouthfeel and sourness scores to yoghurt made from whole milk in which *Abrabopa* cassava starch at 7.5% had been incorporated and stored for 14 days. The starch of *Abrabopa* cassava variety therefore adequately prevented syneresis in yoghurt.

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Introduction

Yoghurt is a probiotic food product containing the bacteria, *Bifidobacteria* and *Lactobacillus* spp., which help lessen the uncomfortable symptoms of irritable bowel syndrome (IBS), a common disorder that affects the colon [35]. Additionally, yoghurt contains very important vitamins, such as B_{12} and riboflavin, which are good for reducing heart diseases. It also has important micronutrients such as calcium for healthy bones and teeth, phosphorus, magnesium and potassium [12]. Probiotic food development also involves the use of different microbial and prebiotic species; the latter consists of substances acting as a substrate for the probiotic microorganisms. Prebiotics have gelling properties that help to promote the needed viscous property associated with yoghurt [30]. In the production of yoghurt, therefore, one key requirement is the use of a thickening agent as it helps to improve the texture. The thickener helps to prevent syneresis in yoghurt. Syneresis is the shrinkage of a gel by the expulsion of a liquid from the gel and this appears as a collection of whey on the surface of the yoghurt (Vareltzis et al., 2015).

There is an increased interest in the commercial production of yoghurt using flavourless powdered starches such as arrowroot starch, cornstarch, potato starch, cassava and yam and their derivatives as thickeners. In Ghana, studies on yoghurt thickeners has focused on yam starches [31] and imported corn starch. Apart from the cost of corn starch, there is currently a growing controversy of the role of corn gluten affecting the immune responses of some celiac disease patients [21]. Several workers have however examined and recommended the use of cassava starch because of its neutral flavour, high purity, viscosity, good solubility and swelling capacity [9, 10]. Ayrana et al. [7] further recommended and explained the advantages of using starches in reducing the occurrence of syneresis in yoghurt. Mwizerwa et al. [19] successfully used resistant starch from cassava to reduce the occurrence of syneresis in yoghurt. Unfortunately, the processes used by Mwizerwa et al. [19] for the production of the resistant starch from the cassava required freeze drying, a process that certainly increases the production cost of yoghurt by the local industries in Ghana.

Presently, the CSIR-Crops Research Institute of Ghana has developed several new cassava varieties with excellent physicochemical and functional properties for both traditional and commercial utilization [32]. Interestingly, a commercial utilization of these newly developed cassava varieties is the extraction of starch and its use as a thickener in yoghurt production. Further, no study on the suitability of using the starches of the newly cassava varieties grown in Ghana for production of yoghurt has been carried out. Therefore, this current study investigated the effectiveness of starch from three newly developed cassava varieties, *Abrabopa, AGRA* and *Bankye hemaa*, as a thickening agent to reduce the occurrence of syneresis in yoghurt and their effect on the physicochemical, rheological and sensory properties of the yoghurt.

Materials and methods

Raw materials

Fresh milk (whole, partially and fully-skimmed milk) samples were obtained from the CSIR-Animal Research Institute, Accra Ghana. Thermophilic yoghurt starter culture (Danisco YO-MIX LYO 300) with *Streptococcus thermophiles* and *Lactobacillus bulgaricus* was obtained from an accredited agent, Emychem Limited, Accra.

Extraction of starch from the cassava varieties

Mature cassava roots (*Abrabopa, AGRA, and Bankye hemaa*) were obtained directly from demonstration plots in CSIR-Crops Research Institute, Ghana. Starch extraction was by the wet method [8]. Briefly, cassava roots were washed under running water, peeled, washed again and chopped into small particles ($\approx$ 10 $\times$ 10 mm). The small pieces were washed before milling in a blender (Aardee ARMG 550, India) with ample water to aid milling. The mash obtained was strained through a cheese cloth and the filtrate was allowed to stand for 2 h. Thereafter, the supernatant was discarded and the starch layer re-suspended in water. This process was repeated three times until clear supernatant was observed. This was discarded and the wet starch spread thinly on drying trays and dried in an air oven at 40 °C for 5 h. The dried starch was milled (250 μm), packaged air-tight in high-density polyethylene bags and kept at room temperature (28 $\pm$ 1 °C) until used.

Initial characterization of starch

The parameters assessed for the initial characterization of the starch samples were pH, water binding capacity, swelling power, solubility index, colour and the pasting characteristics.

The pH was determined in triplicates using a pH meter (Hanna pH 211 Microprocessor, USA), and according to AOAC, official method 996.11 [5] whilst the water binding capacity, swelling power and solubility index of the starch were determined in triplicate according to the method described by Afoakwa et al. [1]. The colour was determined in triplicates using a Minolta Chromameter (CR- 310 Minolta, Japan) in triplicates. A reference white porcelain tile ($L^0 = 97.63$, $a^0 = 0.31$ and $b^0 = 4.63$) was used to calibrate the Chromameter before each determination. The starch colour was described by L^* which is a measure of lightness or darkness. Finally, the starch pasting characteristics were determined on an 8% slurry using a Brabender Viscoamylograph (Viskograph- E, Brabender Instrument Inc., Duisburg, Germany) equipped with a 1000 cmg sensitivity cartridge. The suspension was heated from 50 to 95 °C at a rate of 1.5 °C/min, held at this temperature for

15 min, cooled to 50 °C at a rate of 1.5 °C/min, and then held at this temperature for 15 min. The viscosity profile indices recorded included the following: pasting temperature, peak viscosity, viscosity at 95 °C and viscosity after 15 min hold at 50 °C (50 °C- hold), breakdown and setback.

Yoghurt production

Yoghurt was produced according to methods of Lee and Lucey [17], with slight modification. This involved homogenizing the milk (whole, partially or fully skimmed milk) and heating to 85–90 °C for 10 min in a pasteuriser. During this period when the temperature was 40 °C, sugar (6.5% w/v) followed by cassava starch (2.5, 5.0 or 7.5% w/v) was added. The heated milk and starch mixtures were then allowed to cool to 45 °C before inoculating with a starter culture (2.5% w/v). The mixture was stirred for 30 s, for complete dissolution and equal distribution of culture granules and incubated at 42–45 °C for 5–6 h to allow fermentation and setting of the yoghurt. Yoghurt samples were then aged at 10 °C overnight to allow for cooling. The curd formed in the process was broken by stirring into a smooth homogeneous product and stored at 6 ± 1°C for further analysis.

Analyses on the yoghurt

Analyses carried out on the yoghurt were pH, syneresis, viscosity, back extrusion and sensory properties. The pH was determined as described earlier.

Syneresis

Syneresis was determined using a centrifugation method [4]. A cup of set yoghurt was stirred manually with a glass rod and 30 g transferred into a 50 mL Blue max^{TM} polypropylene conical tube (Becton Dickinson Laboratory, NJ, USA) and left to stabilise at 4 °C for 2 h. Thereafter, samples were centrifuged (Sorvall RT 7) at 3313 g for 15 min. Syneresis was expressed as a percentage of whey separated from the gel over the initial weight of the gel.

Viscosity

Viscosity measurements were done using a Brookfield viscometer (Model DV2T; Brookfield Engineering Labs, Inc., USA) with a No 4 spindle. Using an end condition of 4 points, viscosity data was recorded at 2 min intervals. Measurements were taken in a 250 mL beaker, 2 min after spindle was immersed in a 5% starch gel. Torque was maintained at all times between 10 and 100% for all speeds (5–25 rpm) tested.

Back extrusion

Back extrusion test was performed using TA-XT2 Plus (Stable Micro Systems, Surrey, UK) equipped with 5 kg load cell and a back extrusion rig. Fifty milliliters of yoghurt was filled into the Perspex rig and compressed to a depth of 45 mm with a 40 mm plunger at a test speed of 1 mm/s. The following texture parameters were recorded: firmness (N) - maximum compression force; consistency (N.s) - area within curve during extrusion thrust and cohesiveness (N) - maximum negative force during withdrawal of probe. Numerical values of firmness, consistency and cohesiveness were measured by the Exponent Software 32 (Stable Micro Systems, Godalming, UK).

Sensory evaluation of yoghurt

Sensory evaluation was conducted on yoghurt made from partially skimmed and whole milk, containing 5.0 - 7.5% *Abrabopa* starch. These were selected based on results of the syneresis, viscosity and textural properties of yoghurt samples. Preference test, with a 20-member panel who had previous experience of sensory evaluation of food and who were regular consumers of yoghurt, was used for the evaluation. Using a 9-point Hedonic scale (1-dislike extremely, 9-like extremely), the panelists evaluated samples of yoghurt for sweetness, sourness, thickness, mouth-feel and overall acceptability. The assessors were provided with still water to rinse their mouth and an unsalted cracker to refresh their palates. The assessments were done in three sessions, day 1, day 7 and day 14 of storage, in a facility that conforms to the requirements of ISO 8589.

Experimental design and statistical analysis

The yoghurt experiment was set up in a 3 × 3 × 3 factorial design, with cassava variety (*Bankye hemaa, AGRA, Abrabopa*), type of milk (fully skimmed, partially skimmed, whole milk) and level of cassava starch inclusion (2.5, 5, 7%) as the factors. Data obtained was analyzed using Multifactor ANOVA (STATGRAPHICS Centurion 16.1, StatPoint Technologies Inc.). The initial starch characterization data were analyzed using one-way ANOVA, and differences were separated using Duncan's Multiple Range Test.

Table 1
Physico-chemical and functional properties of starches of *Abrabopa, AGRA and Bankye hemaa* cassava varieties.

Cassava variety	pH	Colour L*	SI (g/g)	SP (g/g)	WBC (%)
Bankye hemaa	6.36b	97.0a	74.0c	9.2a	157.3a
AGRA	6.02a	97.2b	62.0b	13.1b	155.3a
Abrabopa	5.98a	98.0c	36.0a	10.4a	156.0a

SI-Solubility index; SP-Swelling power; WBC-Water binding capacity.
Within a column, means with different superscripts are significantly different ($p<0.05$).

Table 2
Pasting properties of starches of *Abrabopa, AGRA and Bankye hemaa* cassava varieties.

Cassava variety	PV (BU)	Trough (BU)	CPV (BU)	BD (BU)	SB (BU)
Bankye hemaa	817.0a	270.5a	512.5a	545.0a	237.0a
AGRA	913.5b	328.5b	624.0c	582.0b	293.0c
Abrabopa	799.0a	290.0a	550.5b	508.5a	260.0b

PV-Peak viscosity; CPV-Cooked paste viscosity, BD-Breakdown viscosity, SB-Setback viscosity.

Results and discussions

Physicochemical and functional properties of the starches of the three cassava varieties

The physicochemical and functional properties of the starches from the three cassava varieties indicated significant differences in the values of the pH, colour, and solubility index (SI), swelling power (SP), whilst that of water binding capacity (WBC) were comparable (Table 1). The neutral pH values (6.0 – 6.4) indicated bland taste with no add-on effect on the taste, aroma or the flavour of the yoghurt. All the starches had bright white colours as depicted by the high L* values, which ranged between 97.0 and 98.0. However, *Abrabopa* cassava variety had a significant ($p < 0.05$) whiter colour than AGRA and *Bankye hemaa*, and may make it a preferred thickener in yoghurt, based on colour alone. That notwithstanding, the colour of the other starches did not show any sensorial effect on the appearance of the final yoghurt. The whitish appearance of the starches implies that browning reactions did not take place during the drying. Generally, colour affects the appearance and acceptance of food and is therefore considered as an important attribute, and a high degree of whiteness is preferred (Van Hal, 2000).

Although the solubility of *Bankye hemaa* starch was significantly higher than starch from the other varieties, it had the lowest swelling power (9.2 g/g) (Table 1). Therefore ordinarily, this starch would swell poorly compared to the others, when equal hydration conditions are provided [23]. Whereas SI is a good indicator of the bond strength and soluble components present in the starch, SP is useful in assessing the extent of interactions between starch polymer constituents, inside the crystalline and amorphous regions in starch granule [23]. Generally, a pattern of lower SI compared to SP was obtained for all the varieties. This has been explained to be an indication of weak associative forces in the granules that constitute the starch of these varieties of cassava [2].

The results in Table 2 shows that even though the pasting profiles of three starches appear comparable, the viscosity values of *AGRA* were consistently higher ($p < 0.05$) than the rest. This may be attributed to differences in starch granular morphology and or amylose/amylopectin ratio [13]. The viscosity of the hot pastes ranged from 270.0 BU for *Bankye hemaa* to 328.5 BU for *AGRA*, an indication that pastes from *AGRA* has the least resistance (high breakdown) to shearing at high temperatures. *AGRA* starch had a significantly higher pasting viscosity compared to the two, yet it was the least stable of the three, as indicated by its highest breakdown viscosity of 582 BU. Also, the tendency to retrograde was highest in *AGRA* starch and lowest in starch from *Bankye hemaa*. The setback viscosity reflects the ability of starch granules to re-associate and harden after heating and cooling, an important phenomenon in starch known as retrogradation [26]. This property of starches has been ascribed to a high degree of association of starch molecules, caused by the strong tendency for hydrogen bond formation between hydrogen groups on adjacent starch molecules [25]. The pasting properties of starches of these cassava varieties provide insights into their behaviours during and after cooking and therefore should aid in identifying which of starches will be appropriate thickener for the yoghurt. In particular, the peak viscosity indicates the maximum extent of swelling during the heating cycle. The results show that the tendency to retrograde was highest in *AGRA* starch and lowest in starch made from *Bankye hemaa*. In other studies, the pasting viscosities were positively correlated and higher pasting viscosities corresponds to higher swelling power and higher water holding capacity of the samples [27]. In liquid foods such as yoghurt, retrogradation, which is favoured by low temperature conditions is undesirable, since it can enhance the unsightly occurrence of syneresis.

Table 3
Chemical and physical properties of yoghurt prepared from Fully-skimmed milk (FSM), Partially-skimmed milk (PSM) and Whole milk (WM) with added starch from three cassava varieties at the start storage .

Cassava variety	Milk	pH			Syneresis (%)			Apparent Viscosity (cP)		
		2.5%	5.0%	7.5%	2.5%	5.0%	7.5%	2.5%	5.0%	7.5%
Bankye hemaa	FSM	4.43	4.43	4.49	76.0	75.6	73.7	11,240	11,513	11,600
	PSM	4.40	4.39	4.45	75.9	73.6	72.3	11,673	11,627	13,273
	WM	4.49	4.55	4.52	75.2	74.6	73.1	11,380	10,473	10,407
AGRA	FSM	4.48	4.40	4.49	75.3	73.8	72.7	9,233	10,273	11,347
	PSM	4.42	4.38	4.40	72.2	70.2	68.0	10,347	11,453	11,920
	WM	4.54	4.52	4.50	71.4	70.9	70.4	9,267	11,053	11,167
Abrabopa	FSM	4.41	4.39	4.42	79.2	78.5	77.7	9,460	9,533	10,020
	PSM	4.42	4.43	4.41	79.5	76.4	75.7	11,353	11,200	11,573
	WM	4.52	4.50	4.53	65.1	64.6	61.2	10,793	11,207	11,347

Physico-chemical characteristics of yoghurt

In yoghurt manufacture, fermentation leads to a reduction in pH and this affects the flavour and texture attributes of the product. From Table 3, it can be noticed that pH of the yoghurt, at the start of storage ranged between 4.4 and 4.6, which is comparable to the standard pH of 4.6, used as an end-point of yoghurt fermentation by Puvanenthiran et al., [22]. These values were higher than the range (3.96 – 4.27) reported by Salvadore and Fiszman, [24] for whole milk and skimmed milk yoghurt. However, during the storage, post acidification occurred in some of the yoghurt samples, leading to a gradual reduction in pH (Figure 3 - Supplementary Section). Generally, the dips in pH samples prepared occurred more in yoghurt samples prepared from the whole milk occurred, after 14 days in storage, than for those prepared from other milk types. This process is undesirable in yoghurt and may result in accumulation of organic acids and development of a strong acidic taste, reduction in live bacteria count and whey separation [11, 15]. This range is adequate for sufficient acid development and optimum firmness [16]. Multifactor ANOVA showed a significant influence of all factors and their interaction on the pH, with milk type and starch level having a greater effect ($p < 0.01$) (Table 6 – Supplementary Section).

Syneresis

Whey separation is an important quality defect of yoghurt caused by an increase in the rearrangement of casein particles (Lucey [16], Lee and Lucey [18]). The rearrangement, which leads to an increase in particle-particle junction, shrinks the network and expels interstitial serum [33]. The results of the study showed that both main effect and interaction terms affected whey separation immensely. There was a reduction in syneresis, proportional to increasing levels of starch from 2.5 to 7.5% (Table 3). However, the effect of 2.5 and 5% starch on syneresis was comparable. Addition of starch strengthened the density of the gel network structure because starch promotes the formation of a continuous and compact network structure [29]. This effect seemed to be stronger as the levels of starch were increased from 2.5 to 7.5%. The trend of decreasing syneresis by gradually increasing starch levels is consistent with the findings of Ares et al. [6] who reported an 18% reduction in syneresis by adding 1 to 10 mg of starch. Yoghurt produced from whole milk experienced lower serum expulsion compared to those from partially-skimmed and fully- skimmed milk yoghurts. These results are in agreement with Staff [28] who reported that low-fat yoghurts are more susceptible to syneresis than high-fat yoghurts. Keogh and O'Kennedy [14] explained that increased levels of fat enhances the ability of proteins to restrain the movement of water. This occurs because milk protein is adsorbed onto the surface of dispersed fat globules enabling it to form a copolymer, which strengthens the gel network. Higher levels of syneresis were observed in yoghurt made with *AGRA* or *Bankye hemaa* starch, compared to those containing starch from *Abrabopa*. This implies that the gel network formed by the starch made from the previous varieties was not as strong as the latter.

Syneresis occurred during the 14-day storage period (Figure 4- Supplementary Section). Similar to the findings of Salvadore and Fizman [24], whey separation was high during the first week, but was less intense during the second and final week of storage. It is reasonable to suggest that after the first week, the rate of syneresis had almost peaked, and thus a slowing down of the phenomenon beyond this storage period. Over the storage period, starch from *Abrabopa* was more effective in reducing syneresis, recording lower syneresis values compared to starch from *Bankye hemaa or AGRA*. The gradual reduction in pH throughout storage (Figure 4- Supplementary Section) may have contributed to the rearrangement of the gel structure to promote wheying-off of the yoghurt in storage [16, 33]. Furthermore, the period of storage most likely allowed for extensive reorganization within the milk gel network.

Viscosity

All the factors examined (i.e. cassava variety, milk type, starch levels) had a significant influence ($p < 0.05$) on yoghurt viscosity. Increasing amounts of starch resulted in yoghurt with a more viscous consistency. This occurred because of the ability of starch granules to strengthen the protein network by dispersing and filling the gel network. Starch also increases

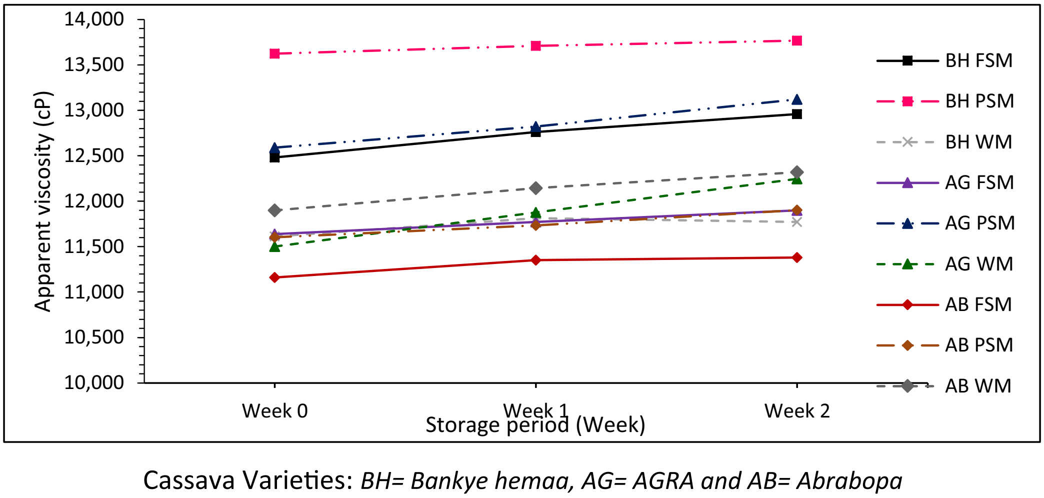

Fig. 1. Variation in viscosity of yoghurt, prepared from Fully skimmed milk (FSM), Partially-skimmed milk (PSM) and Whole Milk (WM), containing 7.5% starch, from three cassava varieties, over a period of 14 day storage at 6 ± 1 °C
Cassava Varieties: *BH= Bankye hemaa, AG= AGRA and AB= Abrabopa.*

Table 4
Flow behavior indices of yoghurt, prepared from Fully skimmed milk (FSM), Partially-skimmed milk (PSM) and Whole Milk (WM), with starches of *Abrabopa, AGRA and Bankye hemaa* cassava varieties at the start of storage at 6 ± 1 °C.

Variety	Milk	K (Pa.s^n)			*n*		
		2.5%	5.0%	7.5%	2.5%	5.0%	7.5%
Bankye hemaa	FSM	4.655	4.650	4.653	0.857	0.831	0.816
	PSM	4.631	4.645	4.765	0.810	0.810	0.808
	WM	4.625	4.660	4.671	0.813	0.784	0.771
AGRA	FSM	4.580	4.580	4.593	0.864	0.839	0.801
	PSM	4.606	4.621	4.651	0.783	0.799	0.813
	WM	4.734	4.763	4.805	0.856	0.776	0.754
Abrabopa	FSM	4.598	4.621	4.594	0.761	0.792	0.818
	PSM	4.651	4.509	4.762	0.813	0.818	0.758
	WM	4.712	4.725	4.766	0.832	0.741	0.745

FSM – Fully skimmed milk, PSM – Partially skimmed milk, WM – Whole milk (full cream milk).

the viscosity of the continuous phase through amylose solubilization, absorption of water (during swelling) and subsequent increased protein concentration within this phase [20]. Milk type seemed to increase the viscosity of yoghurt in this ascending order, FSM < WM < PSM. Interaction between factors had a significant influence on the viscosity of yoghurt. For example, the most viscous yoghurt was obtained when fully skimmed milk was combined with *Bankye hemaa* starch. There was a slight but consistent increase in viscosity in all the during the 2-week storage period (Fig. 1). The setback behaviour of added starches may have contributed to this observation. Similar increase in viscosity in stored yoghurt was observed by Zamberlin [36].

Yoghurt flow behaviour

Power law was used to describe the rheological behaviour of yoghurt samples. The R^2 values (0.997 to 0.999), suggest that the experimental data adequately fit the power law model (Table 4). The yoghurt samples were pseudoplastic, since their flow behaviour index (n) was < 1. An increase in the quantity of added starch decreased the flow behaviour index (more pseudoplastic and susceptible to shear thinning) of the yoghurt. Similar observations were reported by Ares et al. [6] in yoghurt thickened with gelatin or starch, and Yu et al. [34] for yoghurt with added milk solids non-fat. Consistency index (K) ranged between 4.58 and 4.81, and was higher for yoghurt made from whole milk with either *Abrabopa* or *AGRA starch*, compared to partially skimmed milk and fully skimmed milk for these same varieties. As was expected, higher consistency index values were obtained for increasing levels of starch in the yoghurt.

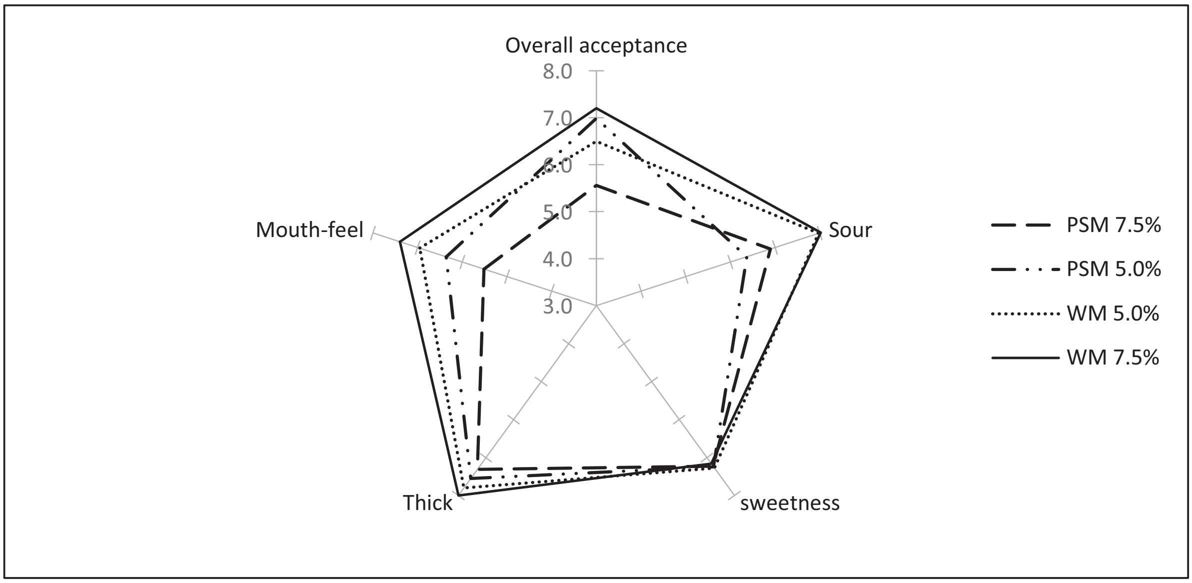

Fig. 2. Sensory scores for yoghurt attributes after (A) Week 0, (B) Week 1, (C) Week 2.
A (PSM – Partially skimmed milk; WM – Whole milk)
B (PSM – Partially skimmed milk; WM – Whole milk)
C (PSM – Partially skimmed milk; WM – Whole milk).

Instrumental texture analysis

Yogurt firmness ranged between 0.4 to 1.4 N correspondingly for WM and PSM containing *bankye hemaa* starch, whereas consistency and cohesiveness ranged from 7.5 to 28.7 N.s, and 0.4 to 2.0 N respectively. The firmness was significantly ($p < 0.05$) affected by the type of cassava starch used (Table 5 Supplementary Section), with yoghurt containing *AGRA* starch being the most firm. Even though a trend of increased firmness occurred with an increase in milk type, ANOVA also showed that this was not significant ($p > 0.05$), implying that the different milk types had a negligible impact on firmness (Table 6 Supplementary Section). This finding is contrary to those of Salvadore and Fiszman [24], who reported a significant effect of different milk types on yoghurt firmness. That notwithstanding, the interaction effect of the factors remarkably affected the yoghurt firmness. A similar trend was observed for consistency and cohesiveness of yoghurt samples. This observation may be explained by the high setback viscosities of *AGRA* starch. Setback is the result of amylose re-orientation after cooling a starch paste, and this is manifested by an increase in gel firmness. Increase in the consistency as a result of increasing starch proportion may be ascribed to the fact that gelatinised starch granules lead to the formation of large protein particles which always give a thick consistency (Lucey and Singh, 1998). Additionally, the thick consistency is intensified by the higher serum viscosity as a result of starch constituents leaching out during starch gelatinization, which enhanced the viscosity of the aqueous phase (Narpinder et al., 2003; Oh et al., 2006).

Sensory evaluation

Sensory evaluation results revealed the influence of cassava starch on the attribute ratings, especially mouth-feel and thickness (Fig. 2A-C). Scores for these two attributes ranged from 5.2 to 7.4 and 4.2 to 8.0 respectively during the first week. Yoghurt made from whole milk with 7.5% *Abrabopa* starch was rated the highest in terms of thickness, mouth-feel and acceptability. This is in agreement with Gonzalez et al. (2005) who reported a relationship between the amount of starch used as a thickener and the organoleptic properties of yoghurt. The enhanced viscosity of the aqueous phase resulting from adding up to 7.5% starch led to yoghurt with a thick smooth consistency. This explains why this yoghurt sample was generally the most acceptable. The results also revealed a conspicuous decrease in attribute scores from week 1 through week 2. This is reflective of the decrease in some of the quality indices evaluated in the study. For instance, the scores for sourness of whole milk yoghurt with 7.5% *Abrabopa* starch decreased from 8.0 in Week 1, to nearly 7 at the end of Week 2. This observation may be attributed to post acidification of yoghurt samples during storage. Similar reductions in sensory quality of yoghurt during storage have been independently reported by Akalin et al. [3] and Zhao et al., [37].

Conclusion

This study shows that starches from all three new cassava varieties, *Abrabopa*, *AGRA* and *Bankye hemaa*, can potentially reduce the incidence of syneresis when added to yoghurt during its preparation. However, this study shows that the starch

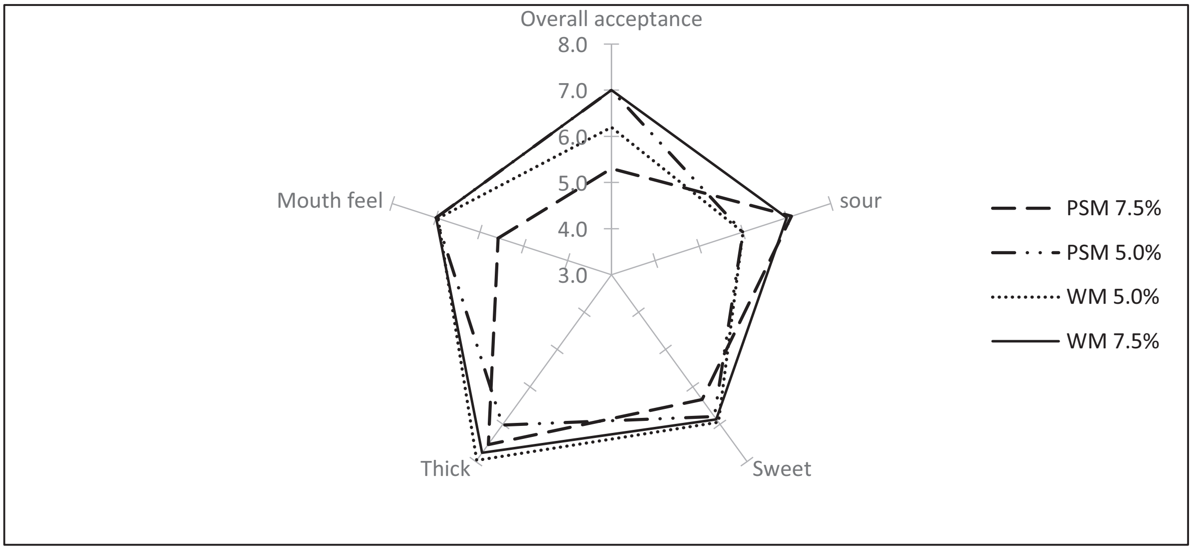

Fig. 2. Continued

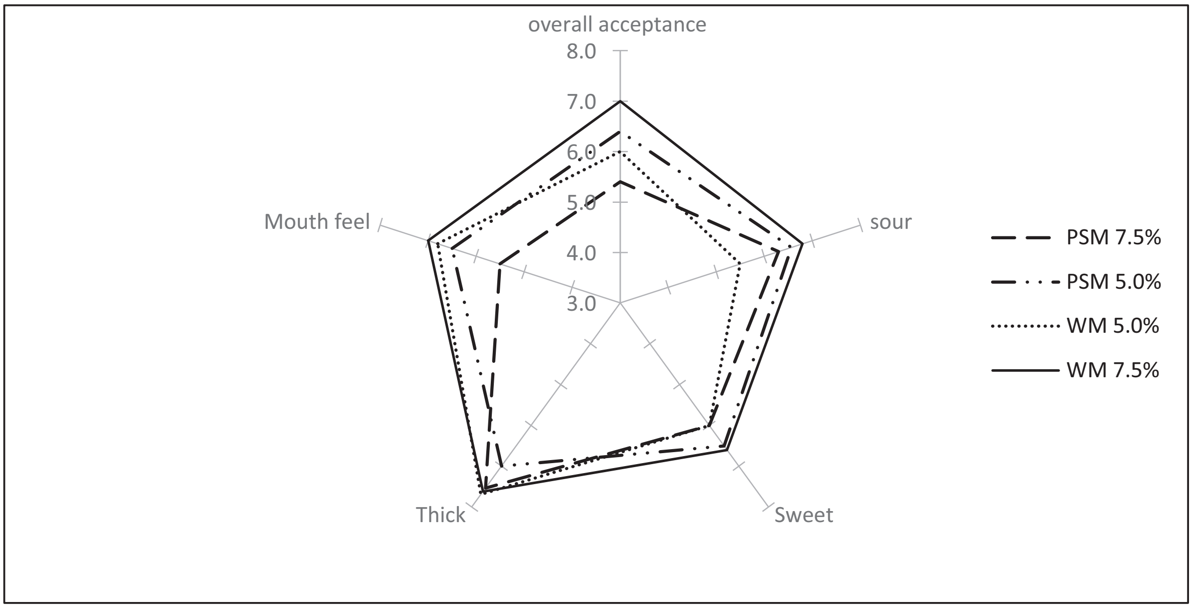

Fig. 2. Continued

from the *Abrabopa* cassava variety, when added at 7.5% during the preparation of yoghurt from the whole milk gave the best results.

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Author contribution

PT Akonor: Writing of Paper, Laboratory Work and Data Analyses
PN. Agyeman: Writing of Paper Laboratory work, Analyses of Data,
C. Tortoe: Study concept and Design, Writing and Editing of Paper
PNT. Johnson: Study Concept and Design; Data Analyses, Writing and Editing of Paper
J Manu-Aduening: Development and Production of Cassava Varieties Used in the study

Declaration of Competing Interest

The authors declare no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2020.e00521.

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