Participatory Action Research to Developing Acceptable Provitamin a Fortified *Gari*

Prof. Dr. Ernest Ekow Abano
University of Cape Coast
Cape Coast, Ghana
email: eabano@ucc.edu.gh

Dr. Enoch Quayson
University of Cape Coast
Cape Coast, Ghana
email: equayson@ucc.edu.gh

Dr. Martin Bosompem
University of Cape Coast
Cape Coast, Ghana
email: mbosompem@ucc.edu.gh

Mr. Emmanuel Atobrah
University of Cape Coast
Cape Coast, Ghana
email: atobrahe@yahoo.com

Mrs. Margaret Quarm Forson
Komenda Edina Eguafo Abirim Municipal Assembly,
Elmina, Ghana
email: magqforson@gmail.com

Abstract

There is severe clinical vitamin A deficiency (VAD) prevalence among Ghanaians and many African countries. Food-based diets has been suggested as a more sustainable approach to solving the VAD situation in Africa. In this study, A participatory action research between orange flesh sweet potato farmers, gari processors within central region and academia was adopted to develop gari containing provitamin A beta-carotene. Gari is a major staple for Ghanaians and people in the West African subregion due to its affordability and swelling capacity. It is mainly eaten raw with

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water, sugar, groundnut and milk as gari-soakings or with hot water to prepare gelatinized food called gari-kai in Ghana or "eba" among Nigerians. However, gari is limited in provitamin A carotenoids. Orange fleshed sweet potato (OFSP) is known to contain large amount of vitamin A precursor. Therefore, addition of OFSP to gari would have the potential to fight the high prevalence rate of vitamin A deficiency amongst less developed regions of Africa. To develop this, different proportions of orange fleshed sweet potatoes (OFSP) was used to substitute cassava mash and fermented spontaneously to produce composite gari - a gritty-crispy ready-to-eat food product. Both the amount of OFSP and the fermentation duration caused significant increases in the β-carotene content of the composite gari. OFSP addition reduced the luminance while roasting made the composite gari yellower when compared with the cake used. Addition of OFSP negatively affected the swelling capacity of the gari although not significant. The taste, texture, flavour and the overall preferences for the composite gari decreased due to the addition of the OFSP but fermentation duration (FD) improved them. The sample with 10% OFSP and FD of 1.81 days was found to produce the optimal gari. One-portion of the optimal gari would contribute to 34.75, 23.2, 23.2, 27, 17 and 16% of vitamin A requirements amongst children, adolescent, adult males, adult females, pregnant women and lactating mothers respectively. The study demonstrated that partial substitution of cassava with OFSP for gari production would have the potential to fight the high prevalence rate of vitamin A deficiency amongst less developed regions of Africa while involvement of farmers and processors prior to the design of research phase enhanced the adoption of intervention strategies.

Introduction

Vitamin A deficiency (VAD) is the leading cause of preventable blindness and contributes to severity of infections, child mortality, maternal mortality and poor pregnancy outcomes. VAD is a serious public health problem in Ghana. The prevalence of VAD in Ghana is estimated at 76% (USAID, 2016; World-Vision, 2014), which is close to double that of Africa's average of 41.9%. (USAID, 2016). Food and Agriculture Organization (FAO) and World Health Organization (WHO) statistics on food systems for better nutrition show that Ghana is the third worst country in the world with severe VAD problems after Sao Tome and Principe (95.6%) and Kenya (84.4%) which occupy the first and second positions respectively (FAO/WHO, 2005). VAD prevalence is highest among children under 5 years of age and among women of childbearing age. VAD prevalence among under-fives and women of childbearing age in Ghana has worsened from an estimated amount of 20% in 2004 to its current rate of 35.6% (Glover-amengor et al., 2016). The main cause of VAD is low dietary intake of foods rich in vitamin A or it's precursors. This is a main problem among the poor since their diets tend to be of limited diversity and low in food of animal parts with high vitamin A content such as the liver. Infections also contribute to VAD. Promotion of food–based diets rich in vitamin A is considered the most sustainable approach to addressing VAD (Low et al., 2017), with supplementation considered a short-term strategy and fortification as medium term. Golden rice (Oryza sativa), carrot (Daucus carota subsp. sativus), and orange-fleshed sweet potato, OFSP (Ipomea batatas) are among the best sources of beta-carotene with about 85% of the carotenoids in them capable of being converted to vitamin A after consumption (FAO/WHO, 2005). However, golden rice is not grown in Ghana while carrot on the other hand is expensive. In addition, although biofortified cassava and red palm oil (RPO) could be used in gari production to enhance colour

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and pro-vitamin A carotenoids, gari produced from RPO is reported to show high β-carotene stability than that from biofortified cassava stored under ambient conditions (Bechoff et al., 2015) but has the disadvantage of generating peroxides, especially at the high roasting temperature (Alyas et al., 2006), and unpleasant smell during storage, which are harmful to the human body. Compared to cassava, sweet potato is reported to have high β-carotene stability (Nascimento et al., 2007).

This leaves OFSP as the viable option to meet the vitamin A needs of Ghanaian citizens (Low et al., 2007). Increased consumption of OFSP products therefore has the potential to contribute to improved vitamin A status among Ghanaians. Incorporation of OFSP into food systems as a strategy to improved nutrition has been suggested (Laurie et al., 2018). Orange fleshed sweet potato (Ipomea batatas) composite bread as a significant source of dietary vitamin A is documented (Awuni et al., 2018). The potential of OFSP to improve the vitamin A status in young children has been confirmed in both efficacy and effectiveness studies (Hotz et al., 2012; Van Jaarsveld et al., 2005; Tumwegamire et al., 2004). OFSP is produced in large quantities in the Central and Eastern Regions of Ghana. However, there are unsold orange fleshed sweet potato roots by farmers who produce them especially during bumper harvest because consumers complain of its undesirable soft texture after wet cooking, rendering wet-cooked OFSP unappealing, so the produce is underutilized, and its cultivation is not encouraged. Farmer's livelihood are seriously affected due to the unsold commodities. In addition, there is unsatisfied demand by farmers and processors to possess adequate knowledge and skills to process OFSP into secondary and tertiary products or develop it into OFSP-containing products. It is against this background the study adopted a strategy to incorporate it into existing and well-known staple, gari, which conventionally lacks the nutrients inherent in OFSP, particularly, pro-vitamin A carotenoids. Gari is a ready-to-eat grits produced from roasted fermented cassava mash and is a major staple for Ghanaians and people in the West African subregion due to its affordability and swelling capacity. It is mainly eaten raw with cold water, sugar, groundnut, and milk as gari-soakings or with hot water to prepare gelatinized food called 'gari-kai' in Ghana or "eba" among Nigerians. During gari processing, the cassava mash is typically fermented for up to 4 days prior to roasting depending on the cassava variety and the taste preferences by the particular community. The fermentation process and roasting affect the taste, flavour and colour of the gari. Some gari processors in Ghana add the artificial egg yellow food colour powder made of sodium chloride, tartrazine E-102 and allura red E-129 to change the natural white gari to enhance its attractiveness. Fermentation of the cassava mash is a two-phase regime. In the first phase, the starch in the mash is broken down to sugars by Corynebacterium and metabolizes into organic acids. The organic acids break down the cyanogenic glucosides in the cassava and release hydrogen cynanide (HCN). The second phase initiates the growth of Geotrichum candida to produce mould leading to release of aldehydes and esters from the sugars, which characterize the typical gari flavour. It is against this background that the project seeks to develop OFSP-gari to investigate how its proportionate amount and fermentation duration affects the nutritional, functional, and sensory quality of OFSP-gari. In addition, the study optimized the OFSP amount and fermentation duration and assessed the contribution of the optimal and validated composite gari to the recommended dietary allowance (RDA) of vitamin A among children, adolescents, adult male and female as well as pregnant and nursing mothers.

Materials and methods

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Sample preparation

Mature and wholesome Afisiafi cassava variety purposely developed for gari production and orange-fleshed sweet potato (OFSP) roots were harvested fresh from certified farms by the Department of Food and Agriculture of the Ministry of Food and Agriculture, Ghana, at Jukwa and Dahyia communities respectively in the Cape Coast Metropolitan Assembly and immediately brought to the gari processing centre for processing. Through a participatory action research, the women gari processors within central region and the University of Cape Coast researchers adopted a model to develop gari containing provitamin A beta-carotene using orange fleshed sweet potatoes. The women peeled the cassava roots and washed while the OFSP roots were thoroughly washed without peeling. After washing, the samples were allowed to drain to remove excess water. A total weight of 20 kg each mixed according to the design proportions (Table 1) was grated into smooth mash. The mash was packed into polypropylene bags, tied, screw-pressed to dewater and fermented spontaneously without the addition of a starter culture.

Experimental Design

A 2-factor, 3-level factorial response surface method was used for the study (Table 1). This design was chosen due to its robustness for optimization studies involving many responses and at least two factors. The effect of different proportions of OFSP ranging from 10 to 30% were chosen based on similar studies for composite bread (Nzamwita, Gyebi, & Minnaar, 2017) and composite gari cost implications (Awuni et al., 2018). The fermentation duration from 1 to 3 days were selected based on the traditional duration of fermentation in the central region of Ghana. This combination yielded 11 experimental runs with 2 centre points using Minitab 17 software with each run duplicated. The control sample was without the addition of OFSP. The effect of the two factors on the β-carotene content, luminescence and colour of gari (brightness, L* redness, a* and yellowness, b*), swelling capacity (SC), and sensory attributes including appearance, colour, flavour, taste (sourness), texture and overall acceptability was investigated and used for the optimization studies.

Roasting of OFSP Composite Gari

After the simultaneous screw-pressing and spontaneous fermentation of the mash, the resulting cake was pulverized and screened through 1.2 mm screens. The screened dough was roasted in stainless steel pans at a temperature of 100±5 oC for 20.14±1.5 min until the moisture content reached 5.0± 1.4 % (dry basis) ensuring that the product is very crispy. These conditions were chosen based on preliminary trials conducted. Temperatures during roasting which allow for gelatinization and drying to take place, and subsequently impacts on the crispiness and grittiness of the composite gari was monitored with an infrared thermometer. After roasting, the product was poured into a clean dry bowl and allowed to cool for 30 min to bring the product temperature to about 40 oC. The cooled OFSP-cassava composite gari was sifted through 0.6 mm screens to ensure uniformity and finer particles size of the final food product and packaged in 500 mL airtight plastics bottles and kept in a freezer at -10 C for further analysis.

Determination of β-carotene

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The β-carotene of the fresh mash and roasted gari was determined following the method reported by Sadaf et al (2013) with slight modification. One gram each of the fresh mash or roasted gari was weighed and transferred into a volumetric flask to which 10mL of absolute ethanol was added and left for about 20 minutes with periodic shaking. The extraction of the carotenoids in the roasted samples was aided by using mortar and pestle. The extraction with ethanol was repeated thrice ensuring that most of the pigment were removed from the test sample. The resulting solution was filtered using 0.45 um filter paper. Exactly 15mL of petroleum ether (40-60 oC) was added to the filtrate, shaken gently and left to stand for 20 minutes resulting in a two-layered solution. The top layer with the beta-carotene was pipetted for the absorbance reading at a wavelength of 450 nm against a blank of petroleum ether. The concentration of β-carotene was calculated (Eq 1 from the average of duplicate readings.

$$Total\ carotenoids\ (\mu g/ml) = \frac{ABS\ X\ V\ (ml) X 10,000}{2592 * W(g)} \quad (1)$$

Where ABS is the absorbance; V (ml) is the volume of solvent used for the extraction; W (g) is the weight/volume of sample initially taken; 2592 is the extinction coefficient of beta-carotene in petroleum ether.

Colour Measurements

The colour of the product was measured in Hunter parameters with a real time automatic colour difference meter (Ocean optics, 77501 400uV. The machine was calibrated by placing the source of the measuring light flux (D65o) against the surface of the white calibration plates supplied by the manufacturer. After standardization, colour spectral for each of the sample was determined. The data was processed through an ocean optics spectra suite data processor to extract the colour parameters from which the L*, a*, b*, hue angles values were selected. The colour brightness coordinates, L*, measures the brightness value of the gari and ranges from black (0) to white (100). The chromaticity coordinates, a*, measures the redness when positive (+60) and greenness when negative (-60), and the chromaticity coordinate, b*, measures yellow when positive and blue when negative.

Swelling Capacity

Swelling capacity (SC) was determined according to the method reported by Iwuoha (2004). Three grams (3 g) of each sample was transferred into clean, dry, and graduated (50 mL) cylinders. The sample was gently levelled and its volume (V1) noted prior to addition of 30 mL distilled water. The cylinder was swirled and allowed to stand for 1hour while the change in volume (swelling) was recorded after 15min (V2). The swelling power of each composite cassava-OFSP gari sample was calculated as a multiple of the original volume using Eq 2.

$$SC = \frac{V_2 - V_1}{V_1} \quad (2)$$

Sensory Analysis

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A sensory panel was formed from among the staff and students of the University of Cape Coast, Ghana. The criteria for selection of the panelists were that (a) they were available and willing to participate in the sensory analysis tests, (b) they were regular consumers of gari, and (c) were of sound health, no allergies and dentures (d) they were not colour blind and could taste sweet, bitter and umami tastes, and (e) could identify roasted gari flavours. A consumer test consisting of 50 people (both males and females) was selected. The panelists were semi-trained to recognize and score different quality attributes of the composite OFSP-cassava gari samples including appearance, colour, flavour, taste (sourness), texture (graininess) and overall acceptability. The test samples were served at room temperature conditions at 11 in the morning to the panelists. Prior to the sensory testing, the panelists stayed away from any food for at least an hour. The samples were served in transparent plastic cups in a well-lit sensory evaluation room maintained at a temperature of 20oC. The panellists were served water for rinsing mouth in between sample testing. The panel assessed the samples using a 9-point hedonic scale denoted as like extremely 9; like very much 8; like moderately 7; like slightly 6; neither like nor dislike 5; dislike slightly 4; dislike moderately 3; dislike very much 2; dislike extremely 1.

Optimization of the OFSP-Cassava Composite *Gari* Process

The optimization of the OFSP-cassava composite gari production was performed using the response optimizer composite desirability index (CDI) in Minitab Statistical Software. Equation 3 suggested by (Myers et al., 2002) was used to compute CDI.

$$\mathrm{CDI} = \left[\prod_{i=1}^{n} \mathrm{di}(\mathrm{Y_i})\right]^{\frac{1}{n}} \quad (3)$$

Where n^* is the number of responses, di is the desirability index for each response variable. Yi is a multivariate optimization approach used to show the desirability of the various responses. The CDI ranges between 0 and 1 with 0 being the least desirable while 1 is the most desirable. Maximization of CDI is the aim of optimization studies. The optimization process combines goals - maximize, minimize, or target for the factors and the responses. In this study, the goal for the OFSP amount and spontaneous fermentation duration was at any level within the design range. However, for the various responses studied, maximizing beta-carotene content, brightness, yellowness, swelling capacity and the sensory attributes were desired with the exception of the redness of the composite gari, which was minimized.

Assessment of the contribution of OFSP-Cassava composite Gari to Vitamin A requirements

The vitamin A content of the optimized composite gari was calculated as retinol activity equivalents (RAE) using a RAE conversion factor of 1 μg beta-carotene equals to 0.167 μg retinol equivalent as recommended by the FAO/WHO joint report (FAO/WHO, 2005). The contribution of the optimized gari to people of different groups was determined based on a volume basis of 100mL as one portion of the OFSP-cassava composite gari. The bioconversion of retinol to vitamin A activity was estimated to be 1 μg beta-carotene to 0.5 μg of retinol. The groups of individuals used for the assessment of the vitamin A contribution of the OFSP-cassava composite gari are children, adolescents, adults

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male and females between the respective ages of 3 and 9 yrs, 10 and 18yrs, and 19 and 65 as well as pregnant women and lactating mothers.

Statistical Analysis

Analysis of variance (ANOVA) was carried out with Minitab 17 Statistical software to determine the influence of OFSP amount and fermentation duration on the beta-carotene content, colour, swelling capacity, and sensory properties of the OFSP gari at a probability of 95%. The response surface plots for the factors and the significance of each model term for a second order polynomial function was generated.

Results and Discussion

Beta-carotene in OFSP-Cassava Composite *Gari*

Beta-carotene, which is converted to vitamin A by the human body when consumed and is in high amount in OFSP has the potential to combat the vitamin A deficiency in developing countries. The effect of OFSP amount and dough fermentation duration on the beta-carotene content of the composite gari is shown in Fig 1. Expectedly, both the increases in the OFSP amount and the fermentation duration caused significant ($p<0.05$) increases in the beta-carotene content of the composite gari (Eq 3). Yet, the contribution of fermentation duration to beta-carotene release in the gari was about 2.5 times higher than the amount of OFSP as shown by the Y_BC quadratic model (Eq 3). Generally, compositing OFSP with cassava for gari production resulted in an increase in the amount of beta-carotene in the composite gari (Table 1). The results agree with related studies where OFSP flour and puree were composited with wheat flour for composite bread production (Nzamwita, Gyebi, & Minnaar, 2017; Awuni et al., 2018). Increases in beta-carotene as OFSP amount is increased may primarily be due to the concentration effect of the OFSP in the cassava dough. There are a number of reasons that could account for the increase in beta-carotene as fermentation time increased. Loss of solid matter as well as unaccounted moisture as fermentation time increased may be one reason (Maziya-Dixon et al., 2008). The increased extraction efficiency of carotene as a result of fermentation could be another possible reason (Rodriguez-Amaya, 1997). Indeed, the fermentation process is associated with disruption of tissues and breaking of barrier allowing for easy accessibility and extraction of supramolecular proteolipid complexes, which are the usual state of occurrence of carotenoids in tissues (De Moura et al., 2015).

Roasting of the gari affected the degradation of the beta-carotene content of the fermented dough. As expected, carotenoids are susceptible to heat and therefore, the relatively high roasting temperature conditions of the gari would lead to some degradation of the beta-carotene. Essentially, heat application results in isomerization of all-trans-β-carotene to the cis-trans-β-carotene, which has a lower vitamin A activity, thus making the contribution of all-trans-β-carotene higher compared to the cis-trans-β-carotene as noted by Nzamwita et al. (2017). The interaction

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as well as the curvature effect of OFSP addition and fermentation duration were not significant model terms on the β-carotene content of the OFSP-cassava composite gari.

$$Y_{BC} = 23.31 + 4.36X_1 + 10.79X_2 + 0.15X_1X_2 - 1.39X_1^2 - 1.34X_2^2 \quad (3)$$

Effect of OFSP-Cassava Composite on the Colour of Gari

Colour is one of the greatest vital quality criteria of food choice by consumers. The brightness of gari is an important indicator for gari consumers as it is a measure of its purity on the Ghanaian market. Though white gari is adjudged pure, yellow hue gari is priced higher in Ghana due to the belief that it has added nutrients from food colour or red palm oil. For this reason, OFSP was chosen to simultaneously add nutrient in the form of β-carotene and colour to the gari. Both the OFSP amount and the fermentation duration significantly affected the whiteness of the composite gari [Table 2]. However, adding OFSP to cassava dough had a negative effect on the gari brightness while fermentation duration had a positive effect. The increases in the amount of OFSP decreased the brightness of the gari significantly with a much higher effect (5.5 times) than fermentation duration (Figure 2A, Table 2). This is expected because OFSP has an orange colour, and this impacted on the whiteness of cassava used for the gari production. The interaction between OFSP and fermentation duration as well as the curvature effect of fermentation was significant. Compared with the control samples, the brightness of all the OFSP-cassava composite gari decreased. This suggests that luminance of the OFSP-cassava composite gari diminished due to the addition of the OFSP but fermentation enhanced it. Since the brightness of the cake (data not shown) decreased after roasting, it does suggest that the high temperature conditions used for roasting the composite cake contributed to the decreased the luminance of the gari. This could be attributed to the high sucrose (30% of total carbohydrate in OFSP) which would undergo caramelization as was reported in a related study involving sweet potato starch in tapioca production (Akintayo et al., 2019).

The redness, a* of the composite gari was affected significantly mainly by the addition of the OFSP and not the fermentation duration although the interaction between the amount of OFSP and fermentation duration as well as the quadratic effect of fermentation duration did affect the redness. Therefore, lower amount of OFSP to cassava mash and fermentation for about 2 days will minimize redness of the composite gari. Since red gari is not a desirable product in Ghana, minimization of this colour attributes should be desirable. It is also worthwhile to mention that the relative contribution of OFSP amount to the redness of the gari was about 8.6 times that of the fermentation duration. This suggest that when OFSP is used to fortify cassava for gari preparation excessive amount (>30%) should be avoided (Fig 2B). In our study, excessive amount of OFSP in the dough produced more lumps and brown pigment after roasting. Redness of the composite gari generally increased when compared to the control, which could also be attributed to caramelization of the high sucrose in OFSP as mentioned in the preceding paragraph. The contribution of Maillard reaction to the redness may be very marginal as OFSP is not a rich source of protein.

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The yellowness, b* of the gari increased with increment in the amount of OFSP while fermentation duration decreased it but not significantly in the main regions. Both the curvature regions of the two factors used in this study affected the yellowness with the OFSP addition playing a positive role (Table 2). The amount of OFSP however contributed more to the yellowness of the gari 1.25 times that of the fermentation duration. Considering the range of hue angles of the dough used for the gari production (59° and 71°), it does indicate that roasting improved the hue angles of the OFSP-cassava composite gari samples (78° and 85°) respectively. A hue angle of 0 ° or 360 ° represents red hue, while angles of 90 °, 180 °, and 270 ° represent yellow, green and blue hues respectively. This suggests that the roasting of the OFSP-cassava composite dough made the gari yellower than the cake used to produce the gari. The second order polynomial for the colour parameters are displayed in Eq 4-6.

$$Y_{L*} = 79.468 - 3.6445X_1 + 0.6592X_2 + 0.351X_1X_2 + 0.296X_1^2 + 0.906X_2^2 \qquad (4)$$

$$Y_{a*} = 7.475 + 2.027X_1 + 0.235X_2 - 0.677X_1X_2 - 0.118X_1^2 - 0.771X_2^2 \quad (5)$$

$$Y_{b*} = 40.297 + 0.909X_1 - 0.723X_2 + 0.59X_1X_2 + 2.644X_1^2 - 3.259X_2^2 \quad (6)$$

Effect of OFSP-Cassava Composite on Swelling Capacity of Gari

Swelling capacity (SC) of gari is one of the quality indices influencing consumer acceptability, as it gives higher volume and a sense of satisfaction to consumers and processors alike. As a result, swelling index of at least 300% of its original volume is preferred by consumers (Akingbala, Oyewole, Uzo-Peters, Karim, & Bacus-Taylor, 2005; Steinkraus, 1995). In this study, depending on the amount of OFSP used for the composite dough, the SC values ranged from 286 to 396% for the OFSP-cassava composite gari (Figure 3). These values are lower than the SC values for the gari made from the dough that had no OFSP (448-478%). The range of OFSP amount used from 10 to 30% for the study was not significant on the SC values (286 to 396%) of the composite gari although the effect was negative (Table 2). However, fermentation duration negatively affected the SC values of the gari significantly ($p<0.01$). Fermentation of the OFSP composite gari contributed about 7.6 times to diminishing the swelling capacity of gari than the amount of OFSP (Figure 3). This may have happened because fermentation breaks down the carbohydrates in the OFSP-cassava dough due to the production of lactic acid. Lactic acid fermentation has been reported to result in significant decrease in carbohydrate and fibre (Ogodo et al., 2017). Additionally, OFSP is a rich source of sugars including reducing sugars such as glucose and fructose and nonreducing disaccharide sucrose and reducing disaccharides maltose. Most likely, it is substituting cassava dough might have decreased the starch content and other carbohydrates such as fibre content of the composite dough, which components contribute greatly to swelling capacity of the product in which they occur. Swelling capacity of gari in water is mainly influenced by the grit particle size, the initial moisture content, fermentation duration as well as the amylose and the amylopectin in the gari. Swelling capacities of gari between 330 and 450% were reported when up to 20% yellow fleshed sweet potato was

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used to fortify bitter TS53201 cassava variety (Olayinka et al., 2016). Similar SC values between 301 and 430% were reported by Ojo & Akande (2013) for cassava and sweet potato mixes up to 50% each.

$$Y_{sc} = 3.0021 - 0.0483X_1 - 0.3717X_2 + 0.1375X_1X_2 + 0.25X_1^2 + 0.040X_2^2 \quad (7)$$

Effect of OFSP-Cassava Composite on Sensory Properties of Gari

The effect of the processing variables on the sensory properties when the composite gari samples were assessed in their dry particulate form by the panellists is shown in Figure 4. The appearance of the composite gari was negatively affected by the addition of OFSP significantly as indicated by the sensory results (Figure 4A) while fermentation duration affected the appearance positively but not significant. The taste, texture, flavour and the overall acceptability were similarly affected by the fortification of cassava with OFSP while fermentation duration for all the model terms had a positive effect on the taste, flavour, texture, and overall acceptability of the OFSP-cassava composite gari. The relative contribution of fermentation to the sensory attributes studied in this present study was higher than the OFSP addition as can be seen from the model coefficients for equations 8 through to 12. It is evident from the curvature effect that beyond 2 days of fermentation, the taste, appearance, and the texture preferences started to decline (Figure 4). This suggests that moderate amount of OFSP in combination with about 2 days of fermentation would have the highest consumers acceptability for the OFSP-cassava composite gari. As fermentation proceeds beyond 2 days more lactic acid is produced which makes the gari taste sour. Excessive sourness caused an unpleasant mouth feel making longer duration of fermentation undesirable to consumers. This observation is consistent with report by Abass et al. (2012) that gari should not be too acidic. Similarly, as the amount of OFSP in the composite gari increases the product particle size becomes coarser, which decreased the texture preference by the consumers (Figure 4B) since a smooth texture gari is preferred by consumers (Abass et al., 2012). Fibre from the OFSP might be contributing to the increased coarseness of the composite gari, especially since the tubers were not peeled before being used. High OFSP inclusion in gari production may therefore not be encouraged. Though there are obvious benefits of fermentation to gari production including improvement in taste, shelf life, flavour, safety, and reduction in cyanide content of bitter cassava variety, fermentation for OFSP-cassava composite gari should not proceed beyond 2 days if the target market is Ghana. This is not surprising because consumers in Ghana and South-East of Nigeria prefer mild sour taste gari while those in the South-West of Nigeria accept an acidic taste (Abass et al., 2012). Overall, the consumer preference and acceptability for the control gari was higher than the OFSP-composite gari. These trends depict that for OFSP to be introduced effectively into gari food-based systems to solve the vitamin A deficiency in Ghana and beyond, smaller amount should be considered for maximum consumer acceptability. Our results agree with studies by Olayinka, Balogun, Olaide, & Wasiu (2016) who reported that 10% partial substitution of gari with yellow fleshed sweet potato scored the highest consumer preference test over the 20% substitution. Intense education is however needed for consumers to understand the benefits of higher amount of OFSP in gari to demystify the negative perceptions that gari should be white and nothing more. The second order polynomial showing the main, interaction and curvature effect of the processing variables on the sensory indices is shown in Eqs 8-12.

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$$Y_{APPEARANCE} = 6.22 - 0.3244X_1 + 3.599X_2 + 0.0185X_1X_2 + 0.00441X_1^2 - 1.004X_2^2 \quad (8)$$

$$Y_{TEXTURE} = 5.904 - 0.1554X_1 + 1.996X_2 + 0.0219X_1X_2 - 0.001X_1^2 - 0.559X_2^2 \quad (9)$$

$$Y_{TASTE} = 7.29 - 0.275X_1 + 1.18X_2 - 0.0055X_1X_2 + 0.00543X_1^2 - 0.267X_2^2 \quad (10)$$

$$Y_{FLAVOUR} = 7.70 - 0.238X_1 + 0.61X_2 - 0.009X_1X_2 + 0.00363X_1^2 - 0.232X_2^2 \quad (11)$$

$$Y_{OA} = 8.16 - 0.3164X_1 + 1.446X_2 + 0.0193X_1X_2 + 0.0042X_1^2 - 0.433X_2^2 \quad (12)$$

Optimization of the OFSP-Cassava Composite Gari

In the range of independent variables used for the production of the composite gari, the simulation with 95% confidence gave 10% OFSP and fermentation duration of 1.81 days or 43 hours as the optimized processing variables. At this optimal condition, the maximum predicted responses were 15.47 µg/mL beta-carotene, 83.38 brightness, 42.16 yellowness, 5.13 redness, 340% swelling capacity, 6.98 score for appearance, 6.63 for texture, 6.23 for taste, 6.2 for flavour, and 6.96 for overall acceptability. The composite desirability of 0.77 was obtained for the effect of OFSP amount and fermentation duration on the gari quality and its sensory attributes. The desirability of each of the response parameters determined in this present study is shown in Figure 5. The taste, texture, and appearance of the composite gari gave the highest desirability index following the optimization prediction model while the beta carotene recorded the least desirability. These predictions are good because taste, texture and appearance are most important attributes of processed gari in the Ghanaian market. Consumers easily perceive texture and appearance when buying gari. Aggregators and consumers most often than not taste gari prior to buying. similarly, gari grittiness, grit uniformity and brightness of the colour is considered more important to processors and consumers than the type of colour (Abass et al., 2012). These attributes motivate consumers to purchase gari to enable them to derive the needed intrinsic nutritional benefits. Verification of the optimized condition gave 16.72 µg/mL beta-carotene, 85.16 brightness, 40.2 yellowness, 4.93 redness, 350% swelling capacity, 6.75 score for appearance, 7.0 for taste, 7.35 for texture, 7.0 for flavour, and 7.2 for overall acceptability. These experimental values are closer to the predicted responses, indicating the goodness of fit of the model.

Contribution of OFSP-Cassava Composite Gari to Vitamin A Requirements

The contribution of gari to the recommended dietary allowance (RDA) of vitamin A largely depended on the amount of OFSP in the composite gari (Table 1). The physiological requirements of each groups of individuals similarly vary with the vitamin A needs. From the verified optimized beta-carotene content of 16.72 µg/mL for the 10% OFSP composite gari the retinol equivalent (RE) was calculated to be 139 µg/100mL or 139 µg/62g RE (average bulk density of the OFSP-cassava composite gari was determined to be 0.619±0.011 g/cm3) or 695 IU. This value is by far higher than the control gari (46.5 µg/100mL). Given that the RDA for children, adolescents, adult males and females are 400, 600, 600, and 500 µg respectively, one portion of the composite gari can contribute to 34, 23.2, 23.2, and

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27.8% of retinol amongst children, adolescent, adult males and adult females respectively. On the other hand, unfortified gari would provide 11, 7, 7, and 9% of retinol amongst the same group of individuals respectively. Regarding pregnant and lactating mothers, one portion of the optimized OFSP-cassava composite gari would supply 17% and 16% while the gari without OFSP would provide 5.8 and 5.4% of the recommended daily requirements for pregnant women and lactating mothers respectively. These contributions to retinol RDA of these groups suggest that additional amounts of retinol are needed to meet the daily requirements. This is because the optimized composite gari would meet less than 50% of the RDA of vitamin A for these groups of individuals. The contribution of total beta-carotene of OFSP-wheat composite bread containing 10% OFSP flour was found to be 115.6 μg/100g, which would contribute 29% of the RDA among children between the ages of 3 and 10years (Nzamwita et al., 2017). As the OFSP amount was increased to 20 and 30% in the bread, the respective vitamin A contribution increased to 61 and 89%. This in an indication that the OFSP amount could be increased in gari but that would mean that consumers would have to pay more for the same quantity of composite gari since OFSP is priced higher 0.52USD/kg than cassava (0.13 USD/kg) in Ghana. In addition, since increasing the level of OFSP negatively affected the appearance and consumer acceptability of the final product, some education would have to be undertaken, about the health benefits the higher amount of OFSP in the composite gari, in spite of the appearance could provide to addressing the vitamin A deficiency problems.

Conclusions

Addition of 10% OFSP to 90% cassava mash and fermented for 1.81 days or 43 hours prior to roasting gari causes an improvement in the beta-carotene content of the OFSP-Cassava composite gari, which can hypothetically be used to reduce 34% of the vitamin A deficiency in children between the ages of 3 and 10 years. Pregnant women and nursing mothers on the other hand may need more OFSP gari (>100mL) or of gari containing higher amount OFSP to meet their vitamin A requirements. To improve processors and consumers acceptability of the sensory attributes and cost implications of the OFSP-cassava composite gari as well as the ease of roasting by processors more than 30% of the OFSP in the composite gari should be avoided.

Acknowledgement

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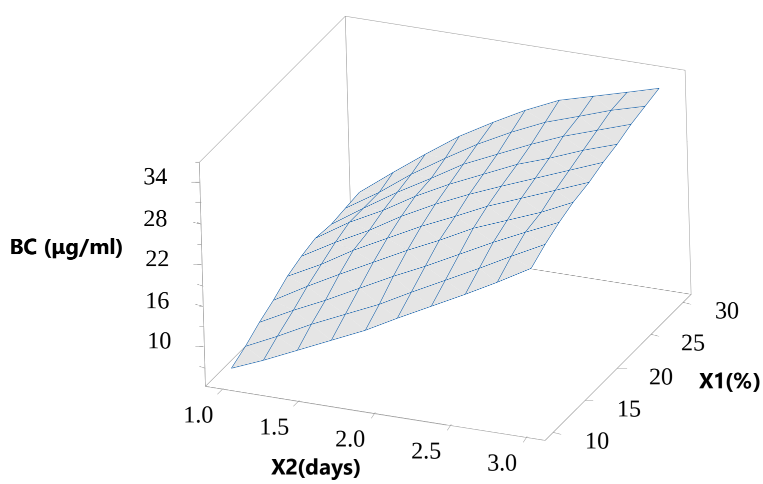

Fig. 3 Effect of OFSP amount and dough fermentation duration on beta-carotene content in OFSP-cassava composite gari. X1 is the percentage amount of OFSP in the composite; X2 is spontaneous fermentation duration in days

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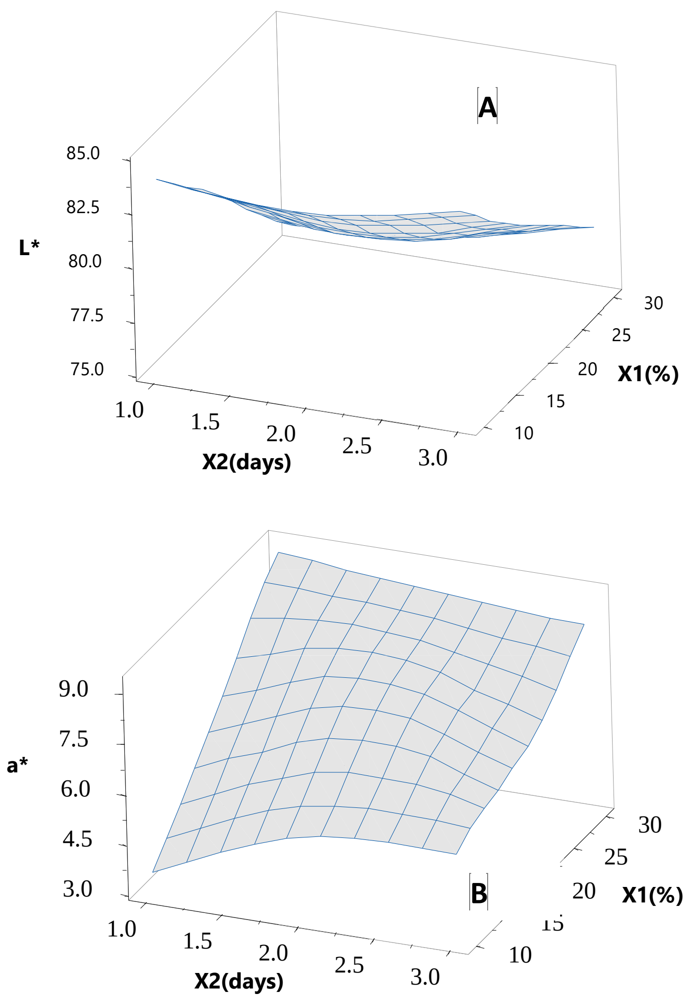

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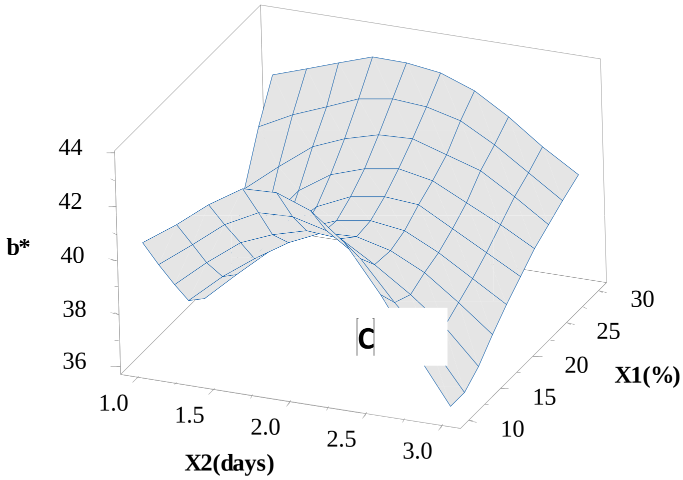

Fig. 4: Effect of OFSP and fermentation duration on (A) brightness, (B) redness, (C)yellowness of composite gari. X1 is the percentage amount of OFSP in the composite; X2 is spontaneous fermentation duration in days

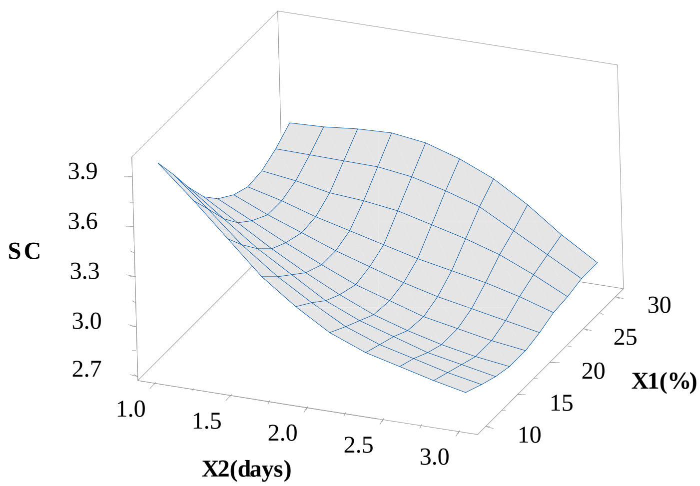

Fig. 5: Effect of OFSP amount and fermentation duration on the swelling capacity (SC) of composite gari. X1 is the percentage amount of OFSP in the composite; X2 is spontaneous fermentation duration in days

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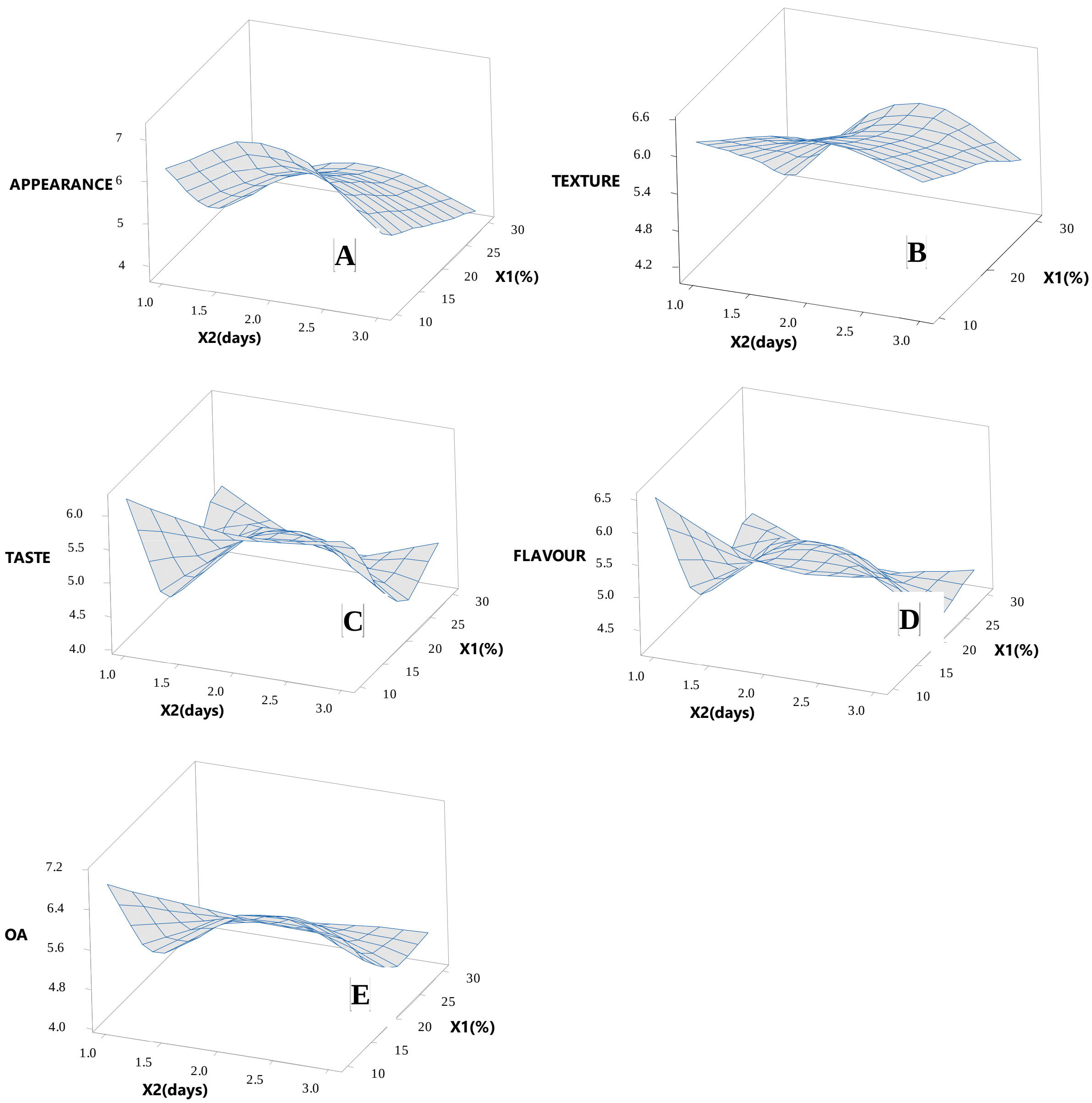

Fig. 6: Effect of OFSP and fermentation duration on the sensory properties of the composite gari (A) Appearance, (B) Texture, (C) Taste (D) Flavour and (E) Overall acceptability. X_1 is the percentage amount of OFSP in the composite; X_2 is spontaneous fermentation duration in days

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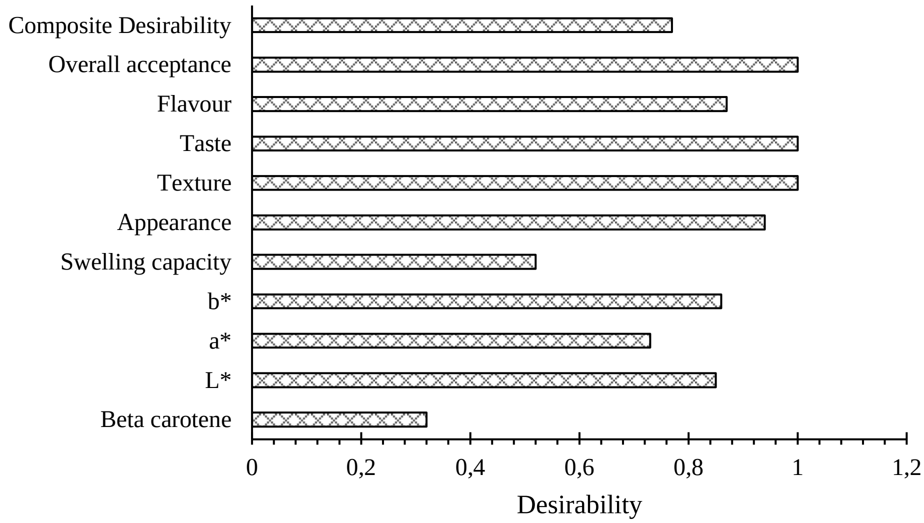

Fig. 7: Desirability of the composite OFSP-Cassava gari for the various responses studied.

Table 1 Result of 2- factor three-level RSM for the OFSP- Cassava composite gari

X1(%)	X2(d)	BC (µg/ml)	L*	a*	b*	SC	APPEARANCE	TASTE	TEXTURE	FLAVOR	OA
10	3	27.85	84.669	5.56	36.17	2.86	5.5	6.1	6.1	5.8	6.5
20	1	11.63	80.032	6.35	36.19	3.36	4.2	5.2	4.1	4.3	4.5
10	1	6.06	83.898	3.58	40.45	3.96	6.2	6.2	6.2	6.5	6.8
20	3	32.32	81.041	6.49	38.06	2.78	4.6	5.6	4.5	4.5	4.9
30	2	27.78	76.382	8.84	43.11	3.40	4.6	5.5	4.3	4.3	4.5
20	2	18.35	79.36	7.66	40.24	3.10	5.4	5.7	5.3	5.0	5.5
30	3	35.36	77.982	8.52	40.00	2.87	3.9	4.9	4.7	4.5	4.7
20	2	23.78	79.36	7.63	40.23	2.96	5.7	5.9	5.1	5.4	5.6
20	2	27.78	83.471	7.66	40.20	2.89	5.2	5.7	5.5	5.6	5.7
10	2	16.07	75.807	5.31	42.96	3.16	7.2	6.5	5.9	5.7	6.6
30	1	13.04	88.938	9.25	41.92	3.42	3.8	4.1	5.0	4.8	4.2
contr	1	5.27	88.938	-0.62	21.92	4.78	8.0	7.2	7.2	7.2	8.0
contr	2	5.58	88.657	0.50	20.39	4.48	7.8	7.0	6.7	6.9	7.4
contr	3	4.97	89.277	0.26	16.85	4.63	7.6	7.1	6.2	6.5	7.0

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Table 1 RSM Coefficients for a quadratic model terms for the OFSP-cassava composite gari responses and their significance

Response	β_0	X_1	X_2	X_1X_2	X_1^2	X_2^2	R^2
BC	23.31	4.36	10.79	0.15	-1.39	-1.34	94.06
P-value	<0.001*	0.021*	<0.0001*	0.932	0.525	0.539	
L*	79.468	-3.6445	0.6592	0.351	0.296	0.906	99.69
P-value	<0.0001*	<0.0001*	0.001*	0.029*	0.098	0.002*	
a*	7.475	2.027	0.235	-0.677	-0.118	-0.771	97.31
P-value	<0.001*	<0.0001*	0.208	0.019*	0.657	0.027*	
b*	40.297	0.909	-0.723	0.590	2.644	-3.259	81.28
P-value	<0.0001*	0.182	0.273	0.450	0.033*	0.015*	
SC	3.0021	-0.0483	-0.3717	0.1375	0.250	0.040	89.28
P-value	<0.0001*	0.500	0.003*	0.152	0.059	0.714	
APPEARANCE	5.422	-1.110	-0.047	0.185	0.441	-1.004	95.91
P-value	<0.0001*	<0.0001*	0.714	0.265	0.063	0.003*	
TASTE	5.019	-0.693	-0.003	-0.055	0.543	-0.267	71.72
P-value	<0.0001*	0.025*	0.988	0.846	0.17	0.466	
TEXTURE	5.832	-0.7128	0.1972	0.219	0.101	-0.559	94.75
P-value	<0.0001*	<0.0001*	0.077	0.10	0.495	0.009*	
FLAVOUR	5.057	-0.745	-0.137	0.090	0.363	-0.232	73.38
P-value	<0.0001*	0.018*	0.555	0.748	0.325	0.516	
OA	5.44	-1.098	0.101	0.192	0.42	-0.433	93.44
P-value	<0.0001*	0.001*	0.499	0.307	0.105	0.098	

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