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Original Research Article

Development of a tigernut based ready-to-use therapeutic spread

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[1]*Otubuah Tei Nartey Bernard, [1]Amanquah Tetteh Otu Daniel, [1]Quashie Anthony Kofi Kamasa and [2] Saalia Kwesi Firibu

[1]Nouveau Foods Ghana Ltd, Accra-Ghana.
[2]University of Ghana, Department of Nutrition and Food science, Legon-Ghana.

*Corresponding Author
Email: botubuah@gmail.com
Tel:+233267642008

This work was necessitated due to rising costs of vital ingredients such as milk powder, sugar and vitamin-mineral mix in formulating a peanut-based ready-to-use therapeutic spread, saviour for severely malnourished children. Development of a new spread with particle size ≤ 158µm from roasted tigernut (*Cyperus esculentus*) flour, roasted soy (*Glycine max*) flour, soyoil (10mg Vit A/Kg) and other ingredients were investigated. Appropriately treated flours with better physicochemical features from whole tigernut and soybean with particle sizes ≤ 450µm were used in developing the spreads. Optimized tigernut-based spreads were well accepted and had an excellent colour, flavour, smoothness, aftertaste, spreadability and sweetness. This work shows that a high calorie (8.512 – 11.647 Kcal/g) tigernut-based spreads containing added sugar (≤ 6%) and iodated salt (50ppm,≤ 0.3%) could be produced as a food aid for malnourished people.

Key words: Ready-to-use therapeutic spread, vitamin, mineral, malnourished, calorie, tigernut-based, physicochemical.

INTRODUCTION

Ready–to- use therapeutic food (RUTF) in the form of spread is an effective food in the rehabilitation of severely malnourished children (Manary, 2006). However, rising costs of vital ingredients such as sugar, milk powder and vitamin-mineral mix in formulating this spread have necessitated for cheaper alternative therapeutic ingredients. Tigernut is a healthy food with therapeutic benefits (Arafat et al., 2009; Dixit et al., 2011; Nwaoguikpe, 2010; Sanchez-Zapata et al., 2012, Djomdi et al., 2013). Soybean on the other hand is a protein rich food with therapeutic benefits (Fabiyi, 2006; Sugano, 2006; Matthan et al., 2007; Udgata and Naik, 2007). Besides their health benefits, soybean and tigernut have good vitamin and mineral profiles as well as an execellent proximate compositions (Venter and Eyssen, 2001; Manary, 2006; Lui, 1997, Oladele and Aina, 2007; Ekeanyanwu and Ononogbu, 2010; Bamishaiye and Bamishaiye, 2011; Dixit et al., 2011; Sanchez-Zapata et al., 2012; Ugwuona et al., 2012; Djomdi et al., 2013; Kumari et al., 2014, Asante et al., 2014). Although antinutritive factors such as alkaloids, phytates, saponins, cyanogenic glycosides, trypsin inhibitors, oxalates and tanins are constituents of soybean and tigernut; preprocessing steps such as soaking and dehulling (Mulyowidarso et al., 1991; Gibson and Roberfroid, 1995, Mumba et al., 2004; Adejuyitan et al., 2009; Ade-Omowaye et al., 2009; Adekanmi et al., 2009; Chukwuma et al., 2010; Nwaoguikpe, 2010; Sanchez-Zapata et al., 2012, Djomdi et al., 2013; Kumari et al., 2014), sprouting (Adekanmi et al. 2009, Kumari et al. 2014), blanching (Adekanmi et al., 2009; Sanchez-Zapata et al., 2012, Ari et al., 2012) and roasting (Adekanmi et al., 2009; Sanchez-Zapata et al., 2012) can significantly reduce these antinutritive factors thus enhancing nutritional compositions and physicochemical properties of its flour. The purpose of this work is to develop and optimize a tigernut-based spread with good sensory attributes which is acceptable, but contains added sugar (≤ 6%) and iodated salt (50ppm,≤ 0.3%) for therapeutic use.

Table 1. Spread formulations

Order	Roasted tigernut flour (%)	Roasted soy flour (%)	Soy oil (10mg Vit a/kg) (%)	Total
4	40	40	20	100
2	30	50	20	100
3	30	30	40	100
10	33	33	34	100
1	50	30	20	100
8	43	33	24	100
7	36	36	28	100
5	40	30	30	100
9	33	43	24	100
6	30	40	30	100

MATERIALS AND METHODS

Sample Preparation

Whole tigernuts (Large Yellow variety, Sucrose [15-18%], Moisture ≤ 8 %) and soybeans (Protein, 38-41g/100g) were obtained from two selected local markets (Ashaiman and Madina, Greater Accra Region-Ghana). The tigernuts and soybeans bought were properly sorted and washed. The washed tigernut were soaked 1:10 (w/v) in tap water (pH= 7.66 ± 0.02) for 48hrs at room temperature (27 ± 2˚C), washed thoroughly; hot water blanched (78.4 ± 1.44˚C) for 10 mins and then dried (Astell scientific air oven) at 50˚C for 48hrs. The washed soybean was also soaked in 0.2% (w/v) $NaHCO_3$ solution (pH= 8.39 ± 0.01) for 48 hrs at room temperature (27 ± 2˚C), thoroughly washed after soaking, mechanically dehulled (Straub model 4E Grinding Mill, Philadephia-USA), hot water blanched (91.43 ± 0.84 ˚C) for 15 mins, and then dried (Astell scientific air oven) at 50 ˚C for 48hrs. The dried treated tigernut and dehulled dried soy bean were roasted at 150 ˚C for 10 and 15 mins respectively in an electric oven (Ariston Thermo, Italy) for which samples in trays below were 15 cm away from the heating coils above. Roasted tigernut and roasted soybean were cooled at room temperature (27 ± 2˚C) and were then milled into respective fine flours of particle sizes 460 ±100 µm and 440 ±50 µm using a size 8 inch laboratory hammer mill (Serial No. 41076, Christy and Norris Ltd, England) with moisture contents of 6.92 ± 0.04% (Roasted Tigernut flour) and 3.85 ± 0.93% (Roasted Soy flour); and sucrose contents of 19.03 ± 1.03 % moist basis (Roasted Tigernut flour) and 2.92 ± 0.15% moist basis (Roasted Soy flour) respectively. Other physicochemical properties of the tigernut flour and soyflour were as follows: Oil absorption capacity (2.71 ± 0.32 mlg^{-1} and 1.97 ± 0.01 mlg^{-1}), Emulsification capacity (53.97 ± 2.24% and 44.44%), Emulsification stability at 80 ˚C for 30mins (41.43 ± 2.03% and 42.22 ± 3.14%), Foaming capacity (19.77 ± 2.04% and 26.81 ± 1.56%) and Foaming stability at 20 and 40mins (95% and 100%).

Formulations

A simple centroid mixture design was used to generate ten (10) formulations with lower and upper limits for three variables as Roasted tigernut flour (30:50), Roasted Soy flour (30:50) and Soy oil (10mg Vit A/Kg) (20:40) as shown in Table 1 with other ingredients held constant (Sugar [6%], Iodated salt [50ppm, 0.3%], Lecithin [0.5%] and Cessa stabilizer [0.8%]).

Mixing and Refining

The weighed ingredients (Roasted soy flour, soy oil [10mg Vit A/Kg], Roasted tigernut flour, sugar, iodated salt [50ppm], cessa stabilizer and lecithin) were mixed in a universal mixer (Stephen universal machine, Germany; Min^{-1} 1420/2810; Kw 1.5/1.9) for 20 mins at a high speed (second speed on the regulator) to obtain uniform pastes prior to refining. The pastes of particle sizes 370 ± 50µm were respectively refined in a ball refiner (Wieneroto Attrition Ball Refiner, Type W1S, Wiener & Co. Apparatenbouw B.V., Netherlands) for 1hr at Speed 8 to obtain pastes of particle sizes ≤ 158 µm.

Sensory analysis

The formulated spreads were presented to 15 panelists (Nutrition and Food science students) for preference testing using a balanced incomplete block design with parameters (t=10, b=15, r=6, N=60, k=4, λ=2) for which each panelist receives four (4) samples at a time. A nine (9) point hedonic scale (9= like extremely and 1= dislike extremely) were used to rank the formulated spreads for colour, flavour, sweetness, smoothness, aftertaste, spreadability and over all acceptability. Developed spread made from six (6) different formulations were chosen from the optimum region and outside the optimum region (Four (4) from the optimum region and two (2) from the outside region) were presented to 60 panelists to rank RUTS samples under the following attributes (colour, flavour,

Table 2. Regression coefficients, Coefficients of determination (R^2), Lack of fit and analysis of variance of regression models for mixture components

Mixture components	Colour	Aftertaste	Flavour	Sweetness	Smoothness	Spreadability	Overall acceptability
RTF	-18.01	34.09	-25.04	-12.39	-21.85	16.9	5.67
RSF	3.04	-37.03	17.29	-0.53	-35.17	55.7	36.09
SL	-34.97	-25.01	-10.60	-25.60	31.53	14.9	1.66
RTF*RSF	27.56	2.85	22.64	24.90	148.11*	-147.6*	-80.75
RTF*SL	142.85*	-89.13	135.63	110.79	-30.29	47.1	76.19
RSF*SL	44.85	235.54*	-44.70	42.79	24.38	-96.9	-62.48
R^2 (%)	7.26	18.17	8.75	8.59	21.25	31.22	14.28
Lack of fit (p)	0.296	0.878	0.876	0.606	0.759	0.972	0.871

Key: RTF = Roasted Tigernut flour, RSF = Roasted Soy flour, SL = Soy oil, *significant at $p \leq 0.1$

sweetness, smoothness, aftertaste, spreadability and over all acceptability) on a nine (9) point hedonic scale (9= like extremely and 1= dislike extremely) inorder to validate the best formulations.

Estimation of Energy Content

The energy content of the optimized spread was estimated using a Parr 6200 calorimeter (Parr Instrument Company, Moline IL, USA, Model A1290DDEE). The energy content of the optimized spread were done in duplicates and were then expressed as kcal/100g dw.

Statistical Analysis

The data derived from the mixture design were presented as mixture contour plot (Minitab version 15) where significant differences for mixtures were set at $p \leq 0.1$. Also, optimization data were analysed for their mean scores (displayed as radar map) using excel spread sheet (Microsoft excel version 2010).

RESULTS AND DISCUSSION

Sensory profiling of mixture components on spreads colour, flavour, aftertaste, sweetness, smoothness, spreadability and overall acceptability

Table 2 shows the regression coefficients, coefficients of determination and analysis of variance of regression models for mixture contour plot of spread colour, flavour, aftertaste, sweetness, smoothness, spreadability and overall acceptability. The data showed mixture contour plot (roasted tigernut flour, roasted soy flour and soy oil) of spread colour (Figure 1a). Specifically, highest colour values were found in region where roasted soy flour, soy oil and roasted tigernut flour used were 30%, 38% and 30% respecively (Figure 1a). In constrast, the least colour values for soy flour, soy oil and tigernut were 30%, 20% and 50% respectively (Figure 1a). As indicated in Table 2, the magnitude of the coefficients for the three pure mixtures indicated that roasted soy flour gives highly desirable spread colour than roasted tigernut flour and soyoil in that order (Table 2). Likewise, roasted tigernut flour by roasted soy flour, roasted tigernut flour by soy oil and roasted soy flour by soy oil act synergistically in giving highly desirable spread colour compared to roasted tigernut flour, roasted soy flour and soyoil pure mixtures (Table 2). However, roasted tigernut flour by soy oil mixture blend has a significant influence on spread colour (t=1.74, p=0.088; Table 2).

Furthermore, the finding of the mixture contour plot (roasted tigernut flour, roasted soy flour and soyoil) of spread flavour shows highest flavour values were found where soyflour (31%), soyoil (30%) and tigernut (38%) were used respectively (Figure 1b). Also, the least flavour values were found where soyflour (30%), soyoil (20%) and tigernut (50%) were used respectively (Figure 1b). The magnitude of the coefficient for the three pure mixtures indicates that roasted soy flour gives highly desirable spread flavour than roasted tigernut flour and soyoil (Table 2). Equally, roasted tigernut flour by roasted soyflour and roasted tigernut flour by soyoil act synergistically in giving highly desirable spread flavour. However, magnitude of the coefficient for the roasted tigernut flour by soyoil blend mixtures indicates that it gives highly diserable flavour than roasted tigernut flour by roasted soy flour. Subsequently, roasted soy flour by soy oil mixture blends are antagonistic towards one another (Table 2). Similarly, the mixture contour plot (roasted tigernut flour, roasted soy flour and soyoil) of spread sweetness is shown in Figure 1c. The highest sweetness values were found at the respective proportions; soyflour (30%), soyoil (40%) and tigernut (30%) respectively. Besides, highest sweetness values were also found where soycflour (20%), soyoil (30%) and tigernut (50%) were used (Figure 1c). Also, the least colour values were found where soy flour (50%), soy oil (20%) and tigernut (30%) were used individually (Figure 1c). The magnitude of the coefficient for the three

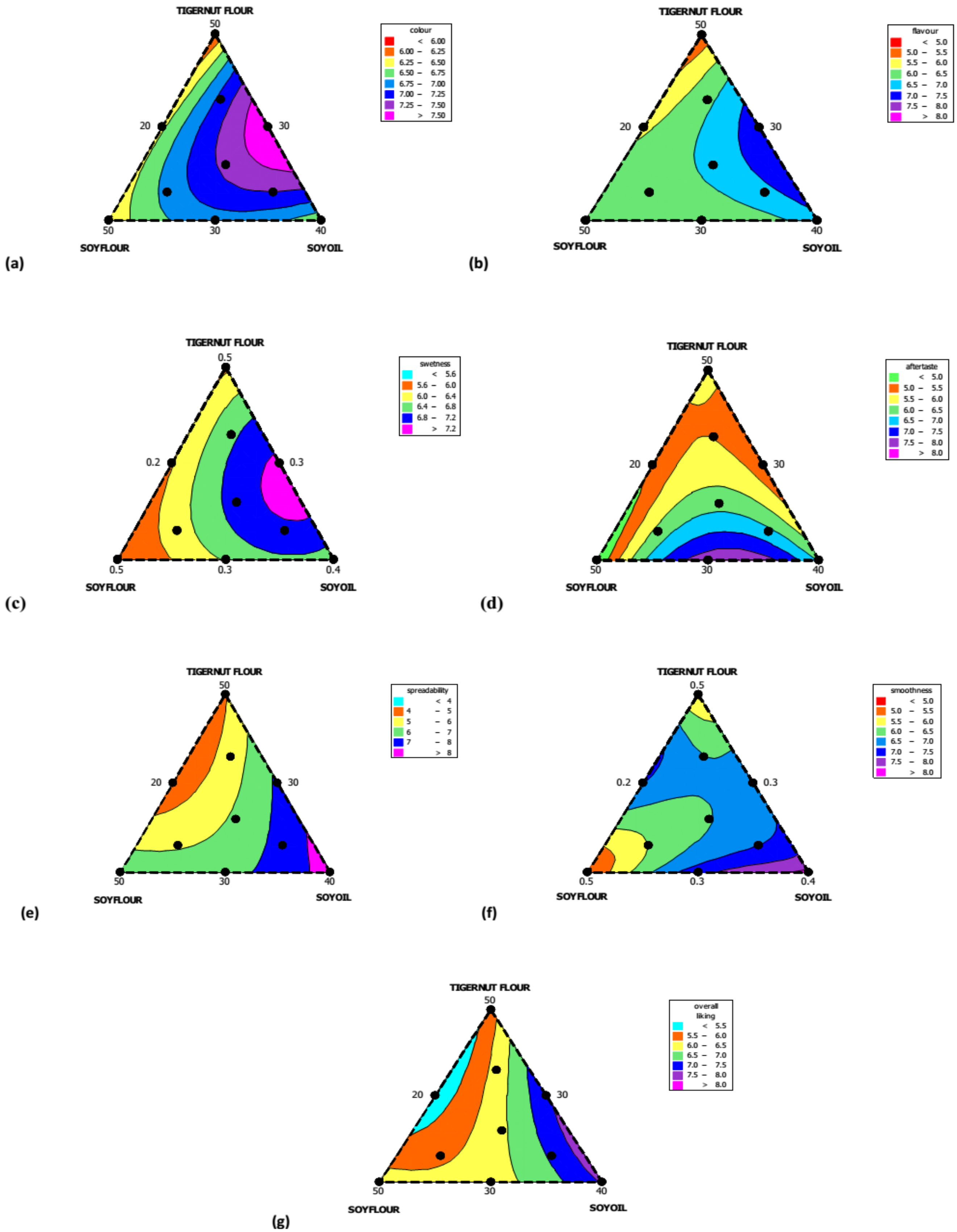

Figure 1: Mixture contour plot showing (a) colour (b) flavour (c) sweetness (d) aftertaste (e) spreadability (f) smoothness (g) overall acceptability ranking of RUTS

pure mixtures specified that roasted tigernut flour gives highly desirable spread sweetness than soyoil and roasted soy flour respectively (Table 2). Roasted soy flour by soy oil acted synergistically in giving highly desirable spread sweetness (Table 2). On the contrary, roasted tigernut flour by roasted soyflour and roasted tigernut flour by soy oil act antagonistic toward one another (Table 2).

However, it was more pronounced in roasted tigernut flour by soy oil mixture blends compared to roasted tigernut flour by roasted soyflour mixture blends (Table 2). The mixture contour plot (roasted tigernut flour, roasted soy flour and soyoil) of spread afterstaste as shown had the highest aftertaste values where soyflour (40%), soyoil (30%) and tigernut (30%) were used together (Figure 1d). Also, the least flavour values were found where soyflour (48%), soyoil (20%) and tigernut (32%) were used respectively (Figure 1d). Besides, magnitude of the coefficient for the three pure mixtures indicated that roasted tigernut flour gives highly desirable spread aftertaste than soyoil and roasted soy flour respectively (Table 2). Roasted soy flour by soy oil mixture blend act synergistically in giving highly desirable spread aftertaste. In constrast, roasted tigernut flour by roasted soyflour and roasted tigernut flour by soyoil act antagonistic toward one another (Table 2). The antagonistic ability of the mixture blends on spread aftertaste was more pronounced in roasted tigernut flour by soyoil mixture blends compared to roasted tigernut flour by roasted soyflour mixture blends (Table 2). However, roasted soyflour by soyoil mixture blend had a significant influence on spread aftertaste ($t=2.62$, $p=0.012$; Table 2).

Correspondingly, mixture contour plot of spread spreadability showed highest spreadability values where soyflour, soyoil and tigernut were 30%, 40% and 30% respectively (Figure 1e). Also, the least spreadability values are found where soyflour (34.5%), soyoil (20.3%) and tigernut (45.2%) are used respectively (Figure 1e). Magnitude of the coefficient for the three pure mixtures also indicated that roasted soy flour gives highly desirable spreadability than roasted tigernut flour and soyoil (Table 2). Roasted tigernut flour by soyoil act synergistically in giving highly desirable spread spreadability (Table 2). Moreover, roasted tigernut flour by roasted soyflour and roasted soy flour by soyoil are antagonistic toward one another. Roasted soy flour by soy oil mixture blend significantly impacted on spread spreadability ($t= -1.74$, $p=0.087$; Table 2). Alike, mixture contour plot (roasted tigernut flour, roasted soy flour and soyoil) of highest spread smoothness values were found where soyflour (30%), soyoil (40%) and tigernut (30%) were used respectively (Figure 1f).

Furthermore, least smoothness values were found where soyflour (50%), soyoil (20%) and tigernut (30%) were used respectively. In addition, least smoothness values were also found where soyflour (30%), soyoil (20%) and tigernut (50%) were used (Figure 1f). The magnitude of the coefficient for the three pure mixtures showed that soy oil gives highly desirable spread smoothness than roasted tigernut flour and roasted soy flour (Table 2). Roasted tigernut flour by roasted soyflour and roasted soyflour by soyoil act synergistically in giving highly desirable spread flavour. However, magnitude of the coefficient for the roasted tigernut flour by roasted soy flour blend mixtures showed that it gives highly diserable spread smoothness compared to roasted soy flour by soyoil. Subsequently, roasted tigernut flour by roasted soy flour mixture blends has significant effect on spread smoothness ($t=1.88$, $p=0.065$; Table 2). Lastly, magnitude of the coefficient for the three pure mixtures indicates that roasted soy flour highly influence spread overall acceptability followed by roasted tigernut flour and soy oil respectively (Table 2). Equally, roasted tigernut flour by soy oil mixture blend act complementary in influencing highly desirable spread overall acceptability. On the contrary, roasted tigernut flour by roasted soyflour and roasted soy flour by soyoil mixture blends act antagonistic toward one another (Table 2). This was more pronounced in roasted tigernut flour by roasted soy flour mixture blends compared to roasted soy flour by soyoil mixture blends (Table 2). However, highest overall acceptability values were found where soyflour (30.2%), soyoil (34.5%) and tigernut (35%) were used respectively (Figure 1g). Also, least overall acceptability values were found where soyflour (37.9%), soyoil (20.9%) and tigernut (41.1%) were used respectively (Figure 1g).

Sensory qualities of optimized tigernut-based spreads

Formulation from optimized and outside regions of the model were tested for their validity (Figure 2). The energy content of optimized formulations of tigernut based ready – to- use therapeutic spreads (RUTS) were between 8.512 – 11.647 Kcal/g. Samples E and F had high amount of soyflour than tigernut flour in it formulation compared to samples A, B, C and D (see footnote, Figure 3). Nevertheless, sample E had the highest spread colour followed by samples F, C, A, D and B respectively (Figure 3a). This observation was as a result of soyflour yielding highly desirable spread colour when used than tigernut flour and soyoil respectively (Table 2). Sample C had a premier spread flavor followed by sample D, F, E, B and A respectively (Figure 3b). This differences in spread flavor is as a result of the magnitude of the coefficient for the roasted tigernut flour by soyoil blend mixtures giving highly diserable flavour than in roasted tigernut flour by roasted soy flour (Table 2). Furthermore, highest sweetness were noted in sample A then in sample C, D, B, F and E respectively (Figure 3c). High sweetness in the optimized spread were due to high levels of tigernut flour (18-20% sucrose).

Again, roasted soy flour by soy oil act synergistically in giving highly desirable spread sweetness (Table 2). Spread smoothness were rated highly in Sample A then in sample

F, C, B, D and E in that order (Figure 3d). Spread spreadability were rated highly in Sample A then in sample C, F, E, D and B in that order (Figure 3e). It was discovered that interface between roasted tigernut flour and soyoil acted synergistically in yielding highly desirable spread spreadability (Table 2). More importantly, roasted soy flour by soy oil mixture blend significantly impacted on spread spreadability (t= -1.74, p=0.087; Table 2). Again, sample A had high aftertaste score then followed by sample D, C, E, F and B (Figure 3f). Once more, sample A and D were rated the same in respect to overall acceptability then followed by Sample C, F, B and E (Figure 3g). This could be explained by the idea that magnitudes for the three pure mixtures indicated that roasted soy flour highly influenced spread overall acceptability followed by roasted tigernut flour and soy oil respectively (Table 2). Equally, interactive effect between roasted tigernut flour and soy oil mixture blends was seen to act complementary in influencing desirable spread overall acceptability (Table 2). This model was intended for generating various tigernut based therapeutic spreads (protein-energy bars) in association (or by substituting soybean (wholly or partially)) with at least suitable therapeutic ingredients such as peanut, halzenuts, milk powder, whey proteins, cocoa powder, pecans, walnut, brazilnut, sesame seeds, amaranth seeds, almond nuts, macadamia nut, cashew nut, strawberry powder and others of various grades.

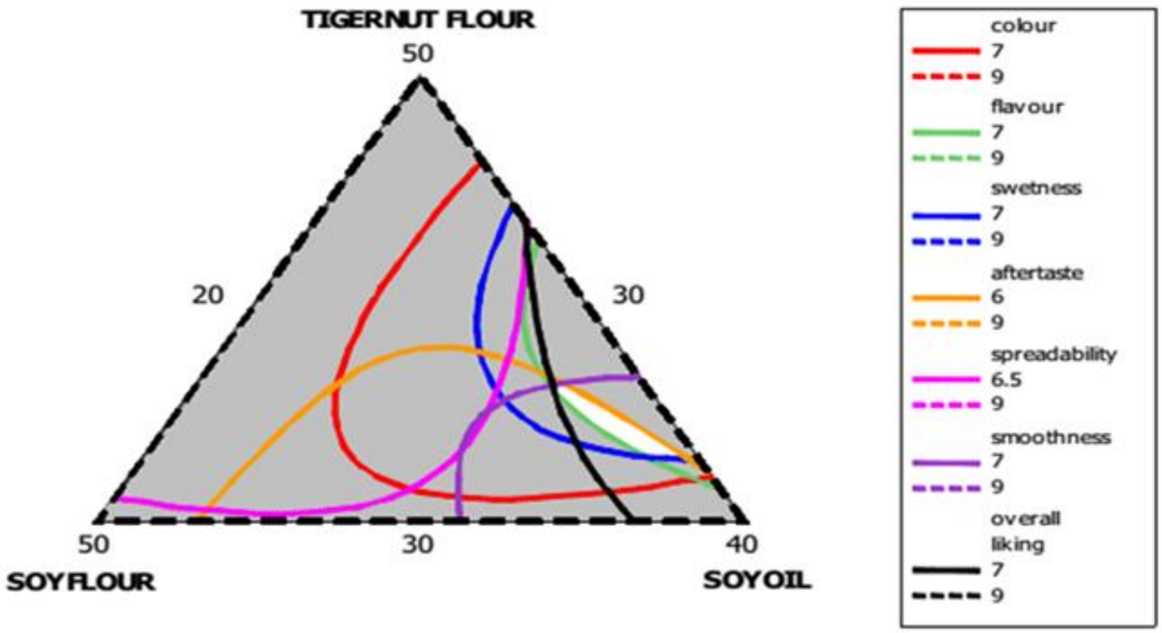

Figure 2: Overlaid contour plot for sensory attributes showing optimum region for roasted tigernut flour, soy oil and roasted soy flour for spread formulation (% component amounts).

Furthermore, substituting the soyoil with other vegetable fats or their modified forms produces a semi-solid/solid tigernut-based bars when cooled at appriopriate temperatures. Once more, this tigernut based spread with soy is similar in appearance to plumpynut and peanut butter. In summary, this new spread were accepted and had an excellent colour, flavour, smoothness, aftertaste, spreadability and sweetness. It evident that an energy dense therapeutic spread from tigernut flour, soy flour and soy oil (10mg Vit A/Kg) containing added sugar (≤ 6%) and iodated salt (50ppm,≤ 0.3%) without milk powder and vitamin-mineral mix could be developed for therapeutic purposes. The nutritional profile of this tigernut-based therapeutic spreads shall be characterized. Again, future research would be aimed at addressing the efficacy of this new spreads on growth of malnourished children and adults.

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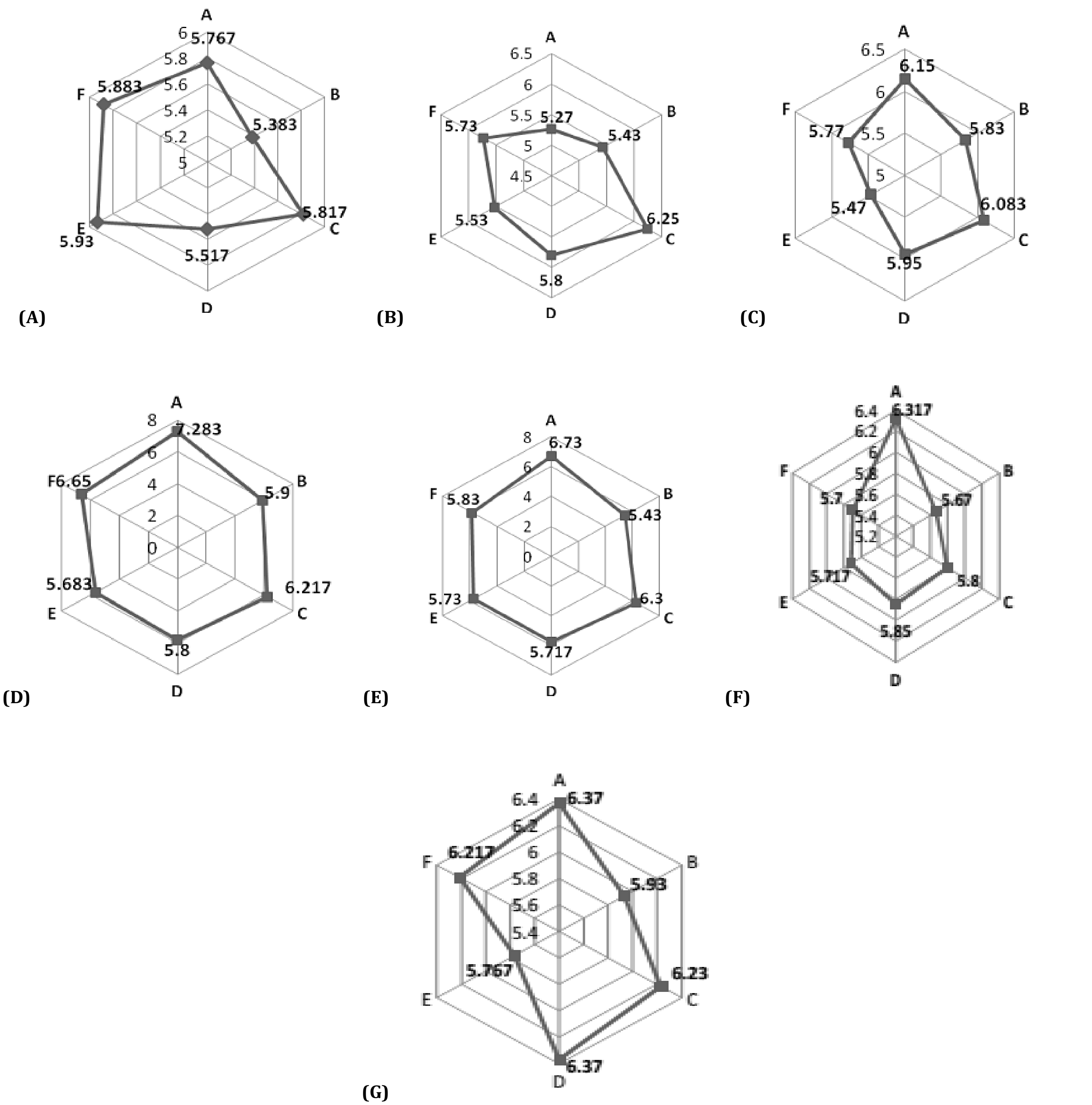

Figure 3: Radar map showing mean (a) colour (b) flavour (c) sweetness (d) smoothness (e) spreadability (f) aftertaste (g) overall acceptability scores of RUTS

A (RUTS 1) was formulated using 30.87% tigernut flour, 28.60% soyflour and 33.45% soyoil; B(RUTS 2) was formulated using 31.43% tigernut flour, 29.67% soyflour and 31.65% soyoil; C (RUTS 3) was formulated using 31.23% tigernut flour, 29.10% soyflour and 32.60% soyoil; D (RUTS 4) was formulated using 31.84% tigernut flour, 29.78% soyflour and 31.32% soyoil; E (RUTS 5) was formulated using 30.19% tigernut flour, 32.40% soyflour and 30.34% soyoil and F (RUTS 6) was formulated using 28.81% tigernut flour, 30.62% soyflour and 30.34% soyoil. A (RUTS 1) predicted sensory score: colour (7.24), flavour (7.12), sweetness (7.04), aftertaste (6.09), spreadability (7.92), smoothness (7.48) and overall acceptability (7.50); B (RUTS 2) predicted sensory scores: colour (7.32), flavour (7.08), sweetness (7.08), aftertaste (6.19), spreadability (7.68), smoothness (7.37) and overall acceptability (7.37); C (RUTS 3) predicted sensory scores: colour (7.33), flavour (7.10), sweetness (7.09), aftertaste (6.09), spreadability (7.77), smoothness (7.38) and overall acceptability (7.44); D (RUTS 4) predicted sensory scores: colour (7.38), flavour (7.06), sweetness (7.11), aftertaste (6.20), spreadability (7.47), smoothness (7.27) and overall acceptability (7.27); E (RUTS 5) predicted sensory scores: colour (7.25), flavour (6.71), sweetness (6.94), aftertaste (6.81), spreadability (7.00), smoothness (7.23) and overall acceptability (6.83); F (RUTS 6) predicted sensory scores: colour (6.91), flavour (6.61), sweetness (6.76), aftertaste (7.08), spreadability (7.66), smoothness (7.64) and overall acceptability (7.09).

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Conflict of Interest

The author declare conflict of interest as an inventor to a pending patent (GH/P/14/00003).

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