beverages

Article

Development and Examination of Sweet Potato Flour Fortified with Indigenous Underutilized Seasonal Vegetables

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Abstract: Developing nutrient-rich vegetable flour using locally under-utilized food crops in Africa would improve rural house-hold nutrition. This study seeks to develop nutrient-dense vegetable flour from different proportions of Sweet potato (Sp) 40–100%, Avocado pear (Avo) 10–40%, and Turkey berry (Tor) 10–40%, using completely randomized design (CRD) with 14 treatment combinations and three replications. The proximate composition, mineral composition, and functional properties were investigated on the composite flour. The results showed significant differences in all the parameters analyzed for the various composite flours. As the amount of Avo and Tor was added to the Sp, the proximate composition was enhanced except for the percentage carbohydrate, which decreased from 83.92 to 54.59 g/100 g. The mineral composition was also improved by the incorporation of Avo and Tor. Favourable functional properties were also obtained. The optimal composite flour was made up of 40% Sp, 35% Avo, and 25% Tor. The functional properties of the composite flours were better than the control (Sweet potato flour). Fortifying Sp flour with Avo and Tor is feasible and could be an easy and affordable means to improve rural nutrition, as it requires simple logistics for the ordinary rural household to produce the composite of the desired choice.

Keywords: sweet potato; fortification; avocado pear; Turkey berry; flour

1. Introduction

Reducing under-nutrition and micronutrient deficiencies is high on the agenda of many developing countries and international partners, as it affects more than one-third of the global population [1]. More importantly, micronutrient deficiencies, a cause of hidden hunger, have staggering consequences for human health and well-being, which hampers economic productivity [2]. For instance, a malnourished child cannot afford to learn properly, appears stunted, and underdeveloped. To overcome this challenge, many have resorted to bio-fortification, however, this approach is very expensive and is not accessible to the rural pro-poor mostly in Africa. There is, therefore, the need to formulate nutrient rich shelf-stable food products that are convenient and accessible to all using under-utilized crops. Also, the intensive formulation and utilization of locally available food crops as a source of energy, protein, vitamin, and minerals will help to fight the problem of under-nutrition and high postharvest losses. Sweet potato, Avocado pear, and Turkey berry are among the potentially rich under-utilized food crops of high nutritious value. Formulating and fortifying Sweet potato powder with Avocado pear and Turkey berry could provide a nutrient dense food product capable of solving malnourishment and hidden hunger among rural folks.

Sweet potato (*Ipomoea batatas*) is believed to be a super-food with excellent sources of vitamins, manganese, copper, potassium, and pantothenic acid [3]. In addition, it is also rich in dietary fiber, niacin, and phosphorus. This crop has been identified as a potential food security crop because it outranks most staple crops in vitamins, minerals, dietary fibre, and protein content [4]. Currently, the cultivation of Sweet potato is popular in most parts of Ghana because it grows well on marginal lands, requires little attention and often reserved as a farmer security crop. However, it has limited storability. Avocado pear (*Persea american*) is considered as one of the main tropical fruits, which contain fat-soluble vitamins that are less common in other fruits, besides it has a high level of protein, potassium, and unsaturated fatty acids [5]. Furthermore, it is known for its health benefits due to the compound lipidic fractions namely omega fatty acids, phytosterols, tocopherols, and squalene, which are known to reduce cholesterol and prevent cardiovascular diseases [5]. Despite all of these numerous health benefits, the consumption of Avocado is seasonal and limited due to high postharvest losses and lack of formulations from Avocado pear in Africa. Turkey berry (*Solanum torvum*) on the other hand is a wild relative of eggplant from the family *Solanaceae*. It is a neglected and under-utilized (NUS) crop, which is potentially rich in nutrients. It contains an appreciable amount of macro and micro-nutrients [6–8]. It is also reported to have health-protecting properties and uses [8,9]. The berries are considered to have tonic, analgesic, haematopoietic, diuretic, sedative, digestive, therapeutic, antiviral, and antimicrobial properties [10]. It also possesses immune-secretory, analgesic, anti-inflammatory, anti-ulcer, cardioprotective, nephron-protective, and metabolic-correction properties. More importantly, the high iron content of the fruits proves the fact that the fruits have hematinic property [11]. However, Turkey berry and Avocado pear have limited uses in fortifying foods, such as sweet potato powder, to make it rich food in curbing malnourishment.

This research, therefore, seeks to formulate and fortify sweet potato powder with Avocado pear and Turkey berry into nutrient dense vegetable flour. This will be a novel low-cost nutrient rich food. It will further solve the problem of food security challenges that affect children and rural pro-poor folks in Africa. It will also address under-nutrition and under-utilization of Sweet potato, Avocado, and Turkey berry. Furthermore, increased utilization, in turn, will lead to increased production and value addition of these vegetables. The specific objectives of this study are to determine the: suitable quantities of Avocado pear and Turkey berry that is required to fortify Sweet potato powder, the nutritional and mineral quality of the fortified Sweet potato powder, and functional characteristics of the fortified Sweet potato powder.

2. Materials and Methods

2.1. Preparation of Sweet Potato Powder

Matured and fresh Sweet potato tubers were obtained from Jukwa market in the Central region of Ghana. The samples were peeled, cut into suitable sizes, and dried in an oven drier at an average temperature of 60 °C for three days at the School of Agriculture Research laboratory, University of Cape Coast. The dried Sweet potato samples were subsequently milled into 30 μm particle size powder using a multi-purpose grinder (QE-100, Zhejiang YiLi Tool Co., Ltd., Longquan, China). The powdered samples were then bagged in an air-tight container and were stored at −4 °C till further analysis.

2.2. Preparation of Avocado Powder

Fresh Avocado fruits were obtained from Mankessim market in the Central Region of Ghana. The fruits were sorted and cleaned before cutting through with a sharp knife to remove the mesocarp. The mesocarp was subsequently cut into smaller sizes and oven dried at an average temperature of 55 °C for two days at the School of Agriculture Research laboratory, University of Cape Coast. The dried samples were milled into 30 μm particle size powder using a multi-purpose grinder (QE-100, Zhejiang YiLi Tool Co., Ltd., Longquan, China). The powdered samples were then bagged in an air-tight container and stored at −4 °C till further analysis.

2.3. Preparation of Turkey Berry Powder

Turkey berries were purchased from the Abura market in the Central Region of Ghana and were conveyed to the School of Agriculture Research laboratory, University of Cape Coast. The berries were removed from the stalk, sorted to remove all debris, and washed with distilled water. After allowing the water to drain from the berries for about 10 min, the cleaned samples were subsequently dried in an oven drier for three days at 55 °C. The dried berries were milled into 30 μm particle size powder using a multi-purpose grinder (QE-100, Zhejiang YiLi Tool Co., Ltd., Longquan, China). The powdered samples were then bagged in an air-tight container and were stored at −4 °C for further analysis.

2.4. Composite Powder Formulation

The three ingredients (Sweet potato powder, Avocado pear powder, and Turkey berry powder) were mixed into three main classes (Sweet potato: Avocado, Sweet potato: Turkey berry, and Sweet potato: Avocado pear: Turkey berry) of composite powders in proportions, as seen in Table 1 using an electric mixer at speed 5 for 10 min to achieve a uniform blend, as done by [12].

Table 1. Percentage (%) formulation of composite powder.

Name	Code	Sweet Potato (%)	Avocado Pear (%)	Turkey Berry (%)
Sp	Control	100	0	0
Sp90-Avo10	SA1	90	10	0
Sp80-Avo20	SA2	80	20	0
Sp70-Avo30	SA3	70	30	0
Sp60-Avo20	SA4	60	40	0
Sp90-Tor10	ST1	90	0	10
Sp80-Tor20	ST2	80	0	20
Sp70-Tor30	ST3	70	0	30
Sp60-Tor40	ST4	60	0	40
Sp80Avo15Tor5	SAT1	80	15	5
Sp70Avo20Tor10	SAT2	70	20	10
Sp60Avo25Tor15	SAT3	60	25	15
Sp50Avo30Tor20	SAT4	50	30	20
Sp40Avo35Tor25	SAT5	40	35	25

Sp: Sweet potato; Avo: Avocado; Tor: Turkey berry.

2.5. Proximate Composition Analysis

Physicochemical analysis such as moisture content, protein, fat, ash, pH, energy content, starch, carbohydrate, and fibre of the composite flours were carried out using the recommended methods with some few modifications. All of the analyses were carried out in triplicate.

2.5.1. Moisture Content

The moisture content was determined by the oven drying method. 5 g of the sample was oven (Gallenkamp Sanyo/Weiss, Leicestershire, UK) dried at 103 °C for 24 h until the stable weight was obtained following Association of Official Analytical Chemists (AOAC) method [13].

2.5.2. pH

The pH of the samples was measured using pH-meter according to the method used by [14], with some few modifications. Five grams (5 g) of previously weighed sample was dissolved in 25 mL distilled water and homogenized until particles were evenly suspended with mixture free of lumps. The pH was measured by a digital pH meter (PHS-3TC; Shanghai Tianda Instrument Co., Ltd., Shanghai, China), with the accuracy of 0.001.

2.5.3. Ash

The ash content was determined by weighing 10 g of the sample into a previously weighed crucible and placed into a muffle furnace at 500 °C for 4 h. The ash content was expressed as a percentage of the initial weight [11].

2.5.4. Fat

The percentage fat content of the sample was determined by the conventional soxhlet apparatus method with hexane, according to AOAC method [13]. The difference between three parallel measurements was less than 0.15% (*wt/wt*).

2.5.5. Protein

The percentage crude protein of the sample was determined by the Kjeldahl apparatus using AOAC method [13].

2.5.6. Fibre

The fibre content of the blends was determined in accordance with AOAC method [13], and the results were computed in percentage crude fibre.

2.5.7. Carbohydrate

The carbohydrate content (CA) was obtained by the difference method as used by [11,12].

2.5.8. Vitamin C (Ascorbic Acid)

Vitamin C analyses were determined according to AOAC's titrimetric method [13], and the results were computed in mg/100 g.

2.5.9. Energy Content

The energy value (EV) was derived in KJ/100 g, using the Atwater factor method described by Osborne and Voogt [15], and used by [12].

2.6. Mineral Content Analysis

The mineral content of the samples was done according to AOAC method [13], using atomic absorption spectrophotometry and flame photometer (GBC Scientific Equipment Ltd., Dandenong, Australia).

2.7. Functional Properties

Functional properties, such as bulk density, swelling capacity, water holding capacity, solubility, and foaming capacity in general are very important attributes that affect the usefulness of ingredients in food [16] and cooking time is influenced by water absorption capacity. All of these properties were determined in triplicate according to standard recommended methods.

2.7.1. Bulk Density

Bulk density of the powders was determined according to method used by other researchers [17–19] with few modifications. A measuring cylinder was weighed (W1) and the sample was filled to 20 mL mark by constant tapping until there was no further change in volume. The contents were then weighed and the difference in weight determined, and the bulk density was computed.

2.7.2. Water Absorption Capacity

Water absorption capacity was determined according to the method described by [20]. One gram (1 g) of the sample was added to 10 mL water in a pre-weighed 25 mL centrifuge tube and allowed to stand at room temperature (29 °C) for 1 h. The suspension was centrifuged at 500 rpm for 30 min. The volume of water on the sediment was measured and the water absorbed is expressed as percentage water absorption based on the original weight of sample.

2.7.3. Foaming Capacity

Two gram (2 g) of the sample was added to 50 mL distilled water at 30 °C in a 100 mL measuring cylinder. The suspension was properly mixed after shaking for 4 min to foam and the volume of the foam was recorded after 30 s. Foaming capacity was expressed as a percentage increase in volume as done by others [17,21].

2.7.4. Swelling Power

This was determined according to the method used by other authors [17,22]. One gram (1 g) of the sample was mixed with 10 mL distilled water in a centrifuge tube. This was heated at 85 °C for 30 min with continuous shaking of the tube. The suspension was then centrifuged for 15 min at 1000 rpm and the supernatant was decanted. The weight of the paste was recorded and the swelling capacity of the sample was computed.

2.7.5. Solubility

The solubility property was determined in the same way as swelling capacity except that, in-addition, the supernatant was evaporated and the residue was re-weighed.

2.8. Statistical Analysis

A completely Randomized Design (CRD) was used with 14 treatment combinations (different formulations) and replicated three times. The different formulations were Sweet potato (Sp) 40–100%, Avocado pear (Avo) 10–40%, and Turkey berry (Tor) 10–40%. The effect of the factors on physicochemical, mineral elements, and functional properties were determined and analyzed using Analysis of Variance (ANOVA) method and least significance difference (LSD) between the means of measured properties were determined by Fisher's methods at $p < 0.05$ in Minitab 16 programme for windows.

3. Results and Discussion

3.1. Initial Nutritional Properties

The three main ingredients were analyzed for their initial nutritional properties, as shown in Table 2. These results showed that each individual vegetable has a unique nutritional quality and incorporating them to form composite flour could provide balance flour with high potential for reducing mal-nutrition in West Africa.

Table 2. Proximate, mineral, Vitamin C, pH, and Energy value of the composite flour.

Sample	Physicochemical Properties of the Raw Materials (g/100 g)								
	Mc	pH	Ash	Protein	Fat	Fibre	COH	Ev (kcal)	Vit C (mg)
Sp	8.36	5.52	2.19	2.87	0.76	3.02	82.80	349.52	3.32
Avo	12.24	5.70	6.83	11.82	37.10	9.32	22.69	471.94	1.36
Tor	8.16	5.84	5.92	2.57	4.80	11.13	67.42	323.16	2.13

Sample	Mineral/Elemental Properties of the Raw Materials (mg/100 g)							
	Fe	Ca	P	K	Mg	Na	Cu	Zn
Sp	3.82	174.44.	56.84	811.21	112.12	46.51	0.815	3.255
Avo	4.23	115.27	145.54	1264.44	115.56	58.14	0.723	1.176
Tor	6.98	113.61	263.92	1542.47	2.293	95.35	0.949	5.710

Where: Sp = Sweet potato; Avo = Avocado pear; Tor = Turkey berry; Ev = Energy value; Mc = Moisture content; and COH = Carbohydrate.

3.2. Proximate, Vitamin C, pH and Energy Value of the Composite Flour

The proximate, vitamin C, pH, and energy value of the Sweet potato flour and their composite blends are shown in Table 3. For Sweet potato flour and the composite blends, the moisture, pH, ash, protein, fat, fibre, carbohydrate, vitamin C, and energy value ranged from 10.31–8.36%, 6.0–5.52, 3.75–2.19%, 8.14–2.08 g/100 g, 16.42–0.76 g/100 g, 13.47–3.01 g/100 g, 83.92–54.59 g/100 g, 0.260–0.034 g/100 g, and 412.6–321.4 kcal, respectively. There were significant differences ($p < 0.05$) among most of the samples.

The moisture content of the samples was within the range favourable for effective flour storage with no risk of microbial contamination. The moisture content of flours below 14% can resist microbial development therefore the samples would be shelf-stable [23]. Also, the range obtained was not different from those given by other researchers [12].

The pH values for all the samples were within the acceptable level for flours and were similar to the ones observed by Sanoussi and co-workers [24] for similar flours. Furthermore, the pH of SA3, SA4, ST4, SAT4, and SAT5 were consistent with pH recommended for active amylase activity in some cereal flours at the optimal cooking temperature [24,25].

Ash content of the samples increased as the amount of Avocado pear was added to Sweet potato flour to form composite blends and this was the same for adding Turkey berry to Sweet potato. This phenomenon could be attributed to Avocado pear and Turkey berry being good sources of minerals. The ranges found were within the limits obtained for similar flour [26].

Protein content in the Sweet potato flour was below 3% and this was consistent with other findings [24]. This lower level of protein in Sweet potato flour is expected as Sweet potato has low protein content. However, the protein content of the composite samples; SA2, SA3, SA4, SAT1, SAT2, SAT3, and SAT5 were above the upper limit (5.5%) of protein per 100 kcal recommended by Food and Agriculture Organization (FAO) and World Health Organization (WHO) [27]. This revealed that incorporating Avocado pear and Turkey berry into Sweet potato flour could increase the protein content among others.

Similarly, the fat of the same samples (SA4, SA4 & SAT1-SAT5) was above the minimum value of 6%, as recommended by FAO and WHO [27]. This further supports the incorporation of Sweet potato flour with Avocado pear. It is known that fat content has the largest amount of food energy (9 kcal/g), and the contribution of fat content in this composite flour would determine its quality as flour for young adults with high energy requirement.

Fibre is one of the most important nutritional components of flour product, it is known to improve laxation, lower blood glucose, and cholesterol concentrations, and decreases the risk of heart disease by binding with cholesterol and preventing it from being absorbed by the body [28]. The incorporation of Avocado pear/Turkey berry showed a positive influence on the fibre content, as seen in Table 3. These values were higher than those that were reported by others for blends of Sweet potato and wheat flour [29].

The carbohydrate content of the composite flour decreased as Avocado and or Turkey berry was added. This phenomenon was expected due to the low level of carbohydrate for Sweet potato and Turkey berry. However, the carbohydrate content of SA1, SA2, ST1, ST2, and ST3 were within the range recorded by other authors [29]. The higher values of some physicochemical properties that were recorded in the blends were due to the substitution effects for Avocado pear and Turkey berry. However, the decrease in carbohydrate could be explained that, the dilution factor of Avocado pear and Turkey berry contains lower carbohydrate composition.

More so, vitamin C content was found to increase when Avocado and Turkey berry was incorporated into Sweet potato flour. This phenomenon was expected, as Avocado and Turkey berry has comparatively high levels of vitamin C than Sweet potato.

On the other hand, the energy value of the samples were increasing for Sweet potato flour incorporated with Avocado pear, while it decreased for Sweet potato flour incorporated with Turkey berry. This could be due to the fact that energy value was influenced by the proportion of fat, protein and carbohydrate; and that, Avocado pear had comparatively higher fat and protein content than Turkey berry hence a higher energy value. The energy value range for Sweet potato incorporated with: Avocado pear, Turkey berry, and Avocado pear + Turkey berry recorded ranges between 412.6 to 362.9 kcal/100 g, 350.1 to 321.4 kcal/100 g, and 380.2 to 369.0 kcal/100 g, respectively. These ranges were similar to the value obtained for Sweet potato flour incorporated with Soy bean flour [24,30]. Furthermore, the composite flour provides low energy as less than 400 kcal/100 g energy gives about 17.30% of the recommended daily energy intake for 70 kg person [12], while SA4, SAT5 and ST1 will also provide 26%, 24%, and 22% of recommended dietary intake for children aged 9–13 years [28].

Table 3. Proximate, Vitamin C, pH, and Energy value of the composite flour.

Sample	Mc (%)	pH	Proximate Composition (g/100 g)						E. Value (Kcal)
			Ash	Protein	Fat	Fibre	CHO	Vit. C	
Control	8.36g	5.52k	2.19k	2.08h	0.76m	3.01k	83.92a	0.034l	362.9h
SA1	8.82f	5.93b	2.85i	3.56g	4.88h	3.68j	77.20c	0.041k	375.0e
SA2	8.80f	5.95a	2.93h	5.56e	8.55g	5.58h	70.88f	0.048j	382.8c
SA3	8.36g	6.00ab	3.02fg	6.62cd	11.51d	4.50i	66.97g	0.051j	398.0b
SA4	8.87f	5.88c	3.37d	8.14a	16.42a	5.94gh	56.48j	0.066h	412.6a
ST1	9.10e	5.76d	2.96gh	2.37h	1.17l	6.29fg	78.86b	0.093g	350.1i
ST2	9.12e	5.70f	3.07f	3.41g	1.70k	10.01d	73.09d	0.122e	333.3j
ST3	9.18e	5.62i	3.45c	4.73f	2.16j	11.20b	70.47f	0.157d	329.8k
ST4	9.63c	5.59j	3.50c	5.37e	2.35i	13.47a	66.67gh	0.178c	321.4l
SAT1	9.12e	5.74e	2.44j	5.65e	6.41g	6.67f	72.32e	0.058i	369.6f
SAT2	9.75b	5.75d	2.96gh	6.36d	8.77f	8.61e	66.13h	0.097g	369.0fg
SAT3	9.52d	5.65h	3.26e	6.82c	10.53e	10.66c	61.20i	0.110f	366.9g
SAT4	9.71bc	5.67g	3.60b	7.33b	13.17c	11.18b	57.15k	0.220b	375.2e
SAT5	10.31a	5.61i	3.75a	7.42b	14.69b	11.47b	54.59l	0.260a	380.2d

Values with different letters within a column are significantly different ($p < 0.05$).

3.3. Elemental Properties

As seen in Table 4, there were significant differences in the mineral composition of the various samples. Generally, the mineral elements were higher in the composite samples than the main Sweet potato flour. This was expected as the Avocado pear and Turkey berry are known to be rich in minerals and that was the reason for using them for the fortification. Specifically, the three most common forms of micronutrient malnutrition are iron, vitamin A, and iodine deficiency. However, of the three, iron deficiency is the most prevalent [1]. The high iron content of most of the composite flour, therefore, could be very useful for overcoming rural hidden hunger that is caused by iron deficiency. This could further reduce morbidity and mortality. The potassium and phosphorus content of the composite flour with respect to the control was higher, and this increased as the percentage addition of Turkey berry increased, a similar phenomenon was observed for copper and magnesium. Generally, the amounts of minerals in the composite flours could meet 45–112% of the recommended dietary intake.

Table 4. Mineral composition of the formulated composite powder (mg/100 g).

Samples	Fe	Ca	P	K	Na	Mg	Zn	Cu
Control	3.89k	108.6bcd	328.7j	8111e	581.4cd	112.24c	32.55g	818.3h
SA1	4.74J	90.5f	657.1h	8971cd	503.9ef	113.29c	105.30cd	888.8e
SA2	4.82i	97.8bcdef	673.7h	9125cd	503.9ef	135.11bc	116.56b	858.3fg
SA3	5.42fg	85.6f	569.3i	9268cd	593.0bcd	141.96c	106.81cd	840.9gh
SA4	7.16a	109.1bcd	1058.4e	9967b	593.0bcd	136.90bc	107.36cd	929.6d
ST1	5.82d	91.3ef	722.6g	8877d	461.2f	159.80ab	83.58f	845.1gh
ST2	5.54ef	110.6bc	995.7f	9354c	503.9ef	149.40ab	95.42e	864.4fg
ST3	5.60e	141.2a	1204.2c	1001.9b	542.6de	116.70c	108.78c	883.3ef
ST4	5.28gh	110.9b	1309.4b	1095.7a	701.9a	114.4c	94.08e	788.8l
SAT1	5.26h	92.73def	713.8g	8951cd	474.8f	120.0c	86.55f	886.7e
SAT2	5.76d	94.27cdef	980.3f	9803 b	593.0bcd	161.6ab	92.34e	956.9bc
SAT3	5.20h	84.92f	1119.8d	9969b	608.7bc	167.0 a	104.15d	975.6ab
SAT4	6.79b	113.72b	1312.7b	10,694a	651.2ab	159.7ab	93.94e	935.2d
SAT5	6.14c	107.67bcde	1383.9a	10,752a	699.8a	160.7ab	127.80a	984.5a

Values with different letters within a column are significantly different ($p < 0.05$).

3.4. Functional Properties

The functional properties of the Sweet potato flour fortified with Avocado pear and Turkey berry powder were evaluated and results are shown in (Table 5). The Swelling capacity (SC), Bulk density (Bk), Formability (Fb), Water holding capacity (WHC), and Solubility (Sb) of the samples ranged from 4.5 to 3.2, 0.710 to 0.454, 17.3 to 4.7, 196.78 to 142.46, and 4.15 to 0.07, respectively.

The statistical analysis of the data showed that there were some significant differences among the different composite flours at $p < 0.05$. SA4 and ST1 showed the highest swelling capacity, while control was the lowest. ST1 had the highest bulk density, while Control was the lowest. However, the ranges were found to be below the bulk density of other different flours [31].

Bk depends on dry matter content and particle size distribution and normally, a high bulk density of flour is suitable for use in food preparation [31]. Control sample and SA1 had the highest foaming capacity, while SAT3 had the lowest. Fb is very useful for bakery products during and after processing, this affects the flexibility of protein molecules, which may decrease the surface tension of water [32,33]. Sample SAT4 had the highest WHC while ST1 was the lowest. WHC is an essential functional property of protein that depends on pore size and the charges on the protein molecules [32].

Furthermore, a higher WHC determines the hydrophilic nature and the high bonding of the protein molecules [32]. WHC above 149 is considered to favourable for the preparation of viscous foods [32], hence, samples; SA1, SAT4, ST4, SAT3, SAT4, and SAT5 were favourable. Control samples had the highest percentage Sb, while SAT3 was the lowest. The solubility gives the evidence of internal interaction of the flour and indicates the degree of dispersion of granules after cooking [34].

The decrease in Sb observed in this study was similar to observation by [12]. This decrease could be attributed to the leaching out of amylose during the process of swelling.

The SC was within the range observed by others [12,17], with the highest being SA4 and ST1. This means that, the samples had more starch to imbibe water and swell compare to others as the swelling power measures the ability of starch to imbibe water and the extent by which the granule swells [12].

Table 5. Functional properties of the formulated composite powder.

Sample	Swelling Power	Bulk Density g/cm^3	% Foamability	* % WHC	Solubility (%)
Control	3.2g	0.4538k	17.3a	193.42b	4.153a
SA1	3.5fg	0.6500d	17.3a	196.78a	1.005f
SA2	3.8cdef	0.5570h	12.7c	144.23fg	0.557j
SA3	4.0bcde	0.6210g	13.3bc	144.23ef	0.981f
SA4	4.5a	0.6400e	14.0b	157.19cd	0.883g
ST1	4.5a	0.7100a	17.3a	142.46i	0.727i
ST2	3.7def	0.6510d	10.0d	143.10gh	1.032e
ST3	3.6efg	0.7060a	8.7e	144.30fg	1.219b
ST4	3.5fg	0.6940b	10.7d	146.37de	0.900g
SAT1	4.1abcd	0.6700c	6.0g	196.40i	0.835h
SAT2	4.2abc	0.6190g	7.3f	149.38fg	1.180c
SAT3	4.2abc	0.6310f	4.7h	152.40c	0.073k
SAT4	4.3ab	0.4900j	8.7e	195.93a	0.892g
SAT5	4.3ab	0.5160i	7.3f	193.33b	1.135d

Values with different letters within a column are significantly different ($p < 0.05$); * % WHC = Percentage water holding capacity.

4. Conclusions

Formulating nutrient-rich flour using locally under-utilized food crop would help in meeting the nutritional needs in Africa. The optimal composite flour was found to be 40% Sweet potato, 35% Avocado pear, and 25% Turkey berry. These findings showed that; composite flours made from Sweet potato, Avocado pear, and Turkey berries had an appreciable amount of nutrients and make the developed composite flour an ideal flour product for people of different ages. The utilization of Sweet potato flour fortified with Avocado pear and Turkey berry could further improve rural nutrition as it is easy to make in most households.

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Author Contributions: Ernest Teye conceived and designed the experiments; Francis Padi Lamptey and Robert Agbemafle performed the experiments and analyzed the data; Ernest Teye contributed reagents/materials/analysis tools and wrote the paper.

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