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Diversity in Nutrient Content and Consumer Preferences of Sensory Attributes of Peanut (*Arachis hypogaea* L.) Varieties in Ugandan Agroecosystems

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Abstract: The cultivated peanut (*Arachis hypogaea* L.) is one of the most widely consumed legumes globally due to its nutrient content, taste, and affordability. Nutrient composition and consumer preference were determined for twenty local farmer (landrace) and commercial peanut varieties grown in the Nakaseke and Nakasongola districts of the central wooded savanna of Uganda through sensory and laboratory evaluation. Significant differences in nutrient content ($p < 0.05$) among peanut varieties were found within and across sites. A significant relationship between nutrient content and consumer preference for varieties within and across sites was also realized (Wilk's lambda = 0.05, $p = 0.00$). The differences in nutrient content influenced key organoleptic characteristics, including taste, crunchiness, appearance, and soup aroma, which contributed to why consumers may prefer certain varieties to others. Gender differences in variety selection were significantly related to consumer preference for the crunchiness of roasted peanut varieties ($F = 5.7$, $p = 0.016$). The results imply that selecting different varieties of peanuts enables consumers to receive different nutrient amounts, while experiencing variety uniqueness. The promotion of peanut intraspecific diversity is crucial for improved nutrition, organoleptic appreciation and the livelihood of those engaged in peanut value chains, especially for the actors who specialize in different peanut products. The conservation of peanut diversity will ensure that the present and future generations benefit from the nutritional content and organoleptic enjoyment that is linked to unique peanut varieties.

Keywords: genetic diversity; sensory evaluation; farmer varieties; landraces; nutritional diversity; groundnut; gender; organoleptic

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1. Introduction

The simplification of agricultural production systems from diversified cropping systems to uniform cereal-based systems has contributed to reduced diet diversity, resulting in increased nutrient deficiencies, particularly in developing countries [1–4]. In sub-Saharan Africa, nutritional deficiencies are still among the major causes of premature deaths, infectious diseases, and physical and mental growth retardation in children [5,6]. Of particular concern are micronutrient deficiencies, which are less related to general food shortages than to low dietary quality and poor diet diversity [7,8]. Smallholder farmers typically consume a sizeable part of what they produce at home. Increasing diversity in small holder farmers' fields provides an opportunity to improve dietary diversity and nutrition [9–13].

The cultivated peanut (*Arachis hypogaea* L.), often referred to as groundnut, is an important oil seed and cash crop worldwide. It is one of the most widely consumed legumes globally due to its nutrient content, taste, and affordability. It is protein and energy-rich and has been utilized worldwide to address nutritional needs. In many countries, peanut seeds provide a significant nutritious contribution to the diet due to their rich protein, lipid, and fatty acid content [14], and in sub-Saharan African countries [15], due to the high nutrient content of peanuts, they have been used to combat malnutrition in most developing countries [16]. Improved knowledge of the nutritional chemistry of peanuts has enabled improved peanut products within the food industry [14].

The peanut is the second most important food legume in Uganda after beans (*Phaseolus vulgaris* L.) [17]. It is a very popular crop, especially in the eastern and northern regions of the country where it has become part of the peoples' culture [18]. According to Okello and colleagues [19], peanut is an important nutritional supplement to the mainly cereal diets of maize, millet and sorghum of many Ugandans, and is also a significant source of income that contributes significantly to livelihoods and food security. The multiple uses of peanut make it an excellent cash crop for domestic markets as well as for foreign trade, and it is highly valued on the Uganda domestic market and its export market has been flourishing in recent years [15]. According to Mugisa and colleagues [20], peanut varieties grown by farmers in Uganda include the Serenut series (high yielding commercial peanut varieties), specifically Serenut 1, 2, 3 and 4 (34%), and local farmer varieties, mainly: Red beauty (21%) and Erudurudu (16%), Igola, Etesot, Egoromoit, Kabonge and Omgwere. Okello and colleagues [15] revealed that research efforts had resulted in the release of 14 improved varieties, and this gives some picture of the intraspecific diversity of peanut in Uganda.

The release of high yielding varieties resistant to most important diseases (e.g., rosette virus) has resulted in a significant increase in peanut productivity, but the adoption rates are still rather low. According to Jelliffe et al. [21], this is linked to the decrease in the yielding capacity over time of the improved varieties to levels below that of the landraces, due to limited access to quality seeds and to mismanagement of the seeds, which are saved and replanted for longer periods than recommended.

Local farmer peanut varieties (landraces) continue to represent the most important seed source for planting materials in Uganda [22], yet, little is known regarding their nutritional composition. Despite the availability of peanut diversity in the country, the crop is not cultivated in all the regions where conditions are conducive for peanut growth [20]. Musalima and colleagues [23] profiled fatty acid composition in Serenuts only, and Achola and colleagues [24] analyzed fatty acids in the same Serenuts that are released varieties. However, little attention has been given to understanding the variation in nutrient content among local and improved varieties, and how this nutrient content relates to utilization and consumer preference. Nor have many studies compared variation in nutritional content of the same varieties grown under different agroecological conditions. The specific objectives of the study, therefore, were to determine the variability of nutrient content and organoleptic characteristics of twenty varieties of peanut consisting of both farmer varieties (landraces) and improved varieties, in two sites, and to assess the relationship between the nutrient content and consumer preference for organoleptic characteristics, including gender differences. In addition, this study examined farmers' selection criteria critical to promoting the production and adoption of diverse nutrient rich varieties, and the development of diverse nutrient rich peanut products.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Central Wooded Savanna ecological zone of Uganda, in the Nakaseke (0°43′29″ N, 32° 54′04″ E) and Nakasongola (1°18′32″ N, 32° 27′23″ E) districts (Figure 1). In Nakasongola, the mean daily maximum temperature is 30 °C. Rainfall ranges between 500 to 1000 mm per annum and there are two rainy seasons. The vegetation in the study site mainly comprises three types, depending on the extent of anthropogenic activities/disturbance on specific ranch sites. The three vegetation cover types include dense vegetation cover (>50% basal cover), sparse vegetation cover (25 to 50% basal cover) and bare grassland. The area is characterized by prolonged droughts and floods due to the changing rainfall pattern [25]. Hitherto dominated by livestock grazing, the area is increasingly changing in land use, with crop farming, especially for maize production, becoming common. Annual daily temperatures in the two districts range from 18 to 35 °C. The altitudinal range is 600–1160 masl.

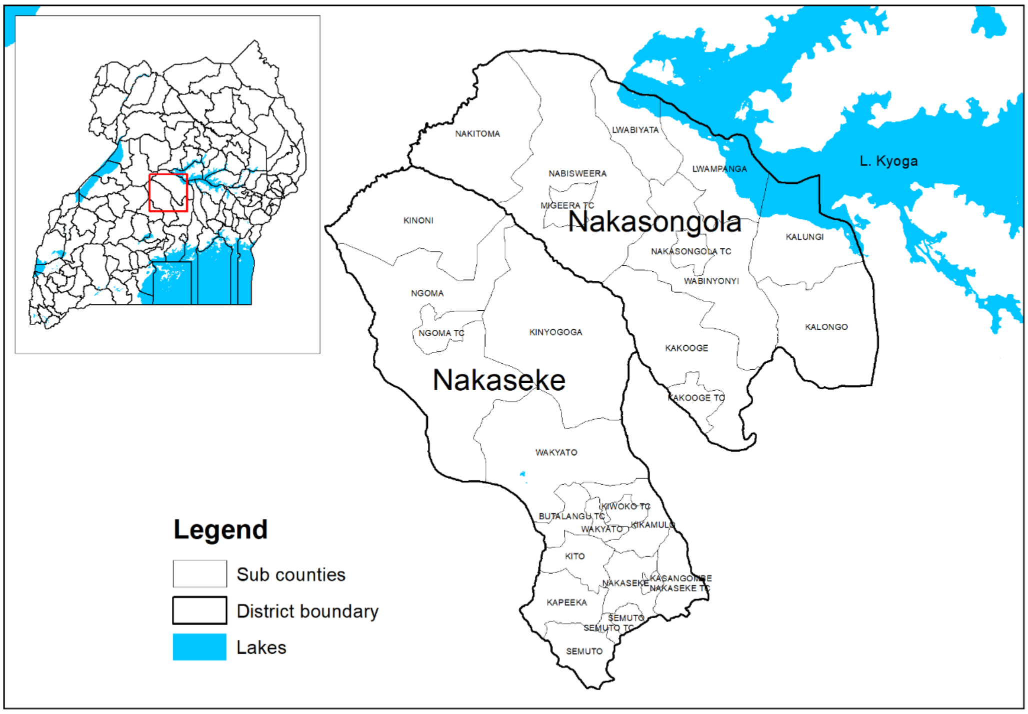

Figure 1. Map of Uganda showing the location of Nakaseke and Nakasongola Districts.

The Nakaseke site has traditionally been described as the coffee–banana farming system. This area has an altitudinal range of 1086–1280 masl, a mean annual rainfall of up to 1100 mm and temperatures ranging from 16 to 30 °C. Bi-modal rainfall distribution characterizes the two districts, with the first rainy season extending from March to June, while the second rainy season starts in late August or early September to November–December [26]. The main rain season occurs from March–April to June–July. A long dry season occurs from December to February, while a short spell comes around July–August.

2.2. Sample Collection and Preparation

Shelled dry clean seeds of peanut varieties grown by farmers in the Nakasongola and Nakaseke districts were collected and bulked in a Nakaseke community seedbank. Seeds equivalent to 0.5 kg of each variety were collected from 120 (60 from each site) peanut farmers randomly selected from eight villages where the Agrobiodiversity and Restoration project was implemented. Seeds equivalent to 30 kg of each variety were mixed up thoroughly and put in a big container. Care was taken not to mix the seeds from Nakaseke with those from Nakasongola and to keep varieties separate. In all, there were forty containers of shelled seeds for twenty varieties, from which samples were collected. Seeds were handpicked from four different parts of the container to make a 4 kg sample for each variety, for each site, which was transported in polyethene bags to the laboratory for nutrient content testing. The rest of the seeds, separated by variety and site, were kept for the sensory evaluation. In the laboratory, the seeds were converted into powder using a grinder.

2.3. Proximate Composition

The moisture content of the flours was determined using the standard Air Oven Method [27] Method No. 925.10 by means of a hot box oven. Protein content was determined based on the standard Kjeldahl method No.960.52 [28] using a Kjeltec machine. Oil content was determined using Method No. 920.39C [28] using a soxhlet machine. Ash was determined by the direct heating method in a muffle furnace, as described by the Association of Analytical Chemists [29].

2.4. Mineral Analysis Procedure

All the reagents used for analysis were of the highest commercially available purity grade. The mqH20, obtained from a Milli-Q Plus water purification system (Merck Millipore, Victoria,, Australia), was employed to prepare all standard and sample solutions. Trace Select®, for trace analysis, ≥69% (T) HNO_3 (Sigma Alderich, New South Wales, Australia), and EMSURE ISO-H_2O_2 30% (PerhydrolR) for analysis (Merck, Dermstadt, Germany) were used for sample dissolution. Mono-elemental, high-purity grade 1000 mg L-1 stock 2% HNO_3 solutions were purchased from Merck (Australia) for analysis of the following elements: Calcium (Ca), Iron (Fe), Potassium (K), Magnesium (Mg), Phosphorus (P), and Zinc (Zn). The purity of the (MPAES) plasma torch argon was greater than 99.99%.

Sample digestion was performed according to [30]. Given weights (approx. 0.3 g) of oven dried (Gallenkamp. London, England) materials were weighed by analytical balance (Mettler Toledo, Greifensee, Switzerland) into 50 mL polypropylene (PP) tubes with High density Polyethylene (HDPE) screw caps (cat # 227261, Greiner Bio-One, Frickenhausen, Germany). Maximum sample mass did not exceed 0.35 g as pressure built-up during initial heating risks could rupture the PP tubes and cause samples to dry out during digestion. Method blanks (MB) with no added plant material were also treated in the same manner. Digestion was initiated by adding 2 mL HNO_3 (Sigma Alderich, New South Wales, Australia) and 0.5 mL H_2O_2 (Merck, Dermstadt, Germany) using calibrated Dispensette® bottle top dispensers. The caps were hand-tightened and the tubes vortexed (Vortex 2 genie, Scientific Industries, USA) to ensure the entire sample was wetted. The samples were pre-digested overnight at room temperature (20–22 °C). The tubes were vortexed (Vortex 2 genie, Scientific Industries, Bohemia, NY, USA) again before incubation in a DigiPREP digestion block system (Perkin-Elmer, MediTec Park, Singapore) at 80 °C for 30 min. The pressure built up during the 30 min incubation in the tube was released by loosening each cap sufficiently. The tubes were immediately retightened firmly and replaced in the digestion block. The temperature of the DigiPREP digestion block system (Perkin-Elmer, MediTec Park, Singapore) was raised to 125 °C and samples were incubated for 120 min. No further sample handling took place until the program was finished. The digested samples were removed from the digestion block and allowed to cool to room temperature. Samples were then made up to final volume in two stages to allow for the cooling of diluted acid. Initially, approximately 22 mL of mqH2O from a Dispensette® bottle-top dispenser was added. Then, water was added to make the total sample volume of 25 mL using a fine tip HDPE wash bottle. The caps were sealed and the samples agitated by an orbital mixer (Ratek Instruments, Bolonia, Victoria Australia) at 300 rpm for 5 min. Undissolved material (silicates) was allowed to settle for at least 60 min. Settled sample extracts were decanted into 15 mL PP tubes with HDPE screw caps (# 227261, Greiner Bio-One, Frickenhausen, Germany). Settled sample extracts were filtered into clean 15 mL PP tubes using 0.45 µm Millex® HV disposable syringe filters (Millipore®, Darmstadt, Germany) to ensure the removal of particulates. Tubes were stored at room temperature and immediately analyzed by Microwave Plasma Atomic Emission Spectroscopy (MP-AES) (Agilent, Mulgrave Victoria, Australia).

2.5. Sensory Evaluation

An evaluation panel of 60 members was established and consisted of farmers from Nakaseke (N = 30) and Nakasongola (N = 30) from the four villages per site where the

Agrobiodiversity restoration project was implemented. The farmers were recruited according to the following criteria: age between 18 and 65 years; nonsmoking; without food allergies; grow peanuts and who eat peanuts in roasted and sauce/soup form. Panelists were selected, using a randomly stratified design, to ensure geographic representation across the target villages, as was performed in Mulumba et al. [31]. Consensus training as explained by Lawless and Heymann [32] was conducted. The preparation of samples and the sensory evaluation of organoleptic characteristics were supervised by scientists. Roasting was performed by putting 1 kg of peanut seeds in a saucepan on a fire and cooking without water, to a stage when the inside of the seeds turned light brown and the seed testa could easily peel off, as is always done by the farmers. Each variety was roasted individually and placed in a container. All containers were arranged randomly in a straight line and assigned a number from 1 to 20. Six seeds were served on a disposable plate and given to each panelist from one container at a time. They were eaten and scored, after which the panelist rinsed their mouth with water and picked another until all the samples were tested and scored.

The cooking method of peanut sauce involved pounding 1 kg of peanut seeds into powder for each variety, mixing the powder with two liters of water to make a paste and steaming in a saucepan to make sauce; as is done and eaten by farmers. The sauce samples for the different varieties were placed randomly in containers in a straight line and marked 1 to 20. The panelists took a tablespoon full of sauce from one container at a time, ate, scored it and rinsed their mouth with water, after which they took another sample until all the samples were scored. The roasted and soup (sauce) samples were scored for color, form and shape (CFS), taste, and aroma, but crunchiness was only scored for the roasted peanut variety seeds. Each panelist was given sheets of paper on which the 9-point hedonic scale, ranging from 1 = dislike extremely to 9 = like extremely, had been typed and was used to evaluate the samples, as was performed in [33–35]. The scale was as follows: 1 = Dislike extremely; 2 = Dislike very much; 3 = Dislike moderately; 4 = Dislike slightly: 5 = Neither like or dislike; 6 = Like slightly; 7 = Like moderately; 8 = Like very much; 9 = Like extremely.

2.6. Data Analysis

The data were analyzed using Paleontological Statistics, version 3.25 (∅yvind Hammer, University of Oslo, Oslo, Norway). Means and standard deviations were calculated. Analysis of variance (ANOVA, $\alpha = 0.05$), Post-hoc Mann–Whitney pairwise test, Turkey's Post-hoc and the Univariate Correlation were performed to find significant differences among means from the chemical and sensory variables of peanut varieties. Cluster analysis (CA) was performed to obtain groups of peanut varieties within a similar range in nutrient content. The nutrient content range similarities were calculated on the basis of the Euclidean distance, and the groups of peanut varieties within a similar range were obtained using the average linkage or the unweighted pair-group method using an arithmetic average (Unweighted Pair Group Method with Arithmetic Mean-UPGMA). Coinertia analysis was performed to determine the relationship between the nutrient content of the varieties and the preference for the sensory attributes, namely roasted color, form and shape (CFS), roasted taste, roasted aroma, roasted crunchiness and soup (sauce) color, form and shape (CFS), soup taste and soup aroma according to Logiciel R version 2.8.1 (22 December 2008)—course6.rnw—Page 5/11—Compil'e le 1 May 2009 Maintenance: S. Penel, URL: http://pbil.univ-lyon1.fr/R/pdf/course6.pdf (accessed on 4 January 2021). The relationships were then discerned using Univariate Correlation.

3. Results

3.1. Subsection

The mean nutrient content of peanut varieties from the two sites is presented in (Tables 1 and 2). The varieties were significantly different ($p < 0.05$) in the amount of nutrients they contained. There were significant site and variety interactions in nutrient content ($p < 0.05$).

Table 1. Mean nutrient content of peanut varieties from Nakaseke site.

Variety Name	%Protein Content	%Oil Content	%Ash Content	Zn (mg/kg)	Fe (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)
Black	30.73 ± 0.90	16.20 ± 0.27	4.26 ± 0.14	15.67 ± 0.14	25.94 ± 0.22	250.58 ± 9.69	407.35 ± 88.87	85.13 ± 14.62
Dok red	40.14 ± 2.70	7.20 ± 0.22	5.05 ± 0.07	16.27 ± 0.46	43.99 ± 0.98	461.01 ± 34.34	536.66 ± 1.91	427.98 ± 27.32
Dok Tan	39.98 ± 0.09	7.43 ± 1.17	4.17 ± 0.58	17.50 ± 0.11	41.55 ± 0.74	355.55 ± 11.59	427.72 ± 98.78	338.04 ± 65.00
Egoromoit	29.66 ± 1.98	6.54 ± 0.01	4.31 ± 0.01	16.24 ± 0.61	34.78 ± 0.04	390.99 ± 14.31	487.29 ± 2.59	384.37 ± 10.04
Emoit	43.15 ± 5.12	7.54 ± 1.18	4.29 ± 0.05	19.79 ± 0.18	37.71 ± 1.22	465.90 ± 9.08	458.38 ± 38.72	362.95 ± 16.09
Garbon	42.10 ± 0.75	7.92 ± 0.18	4.38 ± 0.01	16.15 ± 0.49	32.80 ± 0.76	308.52 ± 6.02	462.69 ± 41.33	385.20 ± 27.91
India	45.54 ± 2.89	6.46 ± 0.62	3.93 ± 0.01	16.41 ± 0.82	35.58 ± 0.99	328.73 ± 15.79	491.16 ± 5.06	414.22 ± 31.63
Kabonge Red	36.62 ± 1.86	7.42 ± 1.02	3.95 ± 0.02	15.40 ± 0.35	40.57 ± 1.07	272.86 ± 1.98	438.12 ± 86.06	91.20 ± 25.33
Kabonge white	47.99 ± 5.09	7.21 ± 0.16	4.64 ± 0.00	17.83 ± 0.98	47.32 ± 0.23	481.53 ± 12.49	512.85 ± 28.97	387.81 ± 5.81
Kawanda bulk	38.05 ± 3.71	8.29 ± 0.40	5.08 ± 0.08	18.79 ± 0.94	44.96 ± 0.42	510.13 ± 3.34	447.87 ± 7.04	357.71 ± 7.23
Ogwara	48.17 ± 3.06	8.20 ± 0.48	3.86 ± 0.03	17.75 ± 0.16	34.28 ± 0.05	412.62 ± 2.32	527.20 ± 33.59	420.34 ± 16.97
Otirai	44.46 ± 2.66	7.31 ± 0.60	4.24 ± 0.03	16.45 ± 0.45	45.39 ± 1.68	375.92 ± 12.25	473.16 ± 20.22	368.61 ± 2.88
Serenut 11T	40.1 ± 0.78	6.58 ± 0.12	3.81 ± 0.01	15.00 ± 0.30	26.49 ± 0.23	256.42 ± 17.89	420.88 ± 3.56	89.33 ± 2.92
Serenut 12	28.54 ± 1.11	5.64 ± 0.29	4.33 ± 0.10	15.07 ± 0.82	26.23 ± 0.09	270.17 ± 2.28	454.01 ± 32.08	91.79 ± 7.50
Serenut 14	34.91 ± 1.91	7.34 ± 0.19	4.63 ± 0.00	16.45 ± 0.73	27.03 ± 0.38	321.10 ± 18.77	396.79 ± 21.10	79.91 ± 12.32
Serenut 5	48.78 ± 1.49	8.50 ± 0.41	4.09 ± 0.03	15.76 ± 0.55	28.92 ± 0.21	200.81 ± 11.36	508.82 ± 17.72	113.92 ± 4.21
Serenut 6	60.88 ± 1.14	7.48 ± 0.46	4.17 ± 0.11	14.85 ± 0.73	45.67 ± 0.17	482.54 ± 1.85	451.80 ± 8.84	352.52 ± 8.36
Serenut 7	42.91 ± 5.91	8.23 ± 1.25	4.27 ± 0.00	16.30 ± 0.84	29.95 ± 1.92	228.07 ± 3.37	459.87 ± 1.82	92.02 ± 0.61
Serenut 9 Tan	43.41 ± 3.47	6.56 ± 0.02	5.02 ± 0.14	14.97 ± 0.05	31.05 ± 1.22	336.93 ± 4.59	373.06 ± 65.73	302.14 ± 32.16

Table 2. Mean nutrient content of peanut varieties from Nakasongola site.

Variety Name	%Protein Content	%Oil Content	%Ash Content	Zn (mg/kg)	Fe (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)
Black	35.54 ± 2.15	8.14 ± 0.37	6.04 ± 0.36	18.60 ± 0.07	37.62 ± 0.52	282.47 ± 13.90	527.72 ± 34.50	408.40 ± 19.37
Dok red	30.73 ± 0.90	8.75 ± 0.22	4.20 ± 0.11	14.91 ± 0.28	110.70 ± 2.78	370.20 ± 5.12	522.99 ± 32.37	407.37 ± 14.63
DokTan	35.38 ± 3.89	7.63 ± 0.07	4.38 ± 0.03	12.36 ± 0.64	29.55 ± 0.93	243.91 ± 14.62	503.49 ± 61.62	333.26 ± 13.17
Egoromoit	43.90 ± 0.95	7.15 ± 0.43	4.94 ± 0.03	14.38 ± 0.95	24.05 ± 0.23	362.99 ± 22.20	475.32 ± 28.91	322.13 ± 11.48
Emoit	30.82 ± 5.16	5.69 ± 0.01	4.94 ± 0.00	14.16 ± 0.81	37.73 ± 0.77	392.19 ± 14.49	480.79 ± 61.04	360.70 ± 25.66
Erudu red	30.26 ± 0.27	8.32 ± 1.90	5.07 ± 0.06	17.44 ± 0.13	37.25 ± 1.62	354.91 ± 35.14	516.19 ± 12.41	377.51 ± 42.37
India	41.25 ± 0.88	7.19 ± 0.57	6.09 ± 0.02	14.62 ± 0.46	30.22 ± 0.66	356.27 ± 4.37	498.64 ± 71.17	323.91 ± 24.36
Kawanda Bulk	35.92 ± 2.21	6.60 ± 0.44	4.28 ± 0.06	15.68 ± 0.04	49.39 ± 1.04	381.90 ± 23.13	512.53 ± 18.01	359.17 ± 8.61
Kobonge white	28.54 ± 1.11	7.60 ± 0.48	5.03 ± 0.12	14.78 ± 0.57	47.73 ± 0.25	456.34 ± 15.75	506.89 ± 33.97	385.35 ± 17.91
Ogwara	25.73 ± 1.98	6.87 ± 0.09	3.94 ± 0.01	10.36 ± 1.51	38.69 ± 0.85	165.93 ± 18.66	423.82 ± 38.40	177.07 ± 17.15
Otirai	26.51 ± 2.45	7.96 ± 0.99	5.17 ± 0.06	13.98 ± 0.27	26.27 ± 0.16	304.05 ± 3.80	507.85 ± 55.07	367.78 ± 8.78
Serenut 11T	32.68 ± 1.15	7.71 ± 0.37	4.82 ± 0.07	21.04 ± 0.35	32.60 ± 0.51	447.05 ± 22.92	544.55 ± 12.98	384.09 ± 6.70
Serenut 14	39.93 ± 2.76	7.20 ± 0.24	4.64 ± 0.00	15.42 ± 0.41	32.25 ± 0.25	250.64 ± 20.05	511.28 ± 88.64	352.61 ± 25.22
Serenut 5	30.47 ± 1.19	8.69 ± 1.95	4.96 ± 0.00	15.70 ± 0.95	49.41 ± 2.51	374.58 ± 5.04	549.18 ± 43.30	413.06 ± 9.99
Serenut 6	26.09 ± 3.74	7.23 ± 0.55	6.72 ± 0.61	15.12 ± 0.46	32.01 ± 0.86	332.40 ± 0.76	501.81 ± 11.17	370.16 ± 3.05
Serenut 7	29.43 ± 0.66	5.75 ± 0.41	5.46 ± 0.08	14.11 ± 0.33	25.84 ± 0.91	272.18 ± 25.22	457.13 ± 28.43	334.09 ± 47.64
Serenut 9 Tan	36.63 ± 3.66	9.08 ± 0.49	5.59 ± 0.07	15.30 ± 0.40	34.12 ± 0.31	237.43 ± 34.16	478.83 ± 30.97	361.86 ± 16.45

3.1.1. Ash

A number of varieties were significantly different ($p = 0.03; 0.02$) in the ash content. The Ogwara variety had a significantly lower ash content than many of the varieties ($p = 0.02$), while Dok tan had a significantly higher content ($p = 0.02$). There were significant site and variety interactions in ash content ($p < 0.05$) for Black, Dok red, Kawanda bulk, Otirai, Serenut 11T, Serenut 5, Serenut 6 and Serenut 7. Kawanda bulk had the highest ash content in Nakaseke, followed by Dok red, Kabonge white and Serenut 14, yet Serenut 11T had the lowest ash content, followed by Ogwara, India and Kabonge red. In Nakasongola, Serenut 6 had the highest ash content, followed by Serenut 9T and Serenut 7, while Ogwara had the lowest ash content, followed by Dok red, Kawanda bulk and Dok tan. The Kawanda bulk and Dok red varieties were highest in ash content in Nakaseke, yet were among the lowest in ash content in Nakasongola. The Ogwara variety was among the lowest in ash content in both sites.

3.1.2. Protein

The protein content was only significantly different in the India and Dok tan varieties ($p = 0.03$). There were significant site and variety interactions in protein content ($p < 0.05$) for the Egoromoit, Emoit, Otirai, Serenut 5 and 7 and Ogwara varieties. Except for Egoromoit, the rest of the varieties had a higher protein content in Nakaseke than Nakasongola. Serenut 6 contained the most protein in Nakaseke, followed by Ogwara, Serenut 5 and Kabonge white, while the lowest content was in Egoromoit, Serenut 12, Black and Serenut 14. In Nakasongola, the Egoromoit variety had the highest protein amount, followed by India, Serenut 14 and Black, while Ogwara had the lowest protein amount, followed by Serenut 6 and Otirai. As was seen in the ash content, Egoromoit had the highest protein content in Nakasongola, yet it had the lowest content in Nakaseke, and it was the same case with the Ogwara variety and Serenut 14.

3.1.3. Iron

The varieties differed significantly in iron (Fe) content ($p = 0.03$). Dok red and Kawanda bulk had a significantly higher iron content than many varieties. There were significant site and variety interactions in iron content ($p < 0.05$) for the following varieties: Black, Dok red, Dok Tan, Egoromoit, Kawanda Bulk, Ogwara, Otirai, Serenut 11T, Serenut 14, Serenut 5 and Serenut 6. Kabonge white had the highest iron content in Nakaseke, followed by Serenut 6, Otirai, Kawanda bulk and Dok red, while Black had the lowest content, followed by Serenut 12, Serenut 11 and Serenut 14. Serenut 5 had the highest iron content in Nakasongola, followed by Kawanda bulk, Kabonge white and Black. Kawanda bulk was among the varieties with the highest content in the two sites, while Otirai was among the varieties with the highest content in Nakaseke, yet it had the third lowest iron content in Nakasongola.

3.1.4. Calcium

The calcium (ca) content was significantly ($p = 0.03$) different among varieties. There were significant site and variety interactions in calcium content ($p < 0.05$) for the Dok Tan, Dok red, Emoit, Kawanda bulk, Ogwara, Otirai, Serenut 11T, Serenut 14, Serenut 5 and Serenut 6 varieties. Kawanda bulk had the highest calcium content in Nakaseke, followed by Serenut 6, Kabonge white and Dok red, while Serenut 5 had the lowest, followed by Serenut 7, Black and Serenut 11T. In Nakasongola, Kabonge white had the highest calcium content, followed by Serenut 11T, Emoit and Kawanda bulk, while Ogwara had the lowest content, followed by Serenut 9T, Dok Tan and Serenut 7. Kawanda bulk and Kabonge white were among the varieties that had the highest content in the two sites, while Serenut 7 was among the varieties that had the lowest content. Serenut 11T had the second highest content of calcium in Nakasongola, yet in Nakaseke it ranked fourth in low calcium content.

3.1.5. Sodium

The Dok red variety was significantly higher in sodium content ($p = 0.03$) than most varieties. There were significant site and variety interactions in sodium content ($p < 0.05$) for these varieties: Black, Ogwara, Serenut 11T, Serenut 14, Serenut 5 and Serenut 7. Dok red had the highest sodium content in Nakaseke, followed by Ogwara, India and Kabonge white, while in Nakasongola, Serenut 5 had the highest content, followed by black, Dok red and Kabonge white. The Dok red and Kabonge white varieties were high in sodium content in both sites. Serenut 14 had the lowest sodium content in Nakaseke, followed by Black, Serenut 11T and Kabonge red, while in Nakasongola, Ogwara had the lowest content, followed by Egoromoit, India and Dok tan. Black was second highest in content for Nakasongola, yet it was second lowest in sodium content in Nakaseke, while Ogwara was second highest in content in Nakaseke, yet it was lowest in sodium content in Nakasongola.

3.1.6. Oil

The oil content was significantly higher in the Black variety ($p = 0.03$) as compared to many other varieties, and there were significant site and variety interactions in oil content ($p < 0.05$) for this variety, where the content in Nakaseke doubled the content in Nakasongola. The Black variety had the highest oil content in Nakaseke, followed by Serenut 5, Kawanda bulk, Serenut 7 and Ogwara, while in Nakasongola, Serenut 9T had the highest, followed by Dok red, Serenut 5, Serenut 10 red and Black. Black and Serenut 5 were among the five varieties with the highest oil content in the two sites. Serenut 12 had the lowest oil content in Nakaseke, followed by India, Egoromoit and Srenut 9T, while Emoit had the lowest content in Nakasongola, followed by Serenut 7, Ogwara and Kawanda bulk. Kawanda bulk, Ogwara and Serenut 7 were among those with the highest oil content in Nakaseke, yet they were among those with the lowest content in Nakasongola.

3.1.7. Zinc

The Kawanda bulk variety zinc content was significantly higher ($p = 0.03$) than that of Serenut 6 and Serenut 9T. There were significant site variety interactions in zinc content ($p < 0.05$) for Ogwara, Serenut 11T, Kawanda bulk and Black. The Emoit variety had the highest zinc content in Nakaseke, followed by Kawanda bulk, Kabonge white, Ogwara and Dok Tan, while Serenut 11T had the highest in Nakasongola, followed by Black, Erudu red, Serenut 5 and Kawanda bulk. Kawanda bulk is the only variety that was among the five varieties with the highest zinc content in both sites. Serenut 6 had the lowest zinc content in Nakaseke, followed by Serenut 9T, Serenut 11T and Serenut 12, while in Nakasongola, Ogwara had the lowest content, followed by Dok Tan, Serenut 10 red and Otirai. Ogwara and Dok tan were among the varieties with the highest zinc content in Nakaseke, yet they were among those with the lowest content in Nakasongola.

3.1.8. Magnesium

Dok red had a significantly higher content ($p = 0.03$) than many varieties. There were no significant site variety interactions for this nutrient. Dok red had the highest magnesium content in Nakaseke, followed by Ogwara, Kabonge white and Serenut 5, while Serenut 5 had the highest content in Nakasongola, followed by Serenut 11T, Black and Dok red. Dok red and Serenut 5 were the two varieties with the highest magnesium content in the two sites. Serenut 9 tan had the lowest magnesium content in Nakaseke, followed by Serenut 4, Black and Serenut 11t, while Serenut 10R had the lowest content in Nakasongola, followed by Ogwara, Serenut 7 and Egoromoit. Black was among those with the highest content in Nakasongola, yet it was among those with the lowest content in Nakaseke, while Ogwara was among those with the highest content in Nakaseke, yet it was among those with the lowest content in Nakasongola.

3.2. Variety Clustering According to the Nutrient Content

Cluster analysis (Figure 2) categorized the varieties in two major groups, where Serenut 10R (62) was alone in one group and all the other varieties were in the second group. The uniqueness of Serenut 10R lies in the fact that it had the lowest content of zinc, calcium, magnesium and protein, yet it had the highest amount of ash and the second highest amount of oil. The other sub-division was into five major groups. The group comprising India (15), Serenut 7 (34) and Serenut 14b (28) was characterized by a high content of magnesium, ash and zinc, a medium content of protein and calcium, and the lowest content of sodium. In this group, Serenut 14 stood on its own possibly because it had the highest amount of zinc and the lowest amounts of calcium and ash among the three varieties in this group. The other group comprised Kabonge red (17), Serenut 11T (26), Black (3), Serenut 12 (38) and Serenut 5 (30), and was characterized by a high calcium, magnesium, ash, oil and protein content and a medium sodium content. Serenut 5 stood on its own in this group possibly because it had the highest content of calcium, magnesium and sodium and the second highest content of oil and protein among the group members.

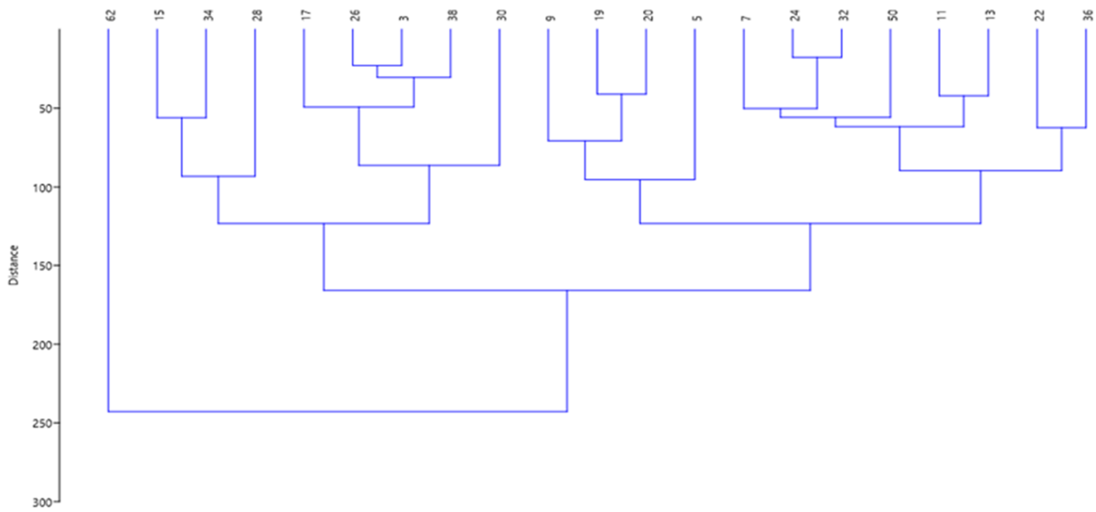

Figure 2. Dendrogram showing the hierarchical clustering variation and the distance among clusters in multivariate data space among the peanut varieties based on the calculated Euclidean coefficients using mean nutrient content (zinc, magnesium, calcium, iron, oil, protein and ash): 62 = Serenut 10R, 15 = India, 34 = Serenut 7, 28 = Serenut 14, 17 = Kabonge red, 26 = Serenut 11T, 3 = Black, 38 = Serenut 12, 30 = Serenut 5, 9 = Egoromoit, 19 = Kawanda bulk, 20 = Kabonge white, 5 = Dok red, 7 = Dok tan, 24 = Otirai, 32 = Serenut 6, 50 = Erudu red, 11 = Emoit, 13 = Gabon, 22 = Ogwara and 36 = Serenut 9T.

The group comprising Egoromoit (9), Kawanda bulk (19), Kabonge white (20) Dok red (5) and Dok tan (7) was characterized by the highest content of calcium, magnesium, sodium and a relatively high content of zinc, protein, ash and oil. Dok red stood alone possibly because it had the highest content of iron, magnesium and sodium, not only among varieties in this group but also overall. The group of Otirai (24), Serenut 6 (32) and Erudu red (50) was characterized by high calcium, iron, magnesium, sodium and ash contents and medium oil and protein contents. Erudu red stood on its own in this group possibly because it had a higher content of calcium, magnesium and oil compared to the other group members, and it had the second highest calcium and magnesium content and the third highest oil content among all the varieties. Emoit (11) and Garbon (13) were placed in their group possibly because they had a high content of zinc, sodium and protein, and a medium content of iron, calcium, magnesium, ash and oil. Ogwara (22) and Serenut 9T (36) were also grouped together possibly because they had medium contents of all the nutrients apart from calcium, which was low.

3.3. Sensory Evaluation of the Varieties

Coinertia analysis showed that the Kawanda bulk, Egoromoit, Emoit, Serenut 12 and Serenut 14 varieties had a high content of calcium, zinc and ash (see Supplementary Data Table S1). These high content levels could have contributed to them not being preferred much for soup aroma. Serenut 11, Serenut 12 and Serenut 14 had a high oil content, which could have contributed to their high preference for roasting attributes: colour, aroma, taste and crunchiness. The Black variety had the highest oil content, but this could have led to its roasting attributes not being preferred so much; however, it could have contributed to its soup taste, colour, form and shape having been preferred so much. Otirai and Serenut 9T had a high content of sodium and iron, which could have led to them not being preferred for soup colour, form and taste, but for soup aroma. India had a high content of magnesium and protein, and this could have contributed to its high preference for soup aroma.

Discerning further the above relationships, the Univariate Correlation revealed that the amount of iron, calcium and sodium in a variety significantly affected the preference for the aroma of the soup of cooked peanut varieties (p = 0.02, 0.01, 0.02, respectively). Iron content significantly affected the preference for soup taste (p = 0.02) and for soup appearance (color, form, shape) (p = 0.006) of the varieties. Magnesium and sodium content also affected the preference for soup appearance (p = 0.015, 0.02, respectively). Sodium content significantly affected the preference for the appearance of roasted peanut varieties (p = 0.02). The amount of protein, ash and oil in a variety did not significantly affect the preference for a variety. Generally, there was a significant relationship between the nutrient content and consumer preference of the varieties within and across the two sites (Wilk's lambda = 0.05, p = 0.00). The acceptability scores differed significantly for the peanut varieties across sites (p = 0.01). For roasted peanut varieties, selection was largely based on appearance, taste, and crunchiness in both sites.

There was a significant difference in preference for soup aroma in varieties across the sites (F = 6.66, p = 0.01; interaction: F = 8.8, $p = 3.21 \times 10^{-16}$), where soup aroma for the Kawanda bulk variety was liked most in both sites, while the soup aroma for the Gabon variety was most disliked in the two sites (Figure 3a,b). Serenut 7 was liked in Nakasongola but not liked in Nakaseke. There was a significant difference in preference for soup appearance (color, form and shape) in varieties across the sites (F = 4.56, p = 0.03; interaction: F = 5.7, $p = 7.52 \times 10^{-10}$), where soup appearance for the Kawanda bulk variety was liked most in both sites, while the soup appearance for Serenut 7 was most disliked in Nakaseke and Gabon in Nakasongola.

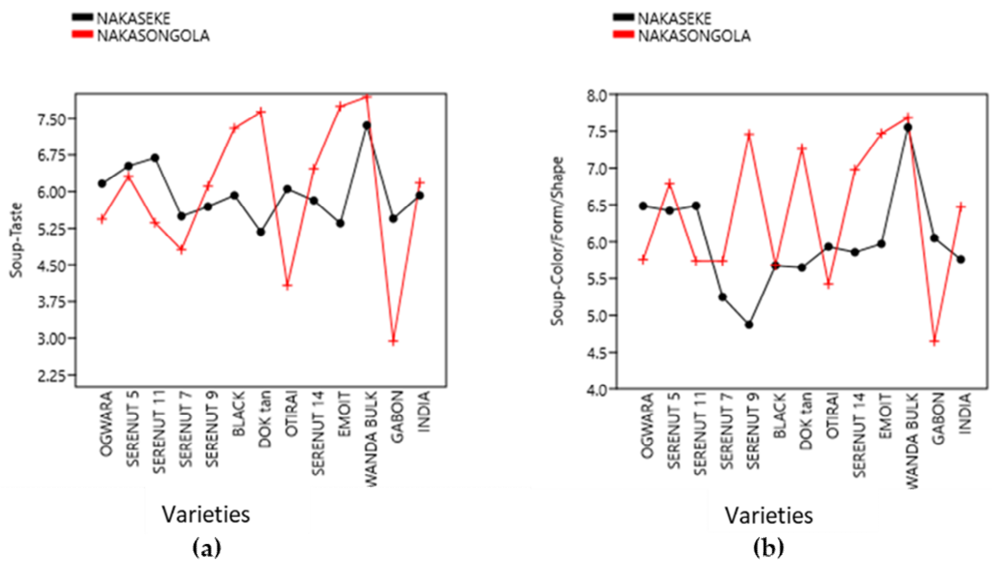

Figure 3. Graphs showing the preference for (**a**) soup taste and (**b**) soup color, form, shape (appearance) for the different varieties in Nakaseke and Nakasongola.

There was a significant difference in preference for the taste of roasted peanut varieties across sites (F = 14.6, p = 0.00; interaction: F = 20.6, $p = 1.79 \times 10^{-15}$; Figure 4a,b; see Supplementary Data—Table S2), where the taste for the Kawanda bulk variety was liked most in both sites, while the soup appearance for Serenut 7 was most disliked in Nakaseke and India in Nakasongola. There was a significant difference in preference for the aroma of roasted peanut varieties across sites (F = 17.6, $p = 2.84 \times 10^{-5}$; interaction: F = 17.5, $p = 1.70 \times 10^{-35}$), where the aroma for the Kawanda bulk variety was liked most in both sites, but in Nakasongola, Black was also liked, while the aroma for Dok Tan was most disliked in Nakaseke and India in Nakasongola.

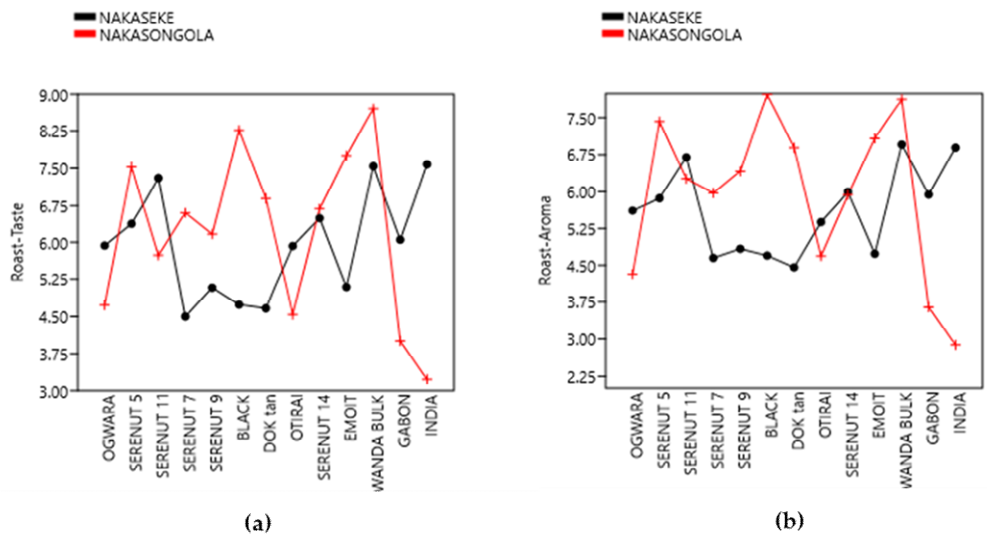

Figure 4. Graphs showing preference for the taste and aroma of roasted peanut varieties in (**a**) Nakaseke and (**b**) Nakasongola.

Gender variety interaction significantly affected the preference for the crunchiness of roasted peanuts (F = 5.7, $p = 0.016$), where Kawanda bulk, Serenut 11 and Black were the varieties liked by both men and women, while India was liked by women yet the men disliked it. A summary of the means score of the taste parameters for peanut varieties across sites is presented in Table 3 (see also Supplementary Data Table S3).

Table 3. Summary of the means score of the taste parameters for peanut varieties across sites.

Site	Nakasongola		Nakaseke	
Variable	**Roasted**	**Soup**	**Roasted**	**Soup**
Appearance	6.5 ± 2.5	6.4 ± 2.4	6.3 ± 2.3	6.0 ± 2.3
Taste	6.5 ± 2.4	6.0 ± 2.5	6.0 ± 2.4	6.1 ± 2.2
Aroma	6.2 ± 2.4	5.9 ± 2.5	5.6 ± 2.3	5.6 ± 2.3
Texture	6.4 ± 2.4	-	6.1 ± 2.2	-

4. Discussion

4.1. Nutrient Content

The varieties were significantly different ($p < 0.05$) in the amount of nutrients they contained.

These findings agree with Okello et al. [15], who noted that peanut seeds contain varying amounts of nutrients depending on the variety. According to Ren [36], variation in nutrient content and quality may depend on variety, climate, soil, harvesting practices and pest control methods, but in this study, it could mainly be attributed to variety since the other factors were the same for all varieties. It is also known that a large diversity in nutritional composition exists among different varieties of species, as well as among different environments in which plants are cultivated [37–39], and the results of this study have confirmed this.

A few varieties had a high content of some of the nutrients in both sites, while a number of the varieties could be among those with the highest content of a particular nutrient in Nakaseke and also be among those with the lowest content in Nakasongola. These trends could be attributed to the genetic differences that influence the way varieties extract nutrients from the soil, retain them in the tissues and/or convert them to other compounds. Investigating the factors behind these trends is recommended. The protein content was only significantly different in the India and Dok tan varieties ($p = 0.03$). This is close to the findings by Alhassan et al. [40], where the proximate analysis of peanut varieties resulted in significant differences in composition, but there was no significant difference in the protein content.

4.2. Site Variety Interaction in Nutrient Content

There were significant site and variety interactions in nutrient content ($p < 0.05$) for all nutrients apart from magnesium. This agrees with Iqbal et al. [41], who reported that peanut proteins sampled from peanut seeds from different geographic locations had differing protein amounts. There were significant site and variety interactions in oil content ($p < 0.05$) for the Black variety. According to Brown et al. [42] and Young [43], the peanut lipid and fatty acid composition is greatly dependent upon cultivar, seed maturity, environmental conditions and geographic location. Since this was only true for the Black variety, further studies will explain why the other varieties did not conform to the findings from these earlier studies. The fact that there was no significant site and variety interaction in magnesium content could perhaps be attributed to the soils in the two sites having had similar levels of magnesium.

4.3. Sensory Evaluation of Organoleptic Characteristics of Varieties

Carrying out a sensory evaluation provided an understanding of farmers' preferences and linked them to the nutritional value of the different peanut varieties. In order to foster famers' knowledge and take advantage of the mutual trust and social interaction among farmers, it was decided to establish an evaluation panel entirely constituted by farmers, who would then contribute to disseminate the information to neighbors and consumers, enhancing the market of the varieties.

A significant relationship was observed between nutrient content and consumer preference for organoleptic characteristics of peanut varieties within and across sites, including taste, crunchiness, appearance, and soup aroma, explaining why consumers may prefer certain varieties to others. There was a significant difference in the preference for soup aroma in varieties across sites, as well as in in the preference for the taste and aroma of roasted peanut varieties across sites. This is in conformity with findings from previous studies, which reported that roasted legumes are characterized by unique flavors which can increase their sensory appeal [44]. The differences observed in preferences for different varieties could be attributed to cultures in cooking, diets and familiarity with the varieties that vary in the sites. The differences observed in preferences also confirm that consumers are aware of varietal differences, not only for productivity but for their diverse organoleptic traits.

5. Conclusions

This is the first study in Uganda in which the nutritional content of both improved and farmer varieties of peanuts has been profiled and compared across agroecological sites. Significant differences in nutrient content among peanut varieties within and across sites, coupled with a significant relationship between nutrient content and consumer preference for varieties with specific organoleptic characteristics within and across sites, confirm that Ugandan peanut varieties contain varying amounts of nutrients, indicating that each variety may contribute to human nutrition differently. The regular consumption of peanuts has been associated with reduced risks of coronary heart disease (CVD), hypertension, inflammation, cancer, gallstones and age related cognitive decline, and has been associated with increased life expectancy. Bonku [16] attributed these benefits to the balanced nutrient composition of peanuts and the lack of trans-fat. Further research is necessary to understand the nutritional quality of proteins contained in the peanut varieties of Uganda and to explain how the site variety interaction for nutrient content would vary with location, as observed in this study.

The different amounts of nutrients in the varieties influenced their organoleptic characteristics, including taste, crunchiness, appearance, and soup aroma, which can explain why consumers enjoy different experiences from eating each variety. The improved availability of nutrient information on local and improved peanut varieties can assist peanut market chain actors to choose varieties, not only on their sensory aspects, but also on micronutrient composition, increasing their value for specialized products (e.g., sauce, butter, oil), locally, nationally, and internationally. For peanut producers, the study provides critical information on the differences in nutritional content and sensory attributes of the different varieties to support local use for special consumers, such as children, lactating mothers, pregnant women and the elderly. Key in our findings is that high nutritional and organoleptic diversity of peanut varieties in Uganda rests not on one type of variety, but is an outcome of the combined portfolio available from both local farmer and improved varieties. It is this complementarity of local and improved peanut varieties that, together, provides the diversity needed to satisfy multiple producers' and consumers' demands, with the potential to improve the earnings of both sellers and producers in internal and export markets of Uganda.

Supplementary Materials: The following are available online at https://www.mdpi.com/2071-1050/13/5/2658/s1, Table S1: Peanut Nutrient Content Data; Table S2: Peanut Cooking Time Data; Table S3: Peanut Sensory Data.

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