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Nutritional Physical and Functional Properties of Wild Cowpea (*Vigna Vexillata* (L.)) Grown in the Sahel Region

Issoufou Amadou[1,*], Abdoulaye Sankhon[2], Roukaya Abdou Souley[3], Laouali Issa Harou[3,4]

[1]Faculty of Agronomy and Environmental Sciences, Dan Dicko Dankoulodo University of Maradi, BP: 465 Niger
[2]Institute of Food Technology of Conakry, Guinea
[3]Hygiene, Food and Nutritional Sciences Research Laboratory, Faculty of Agronomy, Abdou Moumouni University of Niamey, Niger
[4]Centre Imaan de support en recherche transdisciplinaire (Imaan Research), Niamey, Niger
*Corresponding author: amadou.issoufou@uddm.edu.ne

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Abstract The underutilized crop *Vigna vexillata* (L.), is a legume related to cowpea and grown in the wild Sahel. The work aimed to contribute to the valorization of wild cowpeas for human consumption. The variety CS098 (*Vigna unguiculata*) was used as a comparison sample for nutritional, physical, and functional properties analyses. The sensory evaluation test was done by 15 semi-trained panelists. The SPSS was used to carry out the analysis of variance at the 5% significance. The results revealed that the wild variety (CS064) contains 21.89% proteins, 1.56% lipids, and 66.88% total carbohydrates, then the variety CS098 showed 25.61% proteins, 1.49±% lipids, and 62.13±% total carbohydrates. Substantial mineral contents found in the CS064 variety are calcium, magnesium, potassium, and iron with respectively 187.5, 417.04, 936.12, and 2.18 mg/100g dry matter, while CS098 accounted for 248.1, 298.1, 613.49, and 3.52 mg/100g dry matter. The water and oil absorption capacity and swelling index of the wild and control cowpea varieties grains flour are 1.58g/g, 0.68g/g, and 5.73g/g; then 1.78 g/g, 0.81 g/g, and 5.98 g/g respectively. The cooking test revealed a fairly long cooking time with the wild cowpea variety CS064 (59.28') and 46.17' for the CS098 variety. Sensory evaluation results showed broad differences in the sensory attributes. The general acceptability of the cooked cowpea using the word cloud technique revealed that the appreciation "*HighlyAcceptable*" was attributed to CS098 and the "*Acceptable*" to CS064. In conclusion, the wild cowpea variety revealed substantial nutritional values in its proximate analysis despite that is less popular than the control cowpea sample CS098. Therefore, the results might help to contribute to the promotion and consumption of V. vexillata in its grown environment and beyond.

Keywords: *Vigna vexillate, nutritional, sensory parameters, functional properties, cowpea, Sahel*

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1. Introduction

Legume seeds, particularly those of cowpea (*Vigna unguiculata*), constitute one of the staple foods of populations in the arid tropical regions of Africa. It is one of the main sources of proteins, vitamins, and minerals appreciated by consumers. Indeed, cowpeas are likely to fill the numerous protein deficits recorded in developing countries where nutritional deficiencies remain a major concern. In addition, it is increasingly consumed also in developed countries [1,2]. World production of cowpea is estimated at nearly 7 million tons/year over an area of approximately 12.7 million hectares, of which more than 80% is produced in Sub-Saharan Africa, making this region the leading cowpea producer in the world [3].

In Africa, other cowpea species appear to be interesting plants for two reasons, such as Vigna vexillate, in its present morphological variability. The presence of a covering on the leaves and stems, which allows it to protect itself against insects, is one of the morphological characteristics that distinguishes the species from *V. unguiculata* (L.) Walp. This plant could not only constitute a source of genes for improving the resistance of *V. unguiculata* against insects but it could also constitute a food plant in marginal regions with low agricultural potential. *V. vexillata* is considered a wild species with a pantropical distribution closely related to cowpea (*V. unguiculata*) and adapted to infertile soils. In addition, it is a climate-resistant plant and is reported as a source of resistance to bruchids, tolerance to abiotic stresses, and protein tubers [4]. The seeds of *V. vexillata* contain mineral elements, proteins, and lipids, especially linoleic acid and palmitic acid in significant quantities. Evaluation of morphological and nutritional traits of *V. vexillata* storage roots indicated that this species has the potential to meet future needs for food and nutritional security and further use in *V. unguiculata* breeding program [5,6].

First of all, the functional properties of the base material in food processing constituted a major challenge. Thus, cowpea is the subject of multiple uses depending on geographical areas and socio-cultural practices. These uses vary from the valorization of the leaves as livestock and even human food to the processing of the seeds. Cowpea seeds are often ground into flour, and processed into various finished products as needed. The processing of cowpea seeds, especially wild cowpea seeds, has until now been done in an artisanal manner. This development is important in alleviating nutritional deficiency in Sub-Saharan Africa where food insecurity persists. However, various parameters linked to the physical shape of *V. vexillata* seeds (color, size, hardness, etc.) and traditional practices associated with their processing and consumption lead to their underutilization by the current generation [7,8]. A couple of studies on the technological and nutritional aspects of V. unguiculata were done; on the other hand, little information is available on wild forms of cowpea grown in the Sahel. Therefore, the present work aims to determine the nutritional composition and functional properties of dried seeds of *V. vexillate* and to evaluate the acceptability of this Sahel wild cowpea.

2. Materials and Methods

2.1. Materials

The wild cowpea seeds CS064 (*Vigna vexillata*) and cowpea seeds CS098 (Vigna unguiculata) (Figure 1) are samples used in this study. The two (2) cowpea varieties were obtained from the CowpeaSquare/Maradi a McNIGHT grant project. All other chemicals are of analytical grade.

Figure 1. Seeds of wild cowpea (*V. vexillata*) (left) and cowpea CS098 (*V. unguiculata*) (right)

2.2. Methods

2.2.1. Physical Properties of Cowpea Seeds

The length and width of cowpea seeds were determined according to the method of Giami [9]. Twenty (25) seeds of each cowpea variety were measured seed by seed using a Digital caliper (Solar Wind, Taiwan. The average dimensions were calculated according to the following formulas:

$$\text{Average length} = \frac{1}{25}\sum_{i=1}^{25} L \quad (1)$$

$$\text{Average width} = \frac{1}{25}\sum_{i=1}^{25} l \quad (2)$$

The mass of 100 cowpea seeds was measured according to the method of Giami [9]. One hundred (100) healthy cowpea seeds were weighed using a KARNIK Weighing Scale (CKE 6K0.02, China).

2.2.2. Proximate Analysis of Cowpea Seeds

The proximate analysis of wild cowpea seeds CS064 (*V. vexillata*) and cowpea seeds CS098 (*Vigna unguiculata*) were analyzed by the method given by AOAC [10]; ash content (AOAC, Method no. 923.03). The moisture content was determined by drying in an oven at 105°C until a constant weight was obtained. Ash was determined by weighing the incinerated residue obtained at 525°C after 4 hrs. The ash content was estimated using an electric muffle furnace (Drawell Instrument Co., Ltd. Shanghai, China) with an ashing condition of 600°C overnight. The Crude fat was extracted by the Soxhlet method with petroleum ether. The crude protein was determined by the Micro-Kjeldahl method and using a conversion factor of N × 6.25. The carbohydrate content was estimated by subtracting the sum of the percentage of moisture, crude fat, crude protein, fiber, and ash contents from 100% [11].

2.2.3. Energetic Value

The theoretical energy value of the cowpea sample was calculated according to the method described by Merrill and Watt [12].

Energy value (Kcal) = [(% Carbohydrates x 4) + (% Protein x 4) + (% Lipid x 9)] (3)

2.2.4. Mineral Estimation

2.2.4.1. Calcium (Ca) and Magnesium (Mg)

The Ca and Mg content was determined by titrimetric, and the ash previously obtained by incineration was dissolved in 250 mL of distilled water.

A 50 mL sample was taken for the Ca assay into which two drops of Eriochrome blue (indicator) and 3 mL of NaOH solution (1N) were introduced, the mixture was titrated with a solution of EDTA 0, 02N (ethylene diamine tetra acetic acid) until it turns blue and the volume of the EDTA poured, then it is noted for the calculation of the concentration and the content of element Ca contained in the sample. Ca = ([Ca2+] * Vt)/Pe (4)

For the Mg dosage, 50 mL of the solution (ashes and distilled water) was taken, and two drops of Eriochrome black (indicator) and 4 mL of buffer solution (pH=10) were added. The mixture is dosed with EDTA (0.02N) until it turns blue, then the TH (hydrometric titer) is noted for the calculation of the Mg content estimated in the sample. Mg = ([Mg2+] * Vt)/Pe (5)

Where:

Ca: Calcium estimate (mg/100g),

[Ca2+]: Calcium ion concentration of the solution taken (moL/L),

Mg: Magnesium estimate (mg/100g),

[Mg2+]: Magnesium ion concentration of the solution taken (moL/L),

Vt: total volume of the prepared solution (mL),

Pe: test portion for ash (g)

2.2.4.2. Potassium (K) and Iron (Fe)

The ash obtained by incineration was dissolved in 100 mL of distilled water, and the K estimate of the solution was determined using a flame spectrophotometer. The standard solutions were prepared from the K concentrates (10 ppm, 5 ppm, and 1 ppm). The 100 mL of the previously prepared solution was filtered; the K dosage required a fiftieth dilution.

K = ([K+]* Vt)/Pe (6)

As for the iron estimated content was determined using a spectrophotometer (DR 3900). Twice 10 mL samples were taken (placed in a round tank with a cap) from the 100 mL solution previously prepared and filtered. The two samples are the blank (nothing has been added), and the solution to be analyzed into which a pouch of iron reagent (Ferrover) has been introduced which makes the solution turn red in the presence of iron element in the sample. The device was calibrated at 265 nm as the wavelength used for the iron content estimation. For the precision of the results, the zero of the apparatus was made with the blank, then the sample to be analyzed was introduced. After the analysis, the device displays the iron ion concentration contained in the sample, then is noted for calculation of the iron estimated element content in the cowpea sample.

Fe = ([Fe+]* Vt)/Pe (7)

Where:

K: potassium estimate (mg/100g),

[K+]: potassium ion concentration of the solution taken (moL/L),

Fe (mg/100g): the iron estimate,

[Fe+]: iron concentration of the solution taken (moL/L),

Vt: total volume of the solution prepared (ash + distilled water) (mL),

Pe : test portion for ash (g).

2.2.5. Functional Properties

2.2.5.1. Water and Oil Absorption Capacity

To determine the water absorption capacity and oil binding capacity, 1.25 g of the cowpea flour was weighed into pre-weighed 15 mL centrifuge tubes and then mixed with 10 mL of distilled water or oil. The slurry will then be centrifuged at 3,000 × g for 10 min. The water or oil released during centrifugation will be drained and the weight gain will be expressed as a percentage of the water/oil absorption capacity [13].

CAE / CAH (%) = ((Pr-Pi)/Pi) * 100 (8)

Where :

Pr: residue weight (g), Pi: initial weight (g)

2.2.5.2. Swelling Index

The swelling power of cowpea flour was determined by the modified method by Abu et al. [14]. 0.5 g of the flour was weighed into a test tube containing 10 mL of water and then vortexed for one minute. The tubes were then placed in a water bath at 90oC for 30 min, then quickly cooled with water for 30 sec and with ice cubes for 10 min. After centrifugation at 4500 × g for 10 min, the supernatant is carefully removed and the residue is weighed. The swelling index is considered as the ratio of the weight of the final residue and the weight of the initial sample.

SI = Pr/Pe (9)

with Pr=Pt-P0

SI: Swelling index; Pr: Weight of the residue after centrifugation and removal of the supernatant; P0: Weight of empty tube

2.2.5.3. Cooking Test and Seed Swelling Index

The cooking test was carried out according to the method of Balla and Baragé [2]. A hundred (100) healthy cowpea seeds were cooked in a beaker containing 200 mL of distilled water previously brought to a boil on a hot plate (KARNIK). From the 15th minute, four seeds were taken and cut in half using a razor blade. Observations on the state of cooking were noted: the presence of whitish spots inside the cotyledons means the complete non-gelatinization of the starch. Cooked seeds are easy to crush between two fingers. The check was made after every 5 minutes until complete cooking. The cooking time was noted.

The seed swelling index corresponds to the ratio between the volume of cooked seeds and that of seeds before cooking. The volume was determined using the change in the water level in a 100 mL test tube following immersion of the seeds.

2.2.6. Sensory Evaluation

The sensory evaluation of cooked cowpea seeds was carried out using a 9-point hedonic rating scale, anchored by “like extremely” to “dislike extremely” by Uwaegbute et al. [15] with little modifications. Fifteen (n=15) semi-trained academic persons serve as the sensory panel. A training session was placed before the final sensory analysis to explain the purpose of the study. The total mean values received after analyzing the final test were calculated for each sensory parameter, including color, odor, texture, taste, and 4 points for the overall acceptability of the dish.

2.2.7. Statistical Analysis

The quantitative estimation of the nutritional, physical, and functional properties of cowpeas’ varieties was carried out in triplicate and is presented in mean ± standard deviation (Mean ± SD). The standard deviation was calculated using Microsoft Excel 2016 Microsoft ©. The statistical difference was determined using SPSS version 25 Statistical software, Chicago Inc. USA, applying analysis of variance (ANOVA) at the significance of $P < 0.05$.

3. Results and Discussion

3.1. Results

Table 1 depicts the physical characteristics of the seeds of the two (2) cowpea varieties. The analysis of variance at the 5% significance level showed a significant difference between the physical parameters of the seeds.

Table 1. Physical characteristics of the seeds of the two cowpea varieties

Varieties	Weight of 100 seeds (g)	Length (mm)	Width (mm)
CS064	17.20 ± 0.46[a]	5.42 ± 0.21[a]	4.16 ± 0.39[a]
CS098	18.50 ± 0.30[b]	7.08 ± 0,37[b]	5.22 ± 0.40[b]

CS064: wild variety of cowpea, CS098: improved variety of cowpea, NB: The same letters in the same column show that there is no significant difference between the means at 5%.

It appears from the analysis of these results that the control variety (CS098) has a significantly higher weight of 100 seeds than the wild variety (CS064). As for the length and width, it is also observed that both measurements are higher with the seeds of the CS098 variety (Table 1).

The proximate composition with energy value and mineral elements of the two varieties are present in Table 2. The analysis of variance at the significance level of 5% showed that there is a significant difference between these parameters of the two (2) cowpea varieties. It appears from the analysis of these results that the moisture content of the two cowpea varieties studied is higher with the CS098 variety (7.02%). Table 2 also gives the protein content of the two varieties studied. The control variety contains more protein (25.61%) than the wild variety. As for the fat content. the difference is not significant (P > 0.05) wild cowpea contains a little fatter than the CS098 variety. Regarding the total carbohydrates of the cowpea varieties studied. the wild variety has the highest total carbohydrate content with 66.88%. As for the energy value of the cowpea studied. wild cowpea (CS064) presents the highest energy value (369.27 Kcal/l00g).

Table 2. Proximate composition of the two cowpea varieties (dry matter basis)

Varieties	Proximate composition (%)				
	Moisture	*Protein*	*Fat*	*Carbohyd rate*	*Energy value (kcal)*
CS064	6.73 ± 0.11[a]	21.89 ± 0.05[a]	1.56 ± 0.01[a]	66.88 ± 0.13[a]	369.27 ± 0.62[a]
CS098	7.02 ± 0.05[b]	25.61 ± 0.14[b]	1.49 ± 0.04[a]	62.13 ± 0.09[b]	364.48 ± 0.35[b]
	Minerals composition				
	Ash (%)	*Ca (mg/100g)*	*Mg (mg/100g)*	*K (mg/100g)*	*Fe (mg/100g)*
CS064	2.91	187.50	417.04	936.12	2.18
CS098	3.55	248.10	298.10	613.49	3.52

CS064: wild cowpea variety, CS098: improved cowpea variety. the number of repetitions n=2. and the same letters on the same column mean that there is not a significant difference between the means at the 5% threshold.

The CS098 variety (3.55%) has a higher ash content compared to that of wild cowpea. The calcium content of the two (2) cowpea varieties studied is higher with the CS098 variety (248.10mg/100g). As far as the magnesium (Mg) and potassium (K) content wild cowpea present higher Mg (417.04mg/100g) and K (936.12mg/100g), though higher iron content was found with cowpea CS098 (3.52mg) variety.

The samples of functional properties showed a significant difference at the 5% between the two (2) cowpea varieties for water adsorption capacity; however, the oil adsorption capacity and swelling index seemed to show no significant difference among the two cowpea varieties (Table 3). The cooking test revealed a fairly long cooking time with the wild cowpea variety CS064 (59.28') and 46.17' for the CS098 variety.

Table 3. Functional parameters and cooking test of cowpea varieties seeds

	Varieties	
	CS064	**CS098**
Water AC (g/g)	1.58 ± 0.03[a]	1.78 ± 0.03[b]
Oil AC (g/g)	0.68 ± 0.02[a]	0.81 ± 0.02[a]
Swelling index (g/g)	5.73 ± 0.38[a]	5.98 ± 0.44[a]
Cooking time (min)	59.28'[a]	46.17'[b]

CS064: the wild variety of cowpea. CS098: an improved variety of cowpea. AC: Absorption Capacity. Line with the same letters show that there is no significant difference between the means at the 5%.

Sensory evaluation results are presented in Figure 2 showing the appreciations attributed to the CS064 and CS098 varieties. The colors were graded 5.5 points for wild and 7 for CS098 variety. As far as the taste and odor the sample control remains higher, though the texture of CS064 was closer to that of CS098. The analysis of the results with the word cloud technique in Figure 2 on general acceptability showed that the *HighlyAcceptable* rating was awarded by the panelists to cowpea CS098 and the *Acceptable* rating to CS064 variety.

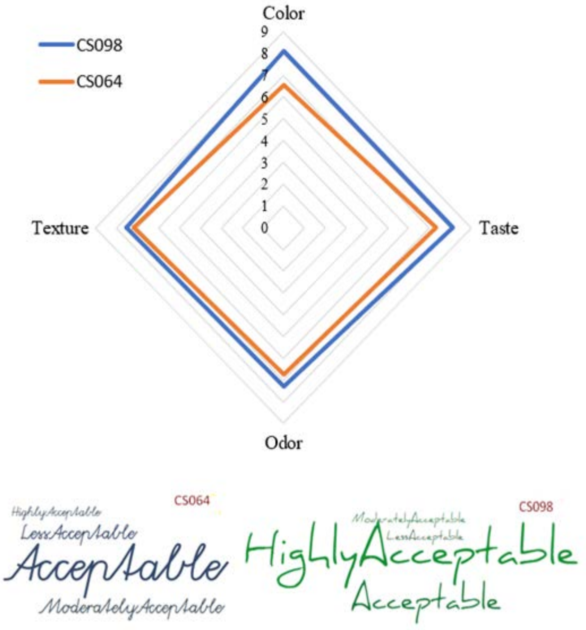

Figure 2. Overall acceptability of the sensory evaluation of cowpea varieties grains

3.2. Discussion

The physical characteristics of wild cowpea variety (CS064) (*V. vexillata*), and commercially improved cowpea variety (CS098) (*V. unguiculata*) seeds are shown in Table 1. The weight of 100 seeds ranges from 17.20g for the wild variety CS064 to 18.50g for the CS098 variety. These results are lower than those reported by Balla and Baragé [2] (23.10g) in their study. This difference in weight could be due to water loss during seed storage or the variety of cowpeas. The length of the cowpea seeds ranged between 5.42mm for the wild cowpea CS064 and 7.08mm for the seeds CS098. These results corroborate those found by Biama [16].

The width of these cowpea seeds varies from 4.16mm for wild cowpea seeds to 5.22mm for CS098 cowpea seeds. These results are in line with those of Biama [16]. The differences in the seeds' weight, length, and width could be due to the varietal effect and agroecological conditions of the soil. The proximate analysis of the samples in this study revealed that the moisture content varies from 6.73% for wild cowpea to 7.02% for cowpea CS098 variety. These results are lower than those reported (12%) by Rose de Lima et al. [17]. This variation could be attributed to the storage conditions of cowpea seeds. However, the grain morphology might contribute also to moisture retention. It can be seen from the grains that the CS064 variety surface looks thicker and smoother than that of the CS098 grains variety.

The data revealed that the protein content of the cowpea varieties ranges from 21.89% for wild cowpea to 25.61% for cowpea CS098. The protein content of wild cowpea is higher than that of the TN5-78 (20.64%) and IT89K-374-57 (20.92%) cowpea varieties reported by Balla and Baragé [2]. Since the variety of cowpea, CS064 is grown in a wild area likely on poor soil and competitive conditions with other plants. However, this difference could be due to the nature of the soils, the varieties, and the types of farming treatments.

The proximate composition of the cowpea seeds, and oil content varies from 1.49% for cowpea CS098 to 1.56% for wild cowpea CS064. These results corroborate with those of Biama [16]. This similarity in lipid content between different varieties of cowpea could exist within the legumes; most of which have a low lipid content [18]. Legumes such as cowpea are also more than half carbohydrates. Thus, this data shows that the carbohydrate contents are found to be 62.13% for the CS098 variety and 66.88% for the wild variety CS064. These results are in agreement with those reported by Boye et al. [19].

The energy value of the cowpea seeds CS098 and CS064 happened to be 364.48 and 369.27 kcals respectively. By comparing these values to that of Alice et al. [20] 363.07kcal. It appears that the cowpea varieties of this work have more energy value. This difference could be explained by the variations observed in the other biochemical components of cowpeas. Indeed, the energy supply of legumes comes from proteins, lipids, and carbohydrates [18].

The mineral estimation of the cowpea seeds studied shows the ash content that varies from 2.91% for CS064 and 3.55% for variety CS098. These results corroborate those reported by Ghabidal et al. [21] 3.94%. The ash content of the seeds could be linked to the variety effect and the combined effect of factors such as nature and soil fertilization [22].

The calcium is found to the sufficient content of the cowpea seeds sample respectively 187.50 for CS064 and 248.10mg/100 g for the CS098 variety. These results are in line with those reported by Nkurikiye and Li [23]. The CS064 accounts for 417.04 mg and 298.1 mg for the variety CS098 magnesium content estimated. It happens that potassium is the most abundant mineral present in these varieties of cowpea; thus, the contents are 613.49mg for CS098 and 936.12mg for CS064. There, the K content present in wild cowpea confirmed the assertion of Siddhuraju et al. [24] who reported that the seeds of *V. vexillata* are rich in potassium.

Iron is a vital function and an essential element of hemoglobin. The iron content was up to 2.18mg for wild cowpea and 3.52mg for the CS098 variety. These results are higher than those of Balla and Baragé [2] (2006) found an iron content of 1.98mg for the cowpea seeds. In addition, these results corroborate also those of Hama-Ba et al. [25] who found 3.66 and 3.94 mg for their respective varieties KVX61-1 and Niizwé. In short. the similarity and difference in mineral element contents observed between the varieties studied and those of other authors in comparison could be related to environmental conditions, agricultural practices, and genetic factors [18].

The functional properties of the cowpea varieties studied are properties that make seeds or grains to be suitable for food processing. The processing of such legumes is well documented in the literature despite that the wild cowpea is yet to be compared to its counterparts. Therefore, the water absorption capacity of the CS064 wild cowpea variety (1.58g/g) happened to be lower than that of CS098 (1.78g/g) a known popular variety in the Saheh [26]. This difference in water absorption capacity between the two varieties could be due to the high protein content of the CS098 variety as it was reported by Prinyawiwatkul et al. [27] that the function is linked to the protein content. The more protein content in cowpea the more capacity to absorb the water. However, the oil adsorption capacity falls between 0.68g/g for CS064 to 0.81g/g for CS098 variety. These results are lower than those reported by Alice et al. [20] (1.14 to 1.95g/g). This difference could be attributed to the presence of non-polar side chains in the flours or the size of the granules [28].

The swelling index of the cowpea varieties falls from 5.73g/g for wild cowpeas and 5.98g/g for the CS098 variety; these results are comparable to previous research work [29,30]. Indeed, the swelling properties of the two cowpea varieties studied appeared to be quite high [29]. The cooking time of grains can vary depending on the various parameters such as grain variety and age. These results revealed the cooking time of the two varieties to be 46.17min for the variety (CS098) and 59.28min for the wild cowpea (CS064). The cooking time obtained with wild cowpea is higher than that found by Alice et al. [20] (57min). This difference could be linked to the hardness of wild cowpea and its seed coat less permeable to water during cooking [2]. Moreover, the swelling of the grains appeared to be 1.26 to 1.29 which is lower than that of Balla and Baragé (2006) (2.2 to 2.6) in their Work. However, this phenomenon could be explained by the duration of storage of cowpea seeds. It has been reported that the longer the storage time of cowpeas, the higher the swelling value of the grains upon cooking (Balla and Baragé (2006).

The sensory evaluation of these two cowpea varieties has shown obvious differences in the sensory parameters. Thus, the color appreciation of CS098 was higher than that of CS064 (Figure, 1 and 2). The odor and taste were moderately higher for CS098, while the texture was closely identical for the two samples. On the sensory evaluation, the general acceptability of the cooked cowpea using the word cloud technique revealed (Figure 2) that the appreciation "*HighlyAcceptable*" for CS098 and "*Acceptable*" for CS064. Meaningly, the variety CS098 happened to surpass the CS064. The hardness of CS064 cowpea grains variety must have contributed to the lower sensory values appreciation than that of CS098.

4. Conclusion

It can be concluded that the wild cowpea variety revealed substantial nutritional values in its proximate analysis. These grains of *Vigna Vexillate* exhibit significant protein content and they are abundant in potassium. The low water and oil absorption capacities have some advantages when it comes to food processing. Therefore, the characteristics of wild cowpea promote this variety to become a candidate for food additives, and its capability on prolonged storage capacity due to its grain hardness; thus, more processing techniques are needed to promote the variety for food consumption.

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