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Agromorphological, Chemical and Biochemical Characterization of Pumpkin (*Cucurbita maxima* and *Cucurbita moschata*, Cucurbitaceae) Morphotypes Cultivated in Cameroon

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Abstract This study was aimed at evaluating pumpkin (Cucurbita maxima and Cucurbita moschata) morphotypes cultivated in Cameroon. A prospective survey was undertaken to sample the knowhow of peasants on the management of pumpkin, followed by an agromorphological, chemical and biochemical characterization in the West (O), Centre (C) and East (E) Regions. The survey revealed that pumpkin is mainly cultivated by women, and that about 20% is grown in association with other crops like maize, cassava and groundnuts. A total of 27 morphotypes were collection from the three regions. The most cultivated morphotypes, C2, C4, C5, E1, E2, E4, O2, O4 and O5 are equally the most consumed by the sampled populations. Principal components analysis on 10 variables revealed a variation between individuals. A positive correlation ($r = 0.43$; $P > 0.05$) was observed between fruit weight and grain number. Ascendant hierarchical classification (CAH) helped to produce a dendrogramme which groups morphotypes into three statistically homogenous classes at a distance of R2= 0.62. Analysis of chemical and biochemical constituents revealed no significant difference between the groups of morphotypes for all parameters ($P < 0.05$) except for sodium and total sugars. These results constitute ground work for selection and improvement of Cucurbita species in Cameroon.

Keywords: *Pumpkin, characterization, prospection, morphotypes, Cucurbita spp. biochemical composition*

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1. Introduction

The term pumpkin designates many plant species of the family *Cucurbitaceae* which belong to the genus *Cucurbita*. Pumpkin is an annual plant originating from Mexico where it was domesticated some 5000 years ago. Pumpkins are considered as part of the foundation plants of agriculture (Whitaker *et al.,* 1962, Bates *et al.,* 1990). Their importance varies with respect to agroecological, socioeconomical characteristics and feeding habits of each zone. They are generally cultivated for their fruits and sometimes for their oil seeds, flowers and leaves (Fu *et al*., 2006). FAO statistics for 2002 estimated world production of pumpkins and gourds (*Lagenaria*) at 17.7 million tonnes from 1.4 million ha (FAO, 2002). According to the same source, China is by far the most important producer (4 million tonnes, constituted especially of *Benincasa*), followed by India (3.5 million tonnes), Ukraine (0.9 million tonnes) and the U.S.A. (750 000 t). Production from Africa was estimated at 1.8 million tonnes from 140 000 ha, corresponding to an average yield of 12.8 t/ha. For tropical Africa, an outstanding production is recorded from Cameroon (122 000 t), Rwanda (210 000 t) and Sudan (68 000 t) (FAO, 2002).

Pumpkin is an excellent source of vitamin A, with its orange colour indicating high content of β-carotene that is transformed by the organism into vitamin A (Palm, 1997). It can thus play an important role in the fight against vitamin A deficiency which concerns more than 250 million children aged less than five around the world. In addition to being a source of vitamin A, β-carotene also has an antioxidant effect and might improve on certain functions of the immune system (Bendich, 2004; Krinsky and Johnson 2005).

The principal antioxidant compounds of pumpkin are carotenoids. Carotenoids, methanol and certain types of sugars (polysaccharides) found in pumpkin might reduce glycemia and could render available insulin in diabetic patients (Saha *et al*., 2012). In fact, some studies on animals (Roman-Ramos *et al.*, 1995; Alarcon-Aguilar *et al.,* 2002) and on type 2 diabetic patients (Acosta-Patino *et al*., 2001) indicate that the juice of pumpkin of the *Cucurbita ficifolia* variety (also called Siam pumpkin) have a hypoglycemic effect, that is, regular consumption of pumpkin leads to reduction in blood glucose (Jun *et al*., 2006; Yang *et al*., 2007).

It is known that besides its nutritive values; pumpkin also has an effect on several target functions of the human body, therefore improving the state of wellbeing or health status of individuals. As stated earlier, pumpkin belongs to several botanical species of the genus *Cucurbita* which exhibits an outstanding genetic variability expressed in fruits by the numerous forms and colours as well as a diversity of sizes (Du *et al*., 2011). To this effect, the choice of the best pumpkin variety for any appropriate usage is today a real challenge for most consumers.

In Cameroon, many studies have been undertaken on the nutritional potential of pumpkin grains (Fokou *et al*., 2004; Achu *et al*., 2005; Achu *et al*., 2013) and on the effect of cooking techniques on the biochemical composition of its pulp (Demasse *et al*., 2009). However, very little work has been done on its distribution, genetic diversity, farming techniques and uses of pumpkin in this context. Elaboration of a programme for the collection and characterization of edible pumpkin morphotypes in the main production basins is therefore indispensible. It is in this context that the present study was initiated with the objective of determining agro-morphological characteristics of the different morphotypes of pumpkin in the main production zones of Cameroon. Specific objectives included (i) survey and collection of the different morphotypes of pumpkin; (ii) study of the agro-morphological variability between collected morphotypes; and (iii) determination of their chemical and biochemical compositions.

2. Materials and Methods

2.1. Study site for Field Survey, Prospection and Collection of Pumpkin Samples

The perception of peasants on their knowhow of pumpkins and collection of morphotypes were realized in the Centre, East and West Regions which are the three main production basins of pumpkin in Cameroon. The Centre and East Regions belong to the humid forest zone with bimodal rainfall regime while the West Region belongs to zone III known as the Western high lands. The bimodal humid forest zone as the name indicates has an annual rainfall of 1500-2000 mm, distributed into two well distinct humid seasons. The warm humid climate is of the Guinean type, with average temperature of 25°C. Majority of the soils are ferralitic, acid, clay and coloured red or yellow depending on the duration of the humid season. The western highland zone on the other hand presents a highly diversified relief with mountainous landscapes characterized by savannah vegetation, steppe plains, degraded basins and plains intersected by forest galleries. It "Cameroonian altitude" climate is marked by two seasons with equal lengths, and an average minimal temperatures (19°C), and abundant rainfall (between 1500 and 2000 mm). Several soil types are found in this zone: yellow soils (inceptisols) on steep slopes, highly leached soils (oxisols) in old plains, horizon B alluvial soils (alfisols and ultisols) in closed depressions, and plains rich in volcanic materials (ashes). On the overall, soils are very fertile and good for agriculture.

2.2. Prospection and Collection of Morphotypes

The collection of data and morphotypes was done through direct interviews with peasant farmers and pumpkin sellers chosen at random in villages. During this study, the proportion of peasants (women and men) who cultivate pumpkins was estimated. The mode of cultivation, criteria for choosing morphotypes cultivated and the methods of seed selection were recorded from the surveyed producers. The agromorphological characterization included parameters such as the form and colour of leaves and fruits, and floral morphology of different morphotypes. Data for these parameters were collected directly from the farms of the peasants. Three fruits chosen at random per morphotype and per farm were analyzed in the laboratory and the data recorded for pulp colour, fruit weight, and number of grains per fruits etc. as well as data on the chemical and biochemical composition of fruits.

2.3. Chemical and Biochemical Analysis

The basic cations (Ca2+, Mg2+, K+ and Na+) were extracted after burning the sample in a muffle furnace, dilution with a mixture of HCl/HNO3, and analysis using an atomic absorption spectrophotometer (Benton and Vernon, 1990). After burning the samples in a muffle furnace, phosphorus was extracted and analyzed with Murphy Riley reagent. Reading was done by the colorimetric method (Murphy and Riley, 1962). Total nitrogen was determined after acid digestion (Buondonno et al., 1995) still with colorimetric analysis (Anderson and Ingram, 1993). For analysis of sugar, the sample was extracted with hot ethanol and the resultant extract was analyzed by colorimetry using phenol and sulphuric acid (Dubois et al., 1956). Protein value was calculated by multiplying the total nitrogen with a factor of 6.25 (Dieter et al., 1956). Total carotenoids content was determined following the Harvest Plus method (Delia et al., 2004).

2.4. Statistical Analysis

Principal component analysis (ACP) and a hierarchical numeric classification were realized respectively to determine the relationships that exist between the agromorphological variables studied and to group morphotypes into more or less homogenous classes. The SAS version 9.2 Software was used for the statistical analysis of data concerning chemical and biochemical characteristics. These analyses consisted essentially in one factor analysis of variance. Average values were then compared amongst themselves with the help of Student Newman Keuls test at the threshold of 5%.

3. Results and Discussion

3.1. Prospection and Collection of Morphotypes

The survey results relative to the proportion of women and men practicing the cultivation of pumpkin in Cameroon are presented in figure I. The figure reveals that pumpkin is mainly cultivated by women (about 90%). Similar observations have been reported from other regions in Africa, notably in Ivory Coast (Irié *et al.*, 2003).

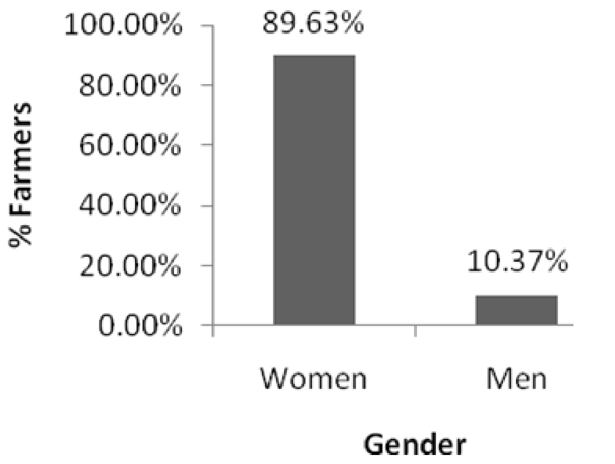

Figure 1. Proportion of women and men who cultivate pumpkins in the study zones

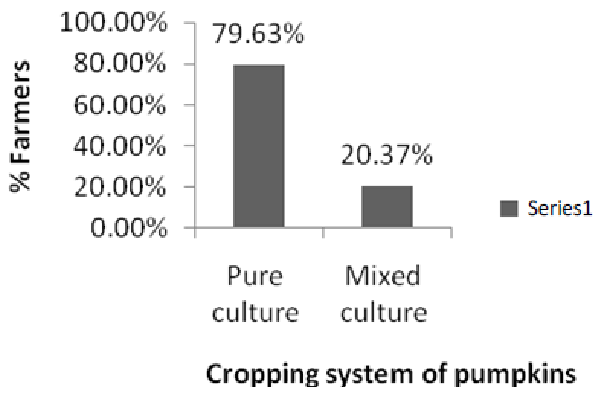

Figure 2. Cultivation systems of pumpkin

Figure 2 indicates the mode of cultivation practiced by the peasant farmers. The figure shows that in Cameroon, about 20% pumpkin is cultivated in association with other plants like groundnuts, maize, cassava, soybeans, and yams. In the same vein with these observations, Sesay *et al.* (1999) reported that in many regions of Swaziland, monoculture represents 98% of plots cultivated, and that mixed farming (2%) is generally established with maize, sorghum, and millet.

3.2. Seed Selection and Cultivation Systems

With good seeds being an essential requirement for productive agriculture, it is thus indispensable for particular attention to be focused on the choice of pumpkin seeds in order to assure better harvest in terms of quality and quantity. Results of our survey have shown that to have good seeds, immature grains or those that are damaged by insects are sorted manually before sewing. Some peasants (3.33%) do the seed selection by floating in water (Figure 3).

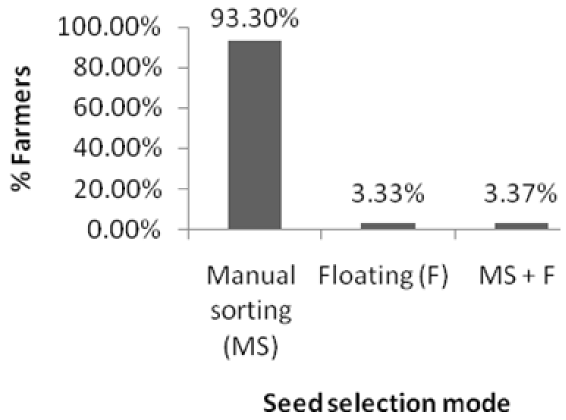

Figure 3. Methods of seed selection

3.3. Agromorphological Characterization of Pumpkin Morphotypes

A total of 27 morphotypes of *Cucurbita maxima* and *Cucurbita moschata* were collected from the three zones [West (O), Centre (C), East (E)]. The local names attributed to morphotypes vary with species and locality. Table 1 presents the nomenclature of pumpkin morphotypes cultivated in the three main production basins of Cameroon.

3.4. Criteria of Choice of Morphotypes Cultivated

The choice of pumpkin morphotypes cultivated by farmers is based amongst other factors on organoleptic characteristics of the fruits, fruit texture, leaf size and fruit yield. According to peasant farmers, morphotypes of *Cucurbita* maxima commonly called ‘large leaves’ in the Centre region are mostly cultivated as leafy vegetables. Their grains are well appreciated in the West Region. Leafy vegetables are very important in Africa, Asia, and Oceania, where they provide the majority of medicinal constituents and micro elements indispensible for human health. Their richness in iron, vitamins A and C is precious in countries where anemia due to malaria and immune deficiency is common. A study undertaken by IITA (2009) in urban households in Yaounde showed that green traditional vegetables such as pumpkin leaves are the most cultivated by families. Results of the present study show that *Cucurbita moschata* is the most cultivated species (up to 90%) in the three regions where the study took place. This corroborates the results of Gwanama *et al.* (2000) who showed that *Cucurbita moschata* is one of the most cultivated vegetables in tropical Africa. This pumpkin species seems harder and sweeter. The most cultivated morphotypes per region are: C2, C4, and C5 for the Centre Region, E1, E2, and E4 for the East Region, and O2, O4 and O5 for the West Region. All these pumpkin morphotypes belong to the species *Cucurbita moschata* even though they differ by certain characteristics.

Table 1. Morphotypes of *C. maxima* and *C. moschata* collected from the three main regions

Zones	Morphotypes	Botanical Name	Local Name
Centre	C1	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C2	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C3	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C4	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C5	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C6	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C7	*C. maxima*	Humbio (Bafia); goa-ndek (Beti)
	C8	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
	C9	*C. moschata*	mezeng, nbamg (Bafia); abok, mendzen (Ewondo)
West	O1	*C. moschata*	Nepock, pouock (Bamiléké)
	O2	*C. moschata*	Nepock, pouock (Bamiléké)
	O3	*C. maxima*	Keulam (Bamiléké)
	O4	*C. moschata*	Nepock, pouock (Bamiléké)
	O5	*C. moschata*	Nepock, pouock (Bamiléké)
	O6	*C. moschata*	Nepock, pouock (Bamiléké)
	O7	*C. moschata*	Nepock, pouock (Bamiléké)
	O8	*C. moschata*	Nepock, pouock (Bamiléké)
	O9	*C. moschata*	Nepock, pouock (Bamiléké)
	O10	*C. moschata*	Nepock, pouock (Bamiléké)
East	E1	*C. moschata*	Mkoum keuk (Makaa)
	E2	*C. moschata*	Mkoum keuk (Makaa)
	E3	*C. moschata*	Mkoum keuk (Makaa)
	E4	*C. moschata*	Mkoum keuk (Makaa)
	E5	*C. moschata*	Mkoum keuk (Makaa)
	E6	*C. moschata*	Mkoum keuk (Makaa)
	E7	*C. moschata*	Mkoum keuk (Makaa)
	E8	*C. maxima*	Bouhor gueu (Makaa)

3.4.1. Principal Component Analysis

A principal component analysis was run in order to describe the relationships or variations that exist between the morphotypes of pumpkin sampled.

3.4.2. Proper Values of the Principal Components

Table 2. Proper values from the 10 variables

Axis number	Proper value	Percentage	Cumulative percentage
1	4.80	0.48	0.48
2	1.81	0.18	0.66
3	1.19	0.12	0.78
4	1.06	0.11	0.89
5	0.53	0.05	0.94
6	0.34	0.03	0.97
7	0.24	0.03	1

The principal component analysis (ACP) helped to group the 10 variables into several axis. Table 2 gives the contribution of each principal axis to the total inertia through proper values and cumulative percentages of qualitative and quantitative parameters on the first 7 axis of ACP. The first two axis explain 66.16% of the total variation within the plant materials (Table 2). These two main axis can thus be retained to describe the variability among the studied plant materials.

3.4.3. Correlation of Variables with the Axis

The following variables: fruit form (ForFruit), dominant body colour (CouldoEcor), secondary body colour (CoulSecEcor), texture and form of pedoncle (TextFormPed), colour of pulp (CouPul), form of leaves (ForFeuil), and form of calyx parts (ForPiCal) are positivement correlated to axis 1. Axis 1 gives information on qualitative traits of the fruit and leaves (Table 3). The table also permits to note that the following variables: weight of fruit (PoFruit) and number of grains are positively correlated with axis 2. Axis 2 is therefore the axis for quantitative variables (Table 3).

Table 3. Correlation of variables within the first two axis

Variable	Axis 1	Axis 2
ForFruit	0.45810*	-0.22559
CouldoEcor	0.51965*	-0.39058
CoulSecEcor	0.50867*	-0.42130
TextFormPed	0.95335*	0.27189
CouPul	0.52417*	-0.36801
ForFeuil	0.95335*	0.27189
CouFeuil	0.95335*	0.27189
ForPiCal	0.95335*	0.27189
PoFruit	-0.04676	0.66030*
NbGraine	-0.38869	0.75241*

Pearson's linear standard correlation. *= significant ($P > 0.05$)

3.4.4. Ascending Hierarchical Classification of Morphotypes

To better appreciate the agro-morphological diversity of morphotypes of pumpkins studied, a ascending hierarchical classification (CAH) was performed on the basis of the 10 quantitative and qualitative parameters evaluated with the SAS software. The CAH helped to obtain a dendrogramme which regroups the morphotypes into statistically homogenous classes. An analysis of the dendrogramme reveals that there are three classes with the distance of R^2= 0.62 (Figure 4). The first class is composed of 14 morphotypes, the second class has 10 morphotypes and class 3 contains 3 morphotypes. The 3 distinct groups have different characteristics.

Figure 4 presents the grouping of different morphotypes into homogenous classes following a numerical hierarchical classification. Group 1 is made of morphotypes C1, C2, O1, O5, E2, C5, E1, E3, C8, O2, C4, O6, E6 and E7. This group is characterized by a high expression of qualitative traits of fruits, leaves and flowers. Group 2 is made up of morphotypes C3, O4, C6, E5, O9, E4, C9, O10, O7 and O8. This Group opposes both Group 1 and 3. Group 3 which is made up of morphotypes C7, E8 and O3 is characterized by strong quantitative values such as weight of fruits and number of grains. Morphotypes of this Group belong to the *Cucurbita* *maxima* species contrary to those of the other two Groups which belong to *Cucurbita moschata* species.

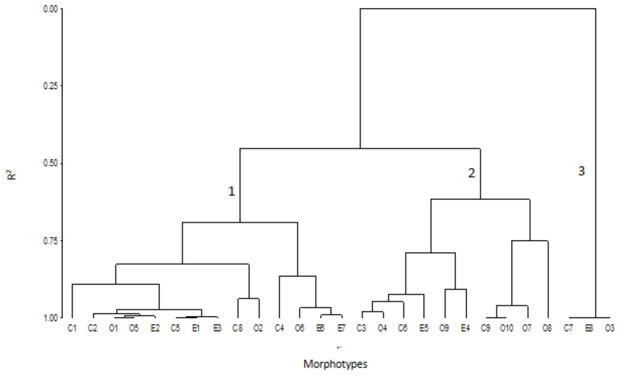

Figure 4. Dendrogramme of quantitative and qualitative variables

This study has revealed morphological heterogeneity among different pumpkin morphotypes. On the overall, the first two axis of ACP have explained 66.16% of the total variation among the plant materials evaluated (Table 2). The variability described by the first axis alone (48%) is mainly due to qualitative traits of fruits, leaves and flowers. In fact, within the *Cucurbitaceae* family, an important contribution to the morphological description of the traits of fruits, leaves and grains have been reported for *Lagenaria siceraria* (Koffi *et al.*, 2009) as well as for water melon (Maggs-Kölling *et al.*, 2000; Gusmini, 2003) and gourd (Morimoto *et al.*, 2005). In the present study, a positive correlation between weight of fruits and number of grains was equally observed. The same positive correlation has been reported for water melon (Nerson, 2002). Consequently, the weight of fruits of *Cucurbita moschata* and *Cucurbita maxima* could be used as a good criterion for the selection of individuals with many grains. This result is in line with the conclusions of Koffi *et al.* (2009) as to what concerns *Lagenaria siceraria*.

3.5. Chemical and Biochemical Composition of Groups of Morphotypes Following a Numerical Hierarchical Classification of most Cultivated Pumpkins

The chemical and biochemical composition including those of antioxydant components such as carotenoids were analyzed for morphotypes of pumpkin surveyed in Cameroon. Table 4 presents the analysis of variance followed by structured means of chemical and biochemical parameters of 3 grougs of pumpkin morphotypes issued from numerical classification (Figure 4). From Table 4, it can be noted that there is no significant difference between groups of morphotypes for all parameters (P <0.05) with the exception of sodium and total sugars. With the test of Student Newman Keuls, the highest values are found in groups 2 and 3 for total sugars and in Group 1 for sodium (Table 4).

Nutrient content in pumpkins can vary considerably with respect to differents Groups of morphotypes. Group 3 which represents the group of *Cucurbita maxima* had more sugar than Group 1 of *Cucurbita moschata* and the intermediary group. Similar results were obtained in Korea by Mi *et al* (2012) on the evaluation of chemical composition and nutritive value of *Cucurbita maxima*, *Cucurbita moschata* and *Cucurbita pepo*. Due to its sweet taste, *Cucurbita maxima* is called "Danhobak" in Korean language; «Dan» meaning soft and «hobak» meaning pumpkin. This staple also permits good hydration of the organism due to its richness in sodium. Sodium is a mineral element needed in the organism and as such should be supplied in sufficient quantity through feeding. It is present in blood and in extracellular fluid. Sodium also helps to maintain acid-base equilibrium and is essential in the transmission of nervous influxes and muscle contraction (Withney and Rady, 2008).

Carotenoids have been considered to be liposoluble antioxidants. Antioxydants play an important role in reducing damages of DNA, thereby reducing peroxydation of lipids and maintaining the immune function (Gropper *et al.*, 2005). Group 3 of *Cucurbita maxima* had more carotenoids even though there was no significant difference between the groups of morphotypes (P> 0.05). Its protein, potassium and phosphorus contents were equally higher.

Table 4. Chemical and biochemical parameters (means ± standard error) of the three groups of pumpkin morphotypes issued from numerical classification

Groups	% Proteins	% Ca	% Mg	% K	% Na	% Total P	Carotenoids (mg/g)	% Sugars
Group 1	6.02±0.17a	0.23±0.08a	0.29±0.16a	1.88±0.09a	0.002±0.00a	0.16±0.03a	25.83±2.82a	1.54±0.29b
Group 2	7.43±0.71a	0.12±0.02a	0.15±0.02a	2.34±0.30a	0.001±0.0001b	0.26±0.04a	197.09±85.70a	2.59±0.41a
Group 3	9.58±2.71a	0.06±0.02a	0.11±0.02a	3.17±0.53a	0.002±0.0003ab	0.28±0.01a	339.25±152.4a	3.02±8.83a
Mean	7.68	0.14	0.18	2.46	0.002	0.23	187.39	2.38
CV%	36.5	65.81	91.47	25.16	30.1	21.66	93.31	22.02
F value	1.23	2.55	0.97	3.31	6.64	4.92	2.42	6.31
P	0.36ns	0.16ns	0.43ns	0.11ns	0.03*	0.05ns	0.17ns	0.03*

ns: non significant at the threshold of 5%; *: significant at the threshold of 5%; **highly significant at the threshold of 5%; ***: very highly significant at the threshold of 5%. Values with same letters for the same parameter are not significantly different according to the test of Student Newman-Keuls (P > 0.05).

4. Conclusion

The results of the present study revealed that pumpkin (*Cucurbita* spp.) is mainly cultivated by women in the West, Centre and East Regions of Cameroon. Several morphotypes were identified. The most cultivated morphotypes identified as a function of locality were: C2, C4, C5, E1, E2, E4, O2, O4 and O5. Mixed farming with pumpkin is the most common practice. Moreover, 90% of seeds are prepared by manual sorting. An ascending hierarchical classification showed that morphotypes of pumpkin collected from the three regions of Cameroon can be classified in three groups: Group 1 characterized by strong variability due mainly to qualitative traits of the fruits, leaves and flowers; Group 3 characterized by high quantitative values like weight of fruit and number of grains; and Group 2 which is intermediary between the two other groups. Chemical and biochemical characterization of the three groups of morphotypes revealed a significant difference only for sodium and total sugar. Finally, the study showed a morphological heterogeneity among the different morphotypes in the three study zones. The information acquired through this study in Cameroon can be exploited by breeders to select and improve on pumpkin production.

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