Some quality attributes of complementary food produced from flour blends of orange flesh sweetpotato, sorghum, and soybean

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Summary

The study investigated the chemical, functional, and sensory attributes of orange flesh sweetpotato, sorghum, and soybean during storage. Orange flesh sweetpotato flour, sorghum flour, and soybean flour were blended together at four different ratios of 40:40:20, 30:50:20, 20:60:20, and 10:70:20, respectively, while 100% sorghum flour was used as control. The five flour blends were used to prepare complementary foods, and sensory attributes of foods were determined using a nine point hedonic scale. The flour blend with the highest overall acceptability score was packaged in a high density polyethylene bag and stored for the period of eight weeks. During storage, the functional properties and the chemical properties of the flour blend were determined every two weeks. The result obtained for the sensory properties of the complementary food shows that the sample 40:40:20 was accepted by the panellists. The functional properties of the blend during storage ranged from 0.57 to 0.60 g/mL, 69 to 86 %, 3.74 to 4.19 g/g, 2.82 to 3.12 %, and 77.50 to 94.50 % for bulk density, dispersibility, swelling power, solubility, and water absorption capacity, respectively, while the chemical analysis ranged from 7.11 to 9.40 %, 1.02 to 3.59 % and 0.05 to1.28 meq/kg for moisture, free fatty acids, and peroxide value, respectively. The study showed that the flour blend of 40:20:40 had the most preferred functional properties and complementary food produced from it had best attributes in terms of taste, colour, viscosity, and overall acceptability.

Keywords: complementary food, sensory acceptability, orange flesh sweetpotato, flour blends

Introduction

Protein-energy malnutrition (PEM), "the silent emergency of the world" which may have hunted mankind since the dawn of history, is by far the most lethal form of malnutrition (Tiencheu et al., 2016). It is an imbalance between the supply of energy and protein, and the body's demand for them, which is required to ensure optimal growth and function. It is currently the most widespread and serious health problem of children in the world, whether in the moderate or severe forms, (FAO/WHO, 1998, USAID, 2002). PEM stands out as the most serious of the nutritional deficiency problems in infants and young children in Nigeria, as well as in other developing countries of the world, and among low income earners in developed countries (Ossai and Malomo, 1988). PEM is associated with poverty and poor nutrition knowledge, resulting in early weaning, delayed introduction of complementary foods, low-protein diet, and severe or frequent infections, (Rice et al., 2000, Müller et al., 2003). The weaning period is a crucial stage of development, characterised by increasing metabolic demands; higher energy and quality proteins are required for the maintenance and continued growth and mental development of the child. Poor quality of weaning foods and improper weaning practices predispose infants to malnutrition, growth retardation, infection, diseases, and high mortality, (Onofiok et al., 2005; Prentice et al., 2005).
The formulation and development of nutritious complementary foods from local and readily available raw materials have received considerable attention in many developing countries. The commercially standardized foods are generally very good and can help meet the nutritional requirements of young children in both developed and developing countries. However, the development of low-cost, high protein food supplements for weaning infants is a constant challenge for developing countries, e.g. Nigeria, where traditional foods used during the weaning process are frequently characterized by low nutrient density and high bulk, which can adversely affect an infant's health (Onyango, 2003; Muhimbula et al., 2011).
Complementary foods are foods given to infants in addition to breast milk when breast milk nutrients become inadequate for their energy and growth needs (Onyekwere, 2007). In Nigeria, the introduction of complementary food usually starts between the ages of four to six months and usually involves the use of a

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semi-liquid porridge prepared locally by the mother from staple cereals or tubers (Bentley et al., 1991; Nout, 1993; Guptill et al., 1993), during that period infants should receive complementary foods two-three times a day between the ages of 6-8 months and 2-4 times daily between the ages of nine-eleven months (WHO, 2004).

In developing countries, baby foods (complementary foods) are mainly based on starchy tubers like cassava, cocoyam, and sweet potato, or on cereals like maize, rice, wheat, sorghum, and millet. Small children are normally given these staples in the form of gruels that are mixed with boiled water or boiled with water. When prepared in this way, the starch structures bind large amounts of water, which results in gruels of high viscosity (Hellstrom et al., 1981).

Seed proteins, especially from leguminous sources such as soybean, have been put forward as potentially excellent sources of protein for the upgrade of the nutritional quality of starchy roots and tubers, for use in baby foods in countries which import their entire milk requirement (Okaka and Okaka, 1990). Sorghum is one of the three most common grains used in traditional complementary foods (Ajanaku et al., 2013), ranks third among the domesticated cereals for human consumption, and is a staple food in many African countries, India, and China (Elkhalifa and El-tinay, 2002, Awadalkarrem et al., 2008; Elemo et al., 2011). Supplementation of cereals such as sorghum with legumes such as soybean has been advocated in complementary feeding (Ajanaku et al., 2013). However, cereal-legume based complementary foods are deficient in essential micronutrients such as vitamin A. Vitamin A deficiency is a major public health problem in developing countries (Bonsi et al., 2013). Orange flesh sweetpotato has been reported to increase vitamin A intake and serum retinol concentrations in children (Bonsi et al., 2014), as well as other micronutrients such as polyphenols and carotenoids (Haskell et al., 2004). Developing complementary foods from sorghum, sweetpotato, and soybean is desirable in view of their seasonality and storage problems. The overall objective of this study was to determine the sensory attributes of complementary foods from orange flesh sweetpotato-sorghum-soybean flour blends and to determine the functional properties of the flour, as well as the sensory acceptability of complementary food produced from flour blends of orange fleshed sweet potato, sorghum, and soybean.

Materials and methods

Materials

Orange flesh sweetpotato was obtained from the Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta. Sorghum and soybean grains were purchased at Osiele market in Abeokuta, Ogun State, Nigeria

Production of orange flesh sweetpotato flour

The method described by Singh et al. (2008) was used for the production of orange flesh sweetpotato flour. The orange flesh sweet potato tubers were peeled and cut into thin pieces manually. The potato slices were soaked in a solution containing potassium metabisulphite (KMS) (1%) for five minutes to prevent browning reactions and enhance the colour of the flour. They were then dried in the cabinet dryer at 50 °C for 48 hours. The dried orange flesh sweet potato chips were milled into flour using the laboratory hammer milling machine (Fritsch, D-55743, Idar-oberstein-Germany) and the milled sample was sieved (using the 250 μm screen) to obtain the flour. The orange flesh sweetpotato flour was packed and sealed in polyethylene bags at ambient temperature (26 ± 2 °C) and 760 mmHg until further analysis.

Production of sorghum flour

The sorghum flour was produced using the method described by Nwakalor et al. (2014). The sorghum grains were sorted out to remove stones and other foreign particles. The grains were soaked in clean water for 8 hours and the water was decanted. The grains were dried in a cabinet dryer at 70 °C for 48 hours. The dried sorghum was milled into flour using a laboratory hammer milling machine (Fritsch, D-55743, Idaroberstein-Germany) and the milled sample was sieved (using the 250 μm screen) to obtain the flour. The sorghum flour was packed and sealed in polyethylene bags at ambient temperature (26 ± 2 °C) and 760 mmHg until further analysis.

Production of soybean flour

The method described by Sanni et al. (2004) was adopted. Soybean seeds were sorted and soaked in water for 12 hours for fermentation. The beans were drained of water and blanched in boiling water for about 15 minutes to free the seed coat. Furthermore, the beans were hulled (by rubbing in-between palms, floating, and decanting the hulled seed coats) and the soybean was dried in a cabinet dryer at 65 ºC for 7 hours. The dried soybeans were milled into flour using the laboratory hammer milling machine (Fritsch, D-55743, Idaroberstein-Germany) and the milled sample was sieved (using the 250 μm screen) to obtain the flour. The soybean flour was packed and sealed in polyethylene bags at ambient temperature (26 ± 2 ºC) and 760 mmHg until further analysis.

Blends formulation of orange flesh sweetpotato-sorghum-soybean complementary food

Five composite flours were prepared by blending orange flesh sweetpotato (OSF), sorghum (SOF), and soybean (SYF) flours in the ratios of 0:100:0, 10:70:20, 20:60:20, 30:50:20, and 40:40:20.

Preparation of orange flesh sweetpotato-sorghum-soybean complementary food

Complementary foods were prepared according to the method of Opara et al. (2012). Complementary foods were prepared by dissolving 50 g of orange flesh sweet potato-sorghum-soybean flour blends in 100 mL of clean water. About 150 mL of boiling water was added to the suspension, and this was brought to a boil for 3-5 min, cooled, and served to a panel of 50 nursing mothers.

Sensory evaluation of orange flesh sweetpotato-sorghum-soybean complementary food

The sensory analysis of the prepared complementary food gruel was determined using a 9-point hedonic scale, according to the method of Iwe (2002). Attributes such as colour, aroma, taste, viscosity, and overall acceptability were evaluated.

Storage stability of orange flesh sweetpotato- sorghum-soybean complementary food

The flour sample of the most acceptable complementary food from sensory evaluation was packed in an air-tight low density polyethylene bag and stored under ambient conditions of (26 ± 2 ºC) for eight weeks. Samples were withdrawn every two weeks and subjected to testing of functional properties such as bulk density, dispersibility, swelling power, solubility index, water absorption capacity, and chemical composition, and properties such as moisture, free fatty acids, and peroxide value were determined.

Functional properties of orange flesh sweetpotato-sorghum-soybean flour during storage

Bulk density

Bulk density was determined using the method described by Wang and Kinsella (1976). 10 g of sample was weighed into a 50 mL graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top. The volume of the sample was recorded.

$$Bulk\ density = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping} \tag{1}$$

Dispersibility

This was determined by the method described by Kulkarni et al. (1991). 10 g of flour was suspended in a 100 mL measuring cylinder and distilled water was added to reach a volume of 100 mL. The setup was stirred vigorously and allowed to settle for 3 hours. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

Swelling power and solubility index

The swelling power and solubility index were determined using the method described by Takashi and Sieb (1988). 1 g of flour was weighed into a 50 mL centrifuge tube. 50 mL of distilled water was added and mixed gently. The slurry was heated in a water bath at 90 ºC for 15 minutes. During heating, the slurry was stirred gently to prevent clumping of the flour. On completion, the tube containing the paste was centrifuged at 3,000 rpm for 10 minutes using a centrifuge machine. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content of sediment gel was thereafter determined to get the dry matter content of the gel.

$$Swelling\ power = \frac{Weight\ of\ mass\ of\ sediment}{Weight\ of\ dry\ matter\ in\ the\ gel} \tag{2}$$

$$Solubility\ index = \frac{Weight\ of\ dry\ solids\ after\ drying}{Weight\ of\ sample} \times 100 \tag{3}$$

Water absorption capacity

The water absorption capacity of flour was determined using the method described by Ruales et al. (1993). 1 g of sample was suspended in 15 mL of distilled water at 30 ºC in a centrifuge tube and centrifuged at 2500 rpm for 30 minutes. The supernatant was decanted and the weight of the formed gel was recorded. The water absorption capacity (WAC) was calculated as gel weight per gram of dry sample.

$$WAC = \frac{Gram\ bound\ water}{Weight\ of\ sample} \times 100 \tag{5}$$

Chemical composition of orange flesh sweetpotato-sorghum-soybean flour during storage

Moisture content

The moisture content of the flour was determined using the method described by AOAC (2000). 5 g of sample was weighed into a dried and pre-weighed moisture can. The can with its content was dried in an oven at a temperature of 105 °C for 3 hours. It was removed from the oven, cooled in a desiccator and after cooling it was weighed and returned into the oven for another thirty minutes; it was cooled and weighed again until constant weight. The moisture content was estimated as weight loss using the formula below:

$$Moisture\ content = \frac{W1-W2}{W} \times 100 \qquad (6)$$

where:
W_1 = weight of pan + fresh sample
W_2 = weight of pan + dried sample
W = weight of sample

Free Fatty Acids

Free fatty acids were determined according to the method of Sani (2015). 2.0 g of the flour was transferred into a 250 cm^3 Erlenmeyer flask followed by the addition of 100 cm^3 of ethanol and 2 cm^3 of phenolphthalein indicator. After mixing the content properly, it was titrated against 0.04 M NaOH. The shaking continued until a slight pink colour was observed, which was steady for about 30 seconds and signified the end point.The % of free fatty acids was calculated using Equation 1.

$$\%FFA = \frac{V \times M \times 28.2}{W} \qquad (7)$$

where:
% FFA = percentage of free fatty acids, V= average volume of NaOH used (cm^3), M = molarity of NaOH, W = weight of the flour sample

Peroxide value

The peroxide value was determined using the method described by Sani (2015). 2.0 g of the flour sample was weighed into a clean dry flask and 22 cm^3 of the mixture of 10 cm^3 of acetic acid and 12 cm^3 of chloroform was added, then 0.5 cm^3 of potassium iodide was also added. The flask was closed and allowed to stay with constant shaking for 1 minute. 30 cm^3 of distilled water was then added and titrated against 0.1 M of sodium thiosulphate ($Na_2S_2O_3$) solution until an initial yellow colour disappeared and a faint blue colour appeared. The titration continued after the addition of 0.5 cm^3 of starch indicator until there was a sudden disappearance of the blue colour, which signifies the end point. The peroxide value is often reported as the mL of 20 mM $Na_2S_2O_3$ per gram of sample. Thus, peroxide value was calculated using Equation 2.

$$Peroxide\ value = \frac{(S-B) \times M \times 100}{W} \qquad (8)$$

where:
peroxide value= mEq of peroxide per 100 g of sample, S=sample titre value (cm^3), B=blank titre value (cm^3), M= molarity of $Na_2S_2O_3$ (mEq/cm^3), W=weight of flour

Statistical analysis

Data obtained was subjected to statistical analysis. Means, Analysis of Variance (ANOVA) were determined using the SPSS Version 21.0 and the differences between the mean values were evaluated at $p<0.05$ using Duncan's multiple range test.

Results and discussion

Sensory evaluation of orange flesh sweetpotato-sorghum-soybean complementary food

Table 1 shows the mean sensory scores of complementary food made from the flour blends of orange flesh sweetpotato, sorghum, and soybean. There were significant differences ($p<0.05$) in all the sensory attributes measured. The aroma of the orange flesh sweetpotato-sorghum-soy flour complementary food ranged from 5.92 to 6.38. Sample 40:40:20 had the highest value for aroma, while samples 0:100:0 and 10:10:20 had the lowest. The taste and colour of orange flesh sweetpotato-sorghum-soy flour complementary food ranged from 5.64 to 7.00 and 5.10 to 6.60, respectively. Sample 40:40:20 had the highest value for taste and colour, while sample 0:100:0 had the lowest value for taste and colour. The viscosity of the orange flesh sweetpotato-sorghum-soy flour complementary food ranged between 5.10 and 6.68. The overall acceptability expresses how the consumer or the panellists generally accept the product. It was observed that complementary food produced from the flour blend of orange flesh sweetpotato-sorghum-soy flour at 40:40:20 was accepted. This could be due to the familiarity of taste, aroma, and colour. The results provide a basis for the development of an acceptable complementary food that can provide the required protein and energy levels that are essential basic nutrients to enable the accomplishment of a day's work (Bilsborough et al., 2006).

Table 1. Mean score for sensory properties of orange flesh sweet potato-sorghum-soy flour complementary food

OF:S:SF	Aroma	Taste	Colour	Viscosity	Overall acceptability
0:100:0	5.92 ± 1.56[a]	5.64 ± 1.41[a]	5.10 ± 1.34[a]	6.32 ± 1.73[cd]	5.72 ± 1.36[a]
40:40:20	6.38 ± 1.51[ab]	7.00 ± 1.36[b]	6.60 ± 1.59[c]	6.68 ± 1.17[d]	6.96 ± 1.38[c]
30:50:20	6.28 ± 1.21[ab]	6.10 ± 1.13[a]	5.96 ± 1.12[b]	5.86 ± 1.48[bc]	6.42 ± 0.95[b]
20:60:20	6.58 ± 1.14[b]	6.08 ± 1.18[a]	5.68 ± 1.50[ab]	5.64 ± 1.48[ab]	6.32 ± 0.87[b]
10:70:20	5.92 ± 1.31[a]	5.70 ± 1.34[a]	5.64 ± 1.48[ab]	5.10 ± 1.53[a]	5.98 ± 1.10[ab]

Mean values with different superscripts within the same column are significantly different (p <0.05). OF - orange flesh sweetpotato, S –sorghum, S- soy flour

Functional properties of orange flesh sweetpotato-sorghum-soybean flour (sample 40:40:20) during storage

The functional properties determine the application and use of food materials for various food products. The results obtained during the storage period show that there were significant differences (p<0.05) in dispersibility, swelling power, solubility, and water absorption capacity of sample 40:40:20 during storage. The bulk density of the flour ranged from 0.57 to 0.60 g/mL, with week 0 having the lowest, while weeks 2, 4, and 6 had the highest. The bulk density obtained during the period of storage in this study was very low and this indicates that the flour sample would be an advantage in preparation of complementary foods (Akpata and Akubor, 1999). The bulk density is influenced by particle size and the density of the flour, and is important in determining the packaging requirement and material handling (Karuna et al., 1996). Plaami (1997) reported that bulk density is influenced by the structure of the starch polymers and the loose structure of the starch polymers could result in low bulk density. Bulk density is a measure of heaviness of a flour sample and this gives an indication that the relative volume of the composite flour in a package will not reduce excessively during storage.

The dispersibility of orange flesh sweet potato-sorghum-soy flour blend ranged between 69 and 86 %. Orange flesh sweetpotato-sorghum-soy flour blends had lower dispersibility during storage at 8 weeks, while orange flesh sweetpotato-sorghum-soy flour blends had higher dispersibility during storage at week 0. Dispersibility is a measure of the reconstitutability of flour or flour blends in water. The higher the dispersibility, the better the flour reconstitutes in water (Kulkarni et al., 1991). However, since the dispersibility value for the flour samples during the storage is relatively high, it implies that the flour sample will reconstitute easily to give fine consistency dough during mixing, as reported by Adebowale et al. (2011).

Swelling power connotes the expansion accompanying the spontaneous uptake of a solvent, while the solubility index is the amount of water soluble solids per unit weight of the sample (Adepeju et al., 2014). The swelling power and solubility index of orange flesh sweetpotato-sorghum-soy flour sample decreased, ranging from 4.19 to 3.74 g/g and 3.12 to 2.82, respectively. The swelling power and solubility index of orange flesh sweetpotato-sorghum-soy flour sample during storage had the lowest value at 8 weeks, while orange flesh sweetpotato-sorghum-soy flour blends had the highest swelling power and solubility index during storage at week 0. Kinsella (1976) reported that swelling causes changes in the hydrodynamic properties of the food, thus impacting characteristics such as body thickening and increased viscosity of foods. This implies that the flour blend (sample 40:40:20) with the highest swelling power during the period of storage at week 0 will produce a thick viscous gruel, compared to other weeks of storage. This might be due to the higher carbohydrate content in the blend before the storage time.

Water absorption capacity is the ability of flour to absorb water and swell, for improved consistency in food. It is desirable for food systems to improve yield and consistency and to give body to the food (Osundahunsiet al., 2003). The water absorption capacity during the period of storage ranged from 77.50 to 94.50 %. Orange flesh sweetpotato-sorghum-soy flour sample had the lowest swelling power during storage at 8 weeks, while orange flesh sweetpotato-sorghum-soy flour blends during storage had the highest swelling power at week 0. The values of the water absorption capacity obtained for the flour sample during the period of storage correspond with the swelling power and solubility. This implies that the low water absorption capacity of the flour blend (sample 40:40:20) obtained in this work during the period of storage will be desirable for making thinner gruel with high caloric density per unit value (Adepeju et al., 2014).

Table 2. Functional properties of orange flesh sweetpotato-sorghum-soy flour blend of sample 40:40:20 during storage

Weeks	Bulk density(g/mL)	Dispersibility (%)	Swelling power(g/g)	Solubility index (%)	Water absorption capacity (%)
0	0.57 ± 0.00^{a}	86.00 ± 0.00^{c}	4.19 ± 0.04^{d}	3.12 ± 0.01^{c}	94.50 ± 0.71^{c}
2	0.60 ± 0.00^{a}	84.50 ± 0.71^{c}	3.99 ± 0.03^{c}	2.93 ± 0.04^{b}	85.00 ± 1.41^{b}
4	0.60 ± 0.00^{a}	75.50 ± 2.12^{b}	3.84 ± 0.01^{b}	2.89 ± 0.02^{ab}	83.50 ± 0.71^{b}
6	0.60 ± 0.00^{a}	71.50 ± 0.71^{a}	3.82 ± 0.02^{b}	2.87 ± 0.01^{ab}	82.00 ± 1.41^{ab}
8	0.60 ± 0.01^{a}	69.00 ± 1.41^{a}	3.74 ± 0.03^{a}	2.82 ± 0.03^{a}	77.50 ± 3.53^{a}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$)
OF- orange flesh sweetpotato, S –sorghum, S- soy flour

Table 3. Storage stability of orange flesh sweetpotato-sorghum-soy flour of sample 40:40:20

Weeks	Moisture content (%)	Free fatty acids (%)	Peroxide value (meq/kg)
0	7.11 ± 0.02^{a}	1.02 ± 0.03^{a}	0.05 ± 0.00^{c}
2	7.72 ± 0.03^{b}	2.46 ± 0.03^{b}	0.09 ± 0.00^{b}
4	8.20 ± 0.03^{c}	2.67 ± 0.03^{c}	1.12 ± 0.02^{d}
6	8.70±0.01a	3.59±0.03c	1.19 ± 0.01^{a}
8	9.40 ± 0.02^{d}	2.26 ± 0.01^{d}	1.28 ± 0.01^{d}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$)

Chemical composition of orange flesh sweetpotato-sorghum–soybean flour (sample 40:40:20) during storage

The moisture content of the flour sample ranged between 7.11 and 9.40 %. The moisture content is a function of the drying time and the loading depth during the drying operation. Higher moisture content indicates increased susceptibility to spoilage and thus reduces shelf life. The low moisture content of the flour sample was within the acceptable limit of not more than 10% for the long storage of flour. The result obtained for the moisture content of the flour sample during storage shows that there was a gradual uptake of moisture by all the flour samples throughout the storage period. The increase in moisture content of the stored flour sample could be attributed to the storage conditions such as temperature, relative humidity, time, and the packaging material (high density polyethylene), which allows the movement of certain gases across the material (Daramola et al., 2010).

Free fatty acids are a measure of the extent to which glycerides in the oil have been decomposed by lipase or other actions (Pearsons, 1991). Rancidity is accompanied by free fatty acids and the formation, i.e. spoilage of the flour, and is used as a condition for edibility. Free fatty acids of the flour samples ranged from 1.02 to 3.59 %. Orange flesh sweet potato-sorghum-soy flour sample had the lowest free fatty acids during storage at week 0, while orange flesh sweet potato-sorghum-soy flour blends had the highest free fatty acids during storage at 6 weeks. The results obtained in this study show that the low free fatty acids value obtained is an indication of the long storage period in the flour sample.

Peroxide value is usually used as an indicator of deterioration of fats. As oxidation takes place, the double bonds in the unsaturated fatty acids break down to produce secondary oxidation products which indicate rancidity (Ihekoronye and Ngoddy, 1985). The peroxide value during the period of storage ranged from 0.05 to 1.28 meq/kg. Orange flesh sweetpotato-sorghum-soy flour sample had the highest peroxide value during storage at 8 weeks, while orange flesh sweetpotato-sorghum-soy flour blends had the lowest peroxide value during storage at week 0. During storage, the peroxide value increased significantly ($p<0.05$) as the storage period increased. This was in agreement with the observation of Gahlawat and Sehgal (1994) that the peroxide value and fat acidity of weaning food developed from locally available food stuffs increased with the increase in the storage period.

Conclusions

The study shows that complementary food can be produced from the flour blends of orange flesh sweetpotato-sorghum-soy flour, however, the flour blend of sample 40:40:20 was the most acceptable in terms of all the sensory attributes for complementary food. It can be deduced from the result that during the storage days of the flour blend sample 40:40:20 the dispersibility and water absorption capacity of the flour blend had a higher affinity for water.

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