Effect of Puffing on Oil Characteristics of *Amaranth* (Rajgeera) Seeds

Rekha S. Singhal* and **P. R. Kulkarni**
Food and Fermentation Technology Division, University Department of Chemical Technology, Matunga, Bombay 400019, India

Puffing or popping is a common method of processing *Amaranthus cruentus* (Syn. *Amaranthus paniculatus* L. or Rajgeera) grain. Investigations into the effect of this processing treatment have shown the percent unsaturation in the oil to decrease from 75.5% to 62.3%. The maximum effect is on linoleic acid, the quantity of which decreased sharply from 46.8% to 27.0%. Squalene also increased by 15.5%, due to puffing of amaranth seeds.

KEY WORDS: ***Amaranthus cruentus*** **(Syn. *Amaranthus paniculatus* L.) seeds, oil characteristics, popping.**

Amaranth are crop species that have been identified as having the potential to increase world food production (1). These lysine-rich, high-protein grains grow in yields comparable to other cereals (2) in a wide range of agronomical conditions. They are doubly promising as they also supply tasty, leafy vegetables of superior nutritional quality (1,3). They grow in isolated mountain valleys of Mexico, Central and South America and Asia. They are gaining a foothold in the United States, and they are predicted to sweep the entire African continent as a new staple grain (4). Puffing is the most widely used method of processing amaranth grain in India and Mexico, where the seeds form a local crop. Puffed grains are lighter, with a desirable, nutty, popcorn-like flavor. They are eaten as snack, as a cold cereal with milk and honey, or held together with honey as a sweet (5). In India, amaranth seeds are most commonly used in the form of candies known as chikkis/laddoos (6), for which the seeds are popped and bound in a sugar syrup. In Mexico, similarly candies, called alegria (5), are prepared from popped amaranth grain and molasses.

Lately, these grains have been studied in detail with respect to the nutrient composition (5,6), and protein quality (7), both in unpuffed and puffed forms, but the effect of puffing on the oil component of this grain has not been studied. Amaranth grains contain 7-8% oil having 70% unsaturated fatty acids (8) and an unusually large amount of 5-8% squalene (9). This study was aimed at determining the effect of puffing on amaranth seed oil with respect to its characteristics, fatty acid composition and squalene content.

MATERIALS AND METHODS

Amaranth seeds, locally known as Rajgeera (*Amaranthus paniculatus* L. or *A. cruentus* L.) were procured from a local market in Bombay City, cleaned of dirt, stones and stems and ground to 60 mesh. Puffing was carried out on 25-g batches of whole seeds by heating in a pan preheated to 185-195°C with continuous stirring for 1-2 min. The temperature was maintained by adjusting the flame. The dimensions of the pan were 20 cm diameter × 5 cm height. The puffed grains were then ground to 60 mesh.

The oil was extracted from unpuffed and puffed seed flour for 16 hr in a Soxhlet extractor with pet. ether (60-80°C, bp) as the solvent. The solvent was then evaporated and the isolated oil was subjected to the following analysis.

*To whom correspondence should be addressed.

Oil characteristics of unpuffed and puffed amaranth seed oil. Analysis was done with respect to iodine value (10), saponification value (10), free fatty acid content expressed as oleic acid (10), peroxide value (10), refractive index (10), color value in terms of lovibond tinctometer units (11), specific gravity (11) and TBA number (12) by using standard well-documented methods.

Squalene content in unpuffed and puffed amaranth seed oil. i) Oils extracted from unpuffed and puffed amaranth seeds were analyzed for squalene content by the AOAC method (10); ii) the oils from unpuffed and puffed amaranth seeds were diluted with spectroscopic grade hexane to 0.005% (w/v) concentration and scanned in the UV region of 400-200 nm; and iii) 1% (w/v) of standard squalene (Sigma Chemical Co., St. Louis, MO) in spectroscopic grade hexane was also scanned in the UV region of 400-200 nm.

Triglyceride composition of amaranth seed oil and changes due to puffing. Fatty acid methyl esters from unpuffed and puffed amaranth seed oil were prepared by refluxing with methanol and chloroform (11). These fatty acid methyl esters were analyzed in a Varian 6000 Gas Chromatograph (Varian Associates, Palo Alto, CA) equipped with a flame ionization detector, and a 3 mm internal diameter × 3 m stainless steel column packed with 20% DEGS on Chromosorb W acid-washed 60-80 mesh. The operating conditions used were: temperature of the column, 200°C, of detector and injection port, 290°C. The flow rate of carrier gas, nitrogen, was 20 mL/min. The identification of fatty acids were based on their retention times, which were determined previously by analysis or standard mixtures under identical conditions.

RESULTS AND DISCUSSION

Table 1 gives the characteristics of oil of amaranth seeds subjected to puffing. It was observed that there was a darkening of oil which had manifested itself in decreased yellow units in the lovibond tinctometer. There was a slight increase in saponification value and, hence, a decrease in mean molecular weight of fatty acid of amaranth seed oil. Some degree of oxidation was apparent from the increased TBA value of puffed amaranth seed oil. An almost three-fold increase in free fatty acids from 4.1% in unpuffed to 11.5% for puffed seed oil and a two-fold increase in peroxide value from 5.1 meq/kg to 10.2 meq/kg confirmed the same. Also, some polymerization of the oil was evident from the increase in specific gravity and viscosity of the oil at room temperature. Refractive index of the oil remained unchanged upon puffing. Squalene content of 4.9% in unpuffed seed oil was in agreement with earlier reports (5,9). However, a 15.5% increase in squalene content was observed on puffing. The increase in squalene content is also clearly seen when the UV scan of pure squalene (Fig. 1) and those of unpuffed and puffed amaranth seed oil are compared (Fig. 2). Both figures showed a peak at 272 nm due to squalene. At similar concentration, the absorbance for puffed amaranth seed oil was higher at 272 nm than that for unpuffed amaranth oil, conforming the increased squalene content due to puffing. Squalene is reported to have an iodine value of 360-380 (13), and this fact could explain the insignificant

change in iodine value of the oil on puffing. The only plausible explanation that can be given for the increased squalene content is that puffing could have possibly destroyed some components of the oil so that it becomes relatively richer in squalene. A recent report has shown squalene content in *amaranth* oil to be increased upon alkali refining from 6.06 to 6.01% (9).

TABLE 1

Changes in Oil Characteristics of Amaranth Seeds Due to Puffing

Characteristics	Oil from unpuffed amaranth seeds	Oil from puffed amaranth seeds
Iodine value[a]	100.0	96.8
Saponification value[a]	217	237
Mean molecular weight of fatty acid (MW)[a, b]	246	324
Refractive index[a]	1.470	1.470
Color value[a]	3 R + 2.8Y	3 R + 2.1Y
Viscosity (η)[c, d]	40.1	42.3
TBA value[c]	1.22	1.59
Specific gravity[a]	9.8155	9.186
Squalene[a] (mg/100 g oil)	4884	5642
% Free fatty acid[a] (expressed as oleic acid)	4.1	11.5
Peroxide value[a]	5.1	10.2

[a]Mean of three determinations.

[b]From the formula, $MW = \frac{56{,}000}{SV} - 12.67$.

[c]Mean of five determinations.

[d]On Ostwald viscometer, $= \frac{\text{time of flow of oil}}{\text{time of flow of water}}$.

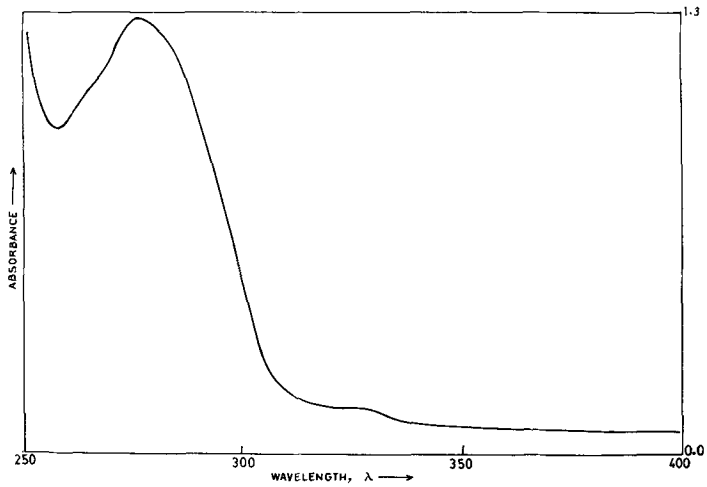

FIG. 1. UV spectrum of 1% standard squalene.

The fatty acid composition of unpuffed and puffed amaranth seed oil is given in Table 2. The fatty acid composition of unpuffed amaranth oil was found to be comparable with oils of other *Amaranthus* species (6), which are as follows: palmitic, 11.8-22.1%; stearic, 2.6-8.6%; oleic, 19.8-39.0%;

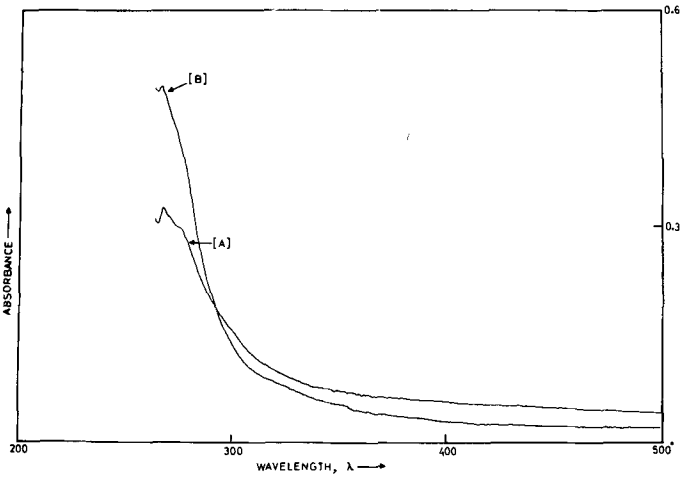

FIG. 2. UV spectra of 0.005% of A, unpuffed; and B, puffed *amaranth* oil.

TABLE 2

Effect of Puffing on Triglyceride Composition[a] of Amaranth Seed Oil

Fatty acid	Fatty acid % in unpuffed amaranth oil	Composition % in puffed amaranth oil
Palmitic acid, $C_{16:0}$	20.65	27.59
Palmitoleic acid, $C_{16:1}$	0.95	1.01
Stearic acid, $C_{18:0}$	3.84	4.96
Oleic acid, $C_{18:1}$	25.75	31.60
Linoleic acid, $C_{18:2}$	46.79	27.04
Linolenic acid, $C_{18:3}$	2.02	2.61

[a]Mean of two determinations.

linoleic, 25.0-62.1%; and linolenic, 0.7-1.8%. Unsaturation of 75.5% was found, which is in agreement with that reported by other researchers (8, 14-16). Puffing caused a decrease in unsaturation to 62.3%, indicating deterioration of unsaturated fatty acids. The maximum damage was caused to linoleic acid, the quantity of which decreased sharply from 46.8% in unpuffed seed oil to 27.0% in puffed seed oil. The higher values of other fatty acids, particularly palmitic and oleic, can be explained as due to changes in the relative distribution of fatty acids in the oil. To conclude, puffing or popping as a method of processing amaranth grain causes deterioration, not only of protein, but of oil as well. However, the deterioration is not severe enough to limit the grain's potential utility. The unsaturation after puffing is 62%, which is more than that of coconut oil. Also, since puffed oil has higher squalene content, it could be used potentially to isolate squalene on a commercial scale.

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[Received October 14, 1989; accepted August 15, 1990]