ELSEVIER

PII: S0308-8146(96)00160-4

Food Chemistry, Vol. 58, No. 4, pp. 313-317, 1997

0308-8146/97 $17.00+0.00

Deep fat-fried snacks from blends of soya flour and corn, amaranth and chenopodium starches

N. Thoufeek Ahamed,[a] Rekha S. Singhal,[a] Pushpa R. Kulkarni[a]* & Mohinder Pal[b]

[a]*Food and Fermentation Technology Division, University Department of Chemical Technology, Matunga, Bombay 400019, India*
[b]*National Botanical Research Institute, Lucknow, India*

(Received 25 September 1995; revised version received 12 December 1995; accepted 12 December 1995)

This work reports on the oil content of fried noodle-like products prepared from a blend of soya flour and starch in ratios ranging from 80:20 to 20:80 of soya flour:starch. Three starches differing in their amylose content, namely corn, *Chenopodium quinoa* and *Amaranthus paniculatus*, were chosen for the study. The oil content in fried products decreased with increased starch content. The extent of decrease was observed to be correlated to the amylose content. The advantage of newer food sources, such as *Amaranthus paniculatus* and *Chenopodium quinoa*, is thus indicated. Copyright © 1996 Published by Elsevier Science Ltd

INTRODUCTION

The importance of dietary fat is now well recognized. Fried foods are considered as concentrated sources of energy and fat. Reduction in oil content of fried foods is therefore an area of interest to researchers (Adambounou & Castaigne, 1981; Greenfield *et al.*, 1984; Gamble & Rice, 1987; Makinson *et al.*, 1987; Varela *et al.*, 1988). Oil content is often not essential for product quality and is disadvantageous to both the food processor (high operating cost) and the consumer (imbalance in nutritional value).

Deep fat frying is very popular and is used widely by food industries and domestic households. Many factors are known to affect oil uptake. These include specific gravity or water content of the food being fried (Adambounou & Castaigne, 1981; Gamble & Rice, 1987; Makinson *et al.*, 1987; Varela *et al.*, 1988), surface of the food in contact with the frying medium (Adambounou & Castaigne, 1981; Greenfield *et al.*, 1984; Makinson *et al.*, 1987; Gamble & Rice, 1987; Varela *et al.*, 1988), frying time (Pravisani & Calvelo, 1986), frying temperature (Varela, 1977; Van Zeddlemann, 1981), number of frying cycles (Varela *et al.*, 1988), method of frying (i.e. single or split frying; Greenfield *et al.*, 1984), batter coatings (Makinson *et al.*, 1987; Duxbury, 1989), physical and chemical properties of the frying medium, ingredients in the foods (solids, moisture, fat and protein), porosity, and prefrying treatments (drying, blanching).

The considerable range in oil uptake during frying has been attributed to differences in formulation and variations between batches and manufacturers (Smith *et al.*, 1985). Fatty foods are known to absorb more fat during frying compared to low fat foods (Varela *et al.*, 1988). Crude sodium bicarbonate, commonly termed papadkhar, is also known to increase oil absorption in papads (Chaudhury *et al.*, 1985). In doughnuts, increasing the egg and/or yolk content leads to a decrease in consumption of frying fat (Van Zeddlemann, 1988).

The mechanism of oil frying is poorly understood, but an increased understanding would enable low-fat food products to be created using locally available raw materials and newer food sources. *Amaranthus* and *Chenopodium* are recognized as lysine-rich high-protein grains which have the potential to meet the world's food requirements (Singhal & Kulkarni, 1988; Ruales & Nair, 1992, 1993). Both these grains contain starch of small granule size (1–2 μm) as the major constituent. While amaranth grains are acceptable as such, chenopodium grains have a limited organoleptic acceptability due to the presence of bitter saponins (Reichert *et al.*, 1986). Hence, utilizing grain constituents such as chenopodium starch, which can be isolated in a saponin-free form, in food formulations would be desirable.

In the present work, the effects of starch content and type on oil absorption of fried noodle-like formulations were evaluated. The study involved corn, *Chenopodium quinoa* and *Amaranthus paniculatus* starches blended with commercial soya flour.

---

*To whom correspondence should be addressed.

MATERIALS AND METHODS

Materials

Corn starch was obtained from Laxmi Starch Pvt. Ltd., Bombay.

Seeds of *Amaranthus paniculatus* (locally known as Rajgeera) was obtained from a local market in Bombay City. Seeds of *Chenopodium quinoa* were obtained as a gift sample from the National Botanical Research Institute, Lucknow. Starches from *A. paniculatus* and *C. quinoa* were isolated in the laboratory by the alkali-steeping method (Yanez & Walker, 1986).

Inactivated soya flour (ISF) was obtained from Encore Ltd., Zurich, Switzerland.

Ground nut oil (Postman brand) was obtained from a local market.

Methods

Preparation of model systems
Each of the three starches was mixed with inactivated soya flour, in ratios ranging from 20:80 to 80:20 of starch:ISF, by dry-blending in a mixer to ensure uniform mixing.

Preparation of the extruded snacks
A 50 g amount of each of the above blends was mixed with 28–36 ml of water, depending upon the requirement, to form a dough of uniform consistency. This dough was then cooked at atmospheric pressure in a pressure cooker for 10 min and then cooled. The cooked dough was extruded through a hand extruder (diameter approx. 4 mm) with a piston and die arrangement. The hand extruder was coated with hydrogenated fat to aid extrusion. The extruded strips were dried in a tray drier at 50–55°C for 4 h to give dry noodle-shaped products.

A 5 g amount of each of the noodle samples was fried in 250 ml of ground nut oil at 160°C for 45–50 s, then drained for 5 min before analysis. The oil was changed after every seven frying cycles.

Analysis of the extruded fried snacks

Oil absorption Each of the extruded fried noodle samples was analysed for oil content in a Soxtec apparatus (Tecator, Sweden) using petroleum ether AR grade (60–80°C) as solvent. Each analysis was carried out in duplicate.

Bulk density The bulk density of each of the products was measured in triplicate before and after frying. The bulk density (ρ) was calculated using the formula:

$$\rho = \frac{W}{\pi r^2 l}$$

where W is the weight of the sample (g), r is the radius of the sample (cm) and l is the length of the sample (cm).

Analysis of amylose contents of the starches under study
This was done colorimetrically by the procedure of McCready & Hassid (1943).

RESULTS AND DISCUSSION

Figure 1(a)–(c) show the oil content in extruded and fried snacks prepared using varying ratios of ISF and the three starches. In the case of amaranth starch, it was not possible to extrude samples containing 70% and 80% starch due to the stickiness of the product, and great difficulties were encountered in handling these batches. In all cases, the oil absorption of the extruded snacks decreased as the starch content in the composite blend increased. At levels below 20% starch and above 80% starch, disintegration during extrusion was observed. However, the rate of decrease in each case varied, as can be seen from the slopes of the graphs (Fig. 1(a)–(c)) of percentage oil absorption versus percentage starch content in the blend. The regression equations so obtained for each of the three starches were as follows:

Corn starch:

$$Y = -0.28X + 34.68 (R^2 = 0.98)$$

Amaranth starch:

$$Y = -0.64X + 45.92 (R^2 = 1.00)$$

Chenopodium starch:

$$Y = -0.44X + 43.44 (R^2 = 0.90)$$

From the values of the slope, it is evident that amaranth starch has a greater effect in reducing oil absorption. This is followed by chenopodium starch and then by corn starch. These differences could be interpreted as follows. Oil uptake during frying is a surface phenomenon. An increased hydrophobic character of the surface would result in an increased oil uptake during frying. This has recently been suggested (Pinthus & Saguy, 1994). Similarly, the effect of product hydrophobicity has also been reported (Blumenthal, 1991). The ability of powdered cellulose to reduce oil uptake in fried foods has been attributed to its hydrophilic character (Ang & Miller, 1991). It can be speculated that, the higher the amount of soya flour in the composite blend, the greater would be the probability of the surface being more hydrophobic. Hence, as the soya flour level decreases, the hydrophobicity decreases, as a consequence of which oil uptake decreases. The differences in the behaviour of the three starches could also be attributed to the surface characteristics. It seems probable that the three starches interact to different extents with soya protein. This affects the hydrophobicity and hence the oil uptake. A reduced surface tension between oil and water also causes an increase in oil absorption (Mohamed *et al.*, 1995). Addition of starch to soya flour probably increases the surface tension, and hence causes a reduction in oil absorption.

The amylose contents of corn, amaranth and chenopodium starches were found to be 22%, 0% and 11%, respectively. It appears that the effect of each starch type on oil uptake is correlated to its amylose content. This can be seen from the plot of slope value (*m*) versus amylose content in the starches (Fig. 2). This is supported by the fact that amylose has a tendency to form complexes with lipids (Czuchajowska *et al.*, 1991; Szczodrak & Pomeranz, 1992). Further investigations need to be carried out in this respect.

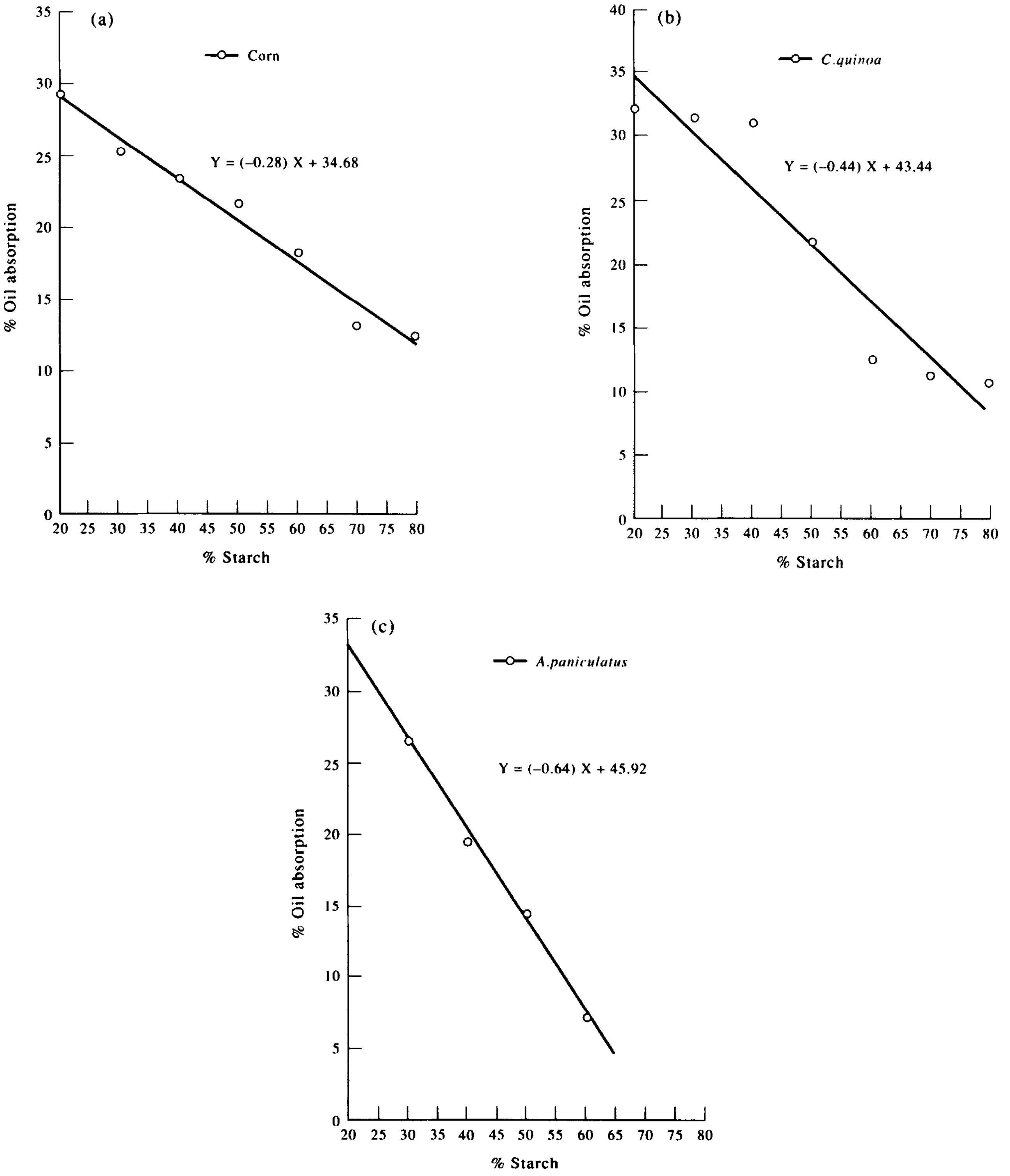

Fig. 1. (a) Effect of the ratio of corn starch to inactivated soya flour on oil absorption of extruded snack; (b) effect of the ratio of *C. quinoa* starch to inactivated soya flour on oil absorption of extruded snack; (c) effect of the ratio of *A. paniculatus* starch to inactivated soya flour on oil absorption of extruded snack.

Table 1. Effect of starch–ISF combination on bulk densities (ρ) of extruded snacks

Starch (%)	Chenopodium starch + ISF			Corn starch + ISF			Amaranth starch + ISF		
	BF	AF	AF/BF	BF	AF	AF/BF	BF	AF	AF/BF
20	0.712 ± 0.043	0.782 ± 0.018	1.098	0.798 ± 0.024	0.782 ± 0.027	0.979	0.831 ± 0.026	0.812 ± 0.015	0.98
30	0.786 ± 0.056	0.830 ± 0.119	1.056	0.634 ± 0.017	0.848 ± 059	1.338	0.914 ± 0.009	0.963 ± 0.048	1.05
40	0.734 ± 0.009	0.888 ± 0.036	1.21	0.705 ± 0.112	0.819 ± 0.090	1.162	0.841 ± 0.008	1.077 ± 0.101	1.28
50	1.335 ± 0.104	1.482 ± 0.287	1.11	0.922 ± 0.040	0.907 ± 0.90	0.984	1.574 ± 0.034	0.785 ± 0.010	0.5
60	1.306 ± 0.130	0.816 ± 0.085	0.625	0.835 ± 0.075	0.782 ± 0.071	0.937	1.564 ± 0.059	—	—
70	1.131 ± 0.059	0.807 ± 0.160	0.714	0.855 ± 0.094	0.843 ± 0.010	0.986	—	—	—
80	1.725 ± 0.440	0.868 ± 0.072	0.503	1.609 ± 0.234	0.844 ± 0.010	0.525	—	—	—

ISF, inactivated soya flour; BF, before frying; AF, after frying.

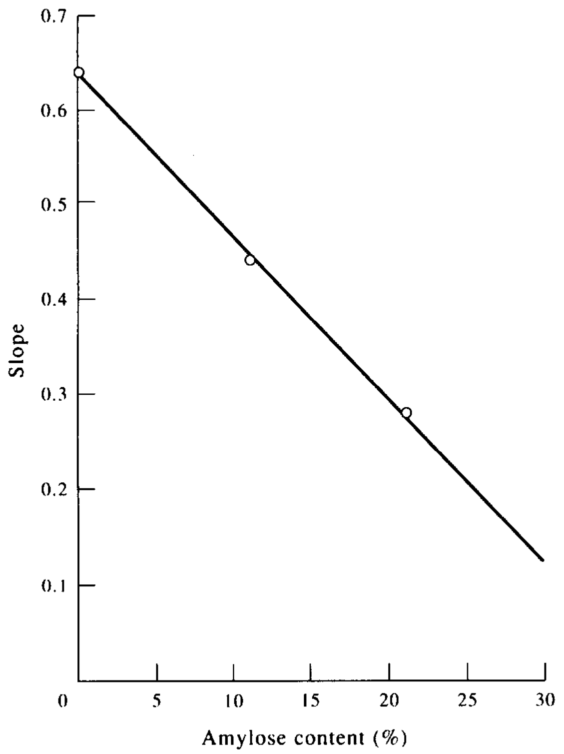

Fig. 2. Correlation between '*m*' (from Fig. 1(a–c)) and amylose content.

Table 1 gives the bulk density of the extruded products before and after frying and the ratios of their bulk densities after and before frying. It is interesting to observe that the product prepared from 60% amaranth starch and 40% ISF disintegrated during frying. No general trend between the ratios of bulk densities and amounts of starch and/or protein was observed. However, at the level of 50% soya flour, among the three starches, amaranth starch had the lowest ratio of bulk density after frying to that before frying; a low ratio would indicate a lighter product, which is preferred organoleptically. Fried snacks from ISF and chenopodium starch had a higher ratio than amaranth starch, and the corn starch–ISF combination had a higher ratio than the chenopodium–ISF blend. Amongst the corn and chenopodium starches at levels of 60%, 70% and 80% in a blend with ISF, chenopodium showed a lower ratio of bulk density after frying to that before frying. Although it would be premature to attribute this behaviour to the amylose content, this appears to be the trend and needs further experimentation.

CONCLUSIONS

The findings from this study should be useful in utilizing constituents of the grain chenopodium in food formulations and could help in utilizing the grain itself. This is of particular relevance since the grain as such has limited organoleptic acceptability due to the presence of bitter saponins. Amaranth starch gave the lowest oil content in deep fat-fried snacks and could be used in the development of low-fat fried formulations.

REFERENCES

Adambounou, T. L. & Castaigne, F. (1981). Influence of partial drying on oil absorption and texture of french fries. *Can. Inst. Food Sci. Technol.*, **14**(4), 304–309.

Ang, J. F. & Miller, W. B. (1991). Multiple functions of powdered cellulose as a food ingredient. *Cereal Foods World*, **36**(7), 558–564.

Blumenthal, M. M. (1991). A new look at the chemistry and physics of deep-fat frying. *Food Technol.*, **45**(2), 68–71, 94.

Chaudhury, N. M., Rajgopal, M. V., Ray, S. P. & Mudambi, S. R. (1985). Effect of incorporating papadkhar (crude sodium carbonate) in papad doughs on the physico-chemical properties of the frying medium. *J. Food Sci. Technol.*, **22**(2), 119–122.

Czuchajowska, Z., Silverb, D. & Pomeranz, Y. (1991). Enzyme resistant starch. Effect of complexing lipids. *Cereal Chem.*, **66**(5), 537–542.

Gamble, M. H. & Rice, P. (1987). Effect of Pre-fry drying on oil uptake and distribution in potato crisp manufacture. *Int. J. Food Sci. Technol.*, **22**(5), 535–539.

Gamble, M. H. & Rice, P. (1988). Effect of initial tuber solids content on final oil content of potato chips. *Lebensm. Wiss. Technol.*, **21**, 62–65.

Greenfield, H. J., Makinson, J. & Wills, R. B. H. (1984). Lipids in french fries: a retail and laboratory study. *J. Food Technol.*, **19**(2), 239–245.

Makinson, J. H., Greenfield, H., Wong, M. L. & Wills, R. B. H. (1987). Fat uptake during deep fat frying of coated and uncoated foods. *J. Food Comp. Anal.*, **1**(1), 93–97.

McCready, R. M. & Hassid, W. Z. (1943). The separation and quantitative estimation of amylose and amylopectin in potato starch. *J. Am. Chem. Soc.*, **65**, 1154–1156.

Mohamed, S., Md Lajis, S. M. & Hamid, N. A. (1995). Effects of protein from different sources on the characteristics of sponge cakes, rice cakes (apam), doughnuts and frying batters. *J. Sci. Food Agric.*, **88**, 271–277.

Pinthus, E. J. & Saguy, I. S. (1994). Initial interfacial tension and oil uptake by deep-fat fried foods. *J. Food Sci.*, **5**(4), 804–807, 823.

Pravisani, C. I. & Calvelo, A. (1986). Minimum cooking time for potato strip frying. *J. Food Sci.*, **51**(3), 614–617.

Reichert, R. D., Tatarynovich, J. T. & Iyer, R. T. (1986). Abrasive dehulling of quinoa (*Chenopodium quinoa*). Effect on saponin content as determined by an adapted hemolytic assay. *Cereal Chem.*, **63**(6), 471–475.

Ruales, J. & Nair, B. M. (1992). Nutritional quality of the protein in quinoa seeds. *Plant Foods Hum. Nutr.*, **42**, 1–11.

Ruales, J. & Nair, B. M. (1993). Contents of fat, vitamins and minerals in *C. quinoa* seeds. *Food Chem.*, **48**(2), 131–137.

Singhal, R. S. & Kulkarni, P. R. (1988). Amaranth: an underutilised resource. *Int. J. Food Sci. Technol.*, **23**, 125–139.

Smith, L. M., Clifford, A. J., Hamblin, C. L. & Creveling, R. K. (1985). Lipid content and fatty acid profile of various deep-fat fried foods. *J. Am. Oil Chem. Soc.*, **62**(6), 976–979.

Szczodrak, J. & Pomeranz, Y. (1992). Starch–lipid interactions and formulation of resistant starch in high amylose barley. *Cereal Chem.*, **69**(6), 626–632.

Van Zeddlemann, H. (1981). Frying and cooking fat and their quality control. *CCB Rev. Choc. Confect. Bakery*, **6**(3), 25–27.

Varela, G. (1977). Heated fats: a contribution to the study of the food frying process. *Bibl. Nutr. Dieta*, **25**, 112–121.

Varela, G., Bender, A. E. & Morton, I. D. (1988). In *Frying of Foods Principles, Changes, New Approaches*. Ellis Horwood, Chichester, UK.

Yanez, G. A. & Walker, X. X. (1986). Effect of tempering parameters as extraction and ash of proso millet flours and partial characterization of prosostarch. *Cereal Chem.*, **63**(2), 164–167.