Food Chemistry **20** (1986) 175–182

Changes in the Parboiled Seeds of *Treculia africana* Caused by Improper Drying and Microbial Infection

R. Ola Lawal

Department of Chemistry, The Polytechnic, Ibadan, Nigeria

(Received: 21 August, 1985)

ABSTRACT

Improper drying of the seeds of Treculia africana *can lead to contamination by moulds and bacteria.*

Investigation revealed that moulds increased from $5{\cdot}2 \times 10^4$ per gram to $3{\cdot}6 \times 10^7$ per gram and bacteria increased from $3{\cdot}5 \times 10^6$ per gram to $76{\cdot}1 \times 10^6$ per gram when parboiled seeds were not dried for 7 days due to humid weather.

The yield of white seed cotyledons decreased to 60·1% from 80·2% due to infection. The resultant white seed cotyledons contained only 4·47% oil compared with 7·07% in the normally dried parboiled seeds (control).

The infection brought about an increase in the levels of sugars, amino acids and polyphenols in the parboiled seeds.

INTRODUCTION

The African breadfruit plant (*Treculia africana*) is widely distributed in the forest zone of Nigeria. It bears fruits which are usually spongy in texture and contain numerous individual seeds embedded at various depths in the fleshy elongated bracts. The fruit has great potential as a food source.

Nutritional studies on the seeds of *T. africana* have shown that the parboiled seeds and the cooked 'testa-free' seeds are good sources of high quality protein (Lawal, 1979; Bassir & Lawal, 1985).

The raw seeds of *T. africana* are normally parboiled and then dried in the sun (using the traditional preparation technique) to enhance the flavour and keeping quality. However, during the months of October to November each year, grains (parboiled seeds) have to be frequently heaped and covered due to threatening, or intermittent, showers of rain. The inadequate drying or non-drying of the grains encourages microbial infection (Anthoni Raj *et al.*, 1981). Most often, the entire produce becomes highly discoloured, stale flavoured and reduced to mere brokens, decreasing the yield, quality and, ultimately, market value. During the course of infection, the grains undergo a variety of changes leading to deterioration in the physical strength of the white seed cotyledons.

Preservation of foodstuffs is one of the most pressing nutritional problems facing the Nigerian Government. This study was undertaken to show the changes in the parboiled seeds of *T. africana* caused by improper drying and microbial infection.

MATERIAL AND METHODS

The fruits of *Treculia africana* were obtained from Ishara-Remo, Ogun State, Nigeria. Large fresh fruits were allowed to macerate by placing them in water in large containers. After five days the seeds, which were embedded in the spongy pulp of the fruits, were extracted. These seeds were washed properly with water. These small seeds are referred to as the raw unprocessed seeds.

The raw seeds (100 kg) were soaked in water for 3 days and parboiled by steaming under atmospheric pressure in a steam kettle. The parboiled seeds, which showed 50% husk opening, were packed in separate cloth bags inside a room and allowed to pick up natural infection. The atmospheric relative humidity ranged from 80% to 90% which provided a favourable environment for infection of the grains. At 2-, 4- and 7-day intervals the moisture content was determined by drying 10 g of the whole grains in an oven at 105 °C for 24 h (AOAC, 1970). The biodeterioration (dry matter loss) due to infection was determined by assessing the initial and final dry weights of 100-g samples of the parboiled seeds, in separate cloth bags.

Duplicate and triplicate samples were withdrawn at the abovementioned intervals and the loss in dry weight determined by comparing with the initial dry matter.

The amount of microflora in the parboiled seeds was determined by the serial dilution plate technique, employing Martin's Rose Bengal agar for the enumeration of fungi and nutrient agar for bacteria. The plates were incubated at 30 ± 2 °C for 5 days. The infection turns part, or all, the parboiled seed kernel into chalky opaque blotches in the otherwise translucent parboiled kernel. The number of parboiled seeds that become chalky due to infection was determined in triplicate taking 10-g samples after de-husking.

Changes in the biochemical constituents were determined in ethanol extracts of the parboiled seeds using the modified method of Anthoni Raj & Singaravadivel (1980).

The total and reducing sugars were estimated following the method of Nelson (1944). The amino nitrogen was determined by the ninhydrin method (Moore & Stein, 1948), while total phenols were determined employing Folin-phenol reagent (Bray & Thorpe, 1954).

The yield of the white seed cotyledons from the infected parboiled seeds was obtained by drawing 100-g samples, at the above-mentioned intervals, which were air-dried quickly to arrest further multiplication of organisms. After drying, the seed coats were cracked with the aid of small stones, thus exposing the white seed cotyledons. These cotyledons were separated from the seed coats and later weighed. The reduction in yields of the white seed cotyledons were obtained by comparing these values at the various intervals mentioned above with those obtained for the control (dried) parboiled seeds.

The oil content and free fatty acids content of the parboiled seeds (control, dried and infected) were determined using hexane extraction (AOAC, 1970).

The heat development during the course of microbial manifestation in the parboiled seeds was measured using a 0–100 °C thermometer.

RESULTS

Table 1 shows the overall results of the changes in moisture content, heat development, grain infection and chalkiness in dehusked seeds due to microbial infection in parboiled seeds of *Treculia africana*. The moisture content of the parboiled seeds for 2 days of non-drying was 37·9 % compared with the initial level of 40·3 %. There was only a 2·4 % moisture reduction, which was quite insufficient to encourage rapid microbial

TABLE 1

Changes in Moisture Content, Heat Development, Grain Infection and Chalkiness in Dehusked Seeds due to Microbial Infection in Parboiled Seeds of *Treculia africana*

	Slow drying for Days			
	0	*2*	*4*	*7*
Moisture content (%)	40·3	37·9	32·6	28·8
Heat development (°C)	32·0	55·0	52·0	55·0
Chalkiness in dehusked seeds (%)	0	0	20	40
Dry matter loss (%)	0	3·5	5·6	6·5
Fungi (1×10^5/g)**	0·60	6·4	89·0	254·1
Bacteria (1×10^6/g)*	5·1	75·3	74·2	75·5
White seed cotyledon yield (%)*	80·2	79·9	65·2	60·1

* Significant at 1% level.
** Standard error for fungi, 3·84; for bacteria, 0·86.

invasion. The higher moisture level of the parboiled seeds and the higher relative humidity facilitated easy invasion by microbes. Okafor (1966) pointed out that the comparatively high ambient temperature and relative humidity, generally experienced in Nigeria, encourages the rapid deterioration of many stored products by microorganisms, especially if the stored materials are moist. Within 2 days the fungal flora increased from 6×10^4 per gram of parboiled seeds just after parboiling to $6{\cdot}4 \times 10^5$ per gram. At the initial stages, the parboiled seeds were infested by fast growing *Mucor mucedo* and *Mucor racemosus* which ramified the whole grain mass, causing webbing and caking. In some cases, it was observed that the fungal species grew, but did not strike deep into the kernel of the parboiled seeds. Subsequently, *Aspergillus flavus* and *A. fumigatus* predominated on the exposed surface of the individual parboiled seed kernel and penetrated it. *A. candidus*, *A. sydowi*, *A. niger* and *Penicillum citrinum* also grew on the parboiled seeds. These organisms sporulated heavily and the proliferating growth increased the fungal flora from $8{\cdot}9 \times 10^6$ per gram after 4 days to $2{\cdot}54 \times 10^7$ per gram after 7 days.

Bacterial flora, initially $5{\cdot}2 \times 10^6$ per gram, multiplied to $7{\cdot}6 \times 10^7$ per gram when the moisture was very high and when conditions were uncompetitive with respect to the fungal multiplication. However, a significant level of $7{\cdot}6 \times 10^7$ per gram, attained by bacteria on the second

TABLE 2
Changes in Sugar, Amino Nitrogen, Phenolics, Oil and FFA Contents in Control (Dried) Parboiled Seeds and Infected Parboiled Seeds

	Slow drying for days			
	0	*2*	*4*	*7*
Phenolics: Control (dried) seeds	0·5	0·4	0·6	0·65
(Infected) (mg/g)	0·5	0·55	0·75	0·85
Reducing sugars: Control (dried) seeds	1·6	1·8	1·8	2·0
(Infected) (mg/g)	1·6	6·0	5·6	5·6
Total sugars: Control (dried) seeds	4·8	4·1	4·0	4·0
(Infected) (mg/g)	4·8	7·0	6·0	6·2
Free fatty acids (FFA): (%) Control (dried)	4·0	3·7	3·8	4·1
(Infected)	4·0	10·2	15·0	20·5
Oil content: (%) control (dried) seeds	24·9	24·9	24·8	24·8
(Infected)	24·9	14·0	13·0	10·2
Amino nitrogen: control (dried) seeds	0·4	1·0	1·2	1·3
(Infected) (mg/g)	0·4	1·4	2·0	1·6

day, remained almost at the same level on the other days (fourth and seventh).

During the course of microbial manifestation, temperatures observed in the grains were 55 °C, 52 °C and 55 °C on the second, fourth and seventh days, respectively, while the ambient temperature was only 28 ± 2 °C.

There was moisture reduction in the parboiled seed, presumably due to the fact that the seeds were drying naturally in the bags. Consequently, the moisture content of the parboiled seeds decreased to 28·8 % after 7 days.

Table 2 shows the changes in sugar, amino nitrogen, phenolics, oil and free fatty acids (FFA) in control (dried) parboiled seeds and infected parboiled seeds.

DISCUSSION

Parboiled seeds are readily infected by fungi and bacteria whenever drying is prevented by an overcast sky or rain. The advancement of infection can be a cause of serious concern after 2 days due to associated heat development, discoloration and biochemical changes brought about by the microorganisms.

As shown in Table 1, bacterial flora, which initially multiplied to $7{\cdot}6 \times 10^7$ per gram on the second day of slow drying of the parboiled seeds, remained almost at the same level on the fourth and seventh days. This might be because fungal multiplication inhibited further bacterial proliferation in the parboiled seeds. Although the rise in temperature occurred when bacterial multiplication was rapid, both groups of microorganisms (fungi and bacteria) contributed to the heat development of the infected seeds. Eggins & Coursey (1964) reported that thermophilic microorganisms raise the temperature of stacks of nuts awaiting decortication up to 60 °C or higher. Three thermophilic fungi—*Penicillium* sp., *Thermomyces* sp. and *Chaetomium thermophile*—were isolated from the stacks of nuts. Also, the mesophiles, *Aspergillus candidus*, *A. fumigatus* and *A. flavus*, have been shown to be involved in the heating of grains (Okafor, 1966).

During the course of invasion, breakdown changes in starch, protein and fats occur, releasing higher levels of their monomeric forms which are utilized by the developing organisms. The presence of higher levels of sugars and amino acids indicates a breakdown of irreversibly fused (gelatinized) starch and proteins by the microbes, ultimately reversing the benefits achieved by parboiling. The breakdown reverses the strength of the seeds achieved in parboiling; thus, chalky pieces of the parboiled seeds often crumble, even with a light disturbance, indicating their inability to withstand strain. The increase in phenolic compounds (Table 2) might be due either to synthesis from the sugars via the shikimate pathway, or by conversion of amino acids (Neish, 1964).

The oil content of the infected parboiled seeds (Table 2) decreased to about 10·2 % after 7 days of infection, from 24·9 %, and consequently the free fatty acids increased from 4·0 % to 20·5 % over this period. This might be due solely to the action of the microbes on fats since the seed lipase is inactivated during parboiling (Shaheen *et al.*, 1975). The resultant cotyledon of the seeds has a low oil content and a high FFA content.

The infection by the microorganisms turned part, or all, of the parboiled seed kernel into dark brown chalky opaque blotches. The discoloration of the parboiled seeds due to infection might be due to either the reaction of sugars with amino acids released in higher levels in infected grains to form Maillard browning (Hunter *et al.*, 1956) or formation of phenol–amino acid complexes (Ramaswamy & Rege, 1975) or oxidation of phenolics to quinones, as observed in vascular browning of infected tissues (Mace, 1963) and in processed foods (Ramaswamy &

Rege, 1975). The production of pigments by the microorganisms, particularly the fungi, might also cause discoloration of the infected seeds (Bassir, 1964; Okafor, 1966).

The yellow colour of the lipids in the parboiled seeds might itself become intensified due to heat stress during the course of infection, as observed by Sowbhagya & Battacharrya (1976) for rice.

Spoilage changes can be reduced through the prevention of husk opening during parboiling and proper drying of the parboiled seeds in the sun for two days (Bassir & Lawal, 1985).

CONCLUSION

(1) The handicap in slow drying (during the rainy season) of the parboiled seeds results in heavy microbial contamination.
(2) The resultant white seed cotyledons are also of inferior quality with low oil and high FFA contents.
(3) The use of infected parboiled seeds and white seed cotyledons as food might pose health hazards due to mycotoxin contamination.

REFERENCES

AOAC (1970). Association of Official Agricultural Chemists. *Methods of analysis*. (11th edn).

Anthoni Raj, S. & Singaravadivel, K. (1980). Influence of soaking and steaming on the loss of simpler constituents in paddy rice. *J. Fd. Sci. Technol.*, **17**, 141–43.

Anthoni Raj, S., Venkatesan, V., Singaravadivel & Vasan, B. S. (1981). Improvement in conventional parboiling of rice through prevention of husk opening. *J. Fd. Sci. Technol.*, **18**, 252–53.

Bassir, O. (1964). The use of Nigerian foods containing cultures of toxic strains of *Aspergillus flavus*, *W. Afr. J. Biol. appl. Chem.*, **8**, 3–15.

Bassir, O. & Lawal, R. O. (1985). Changes in the major nutrients of the seeds of *T. africana* during dietary preparation. *J. of Plant Foods.*, **6**(3) (In press.)

Bray, H. C. & Thorpe, M. V. (1954). Analysis of phenolic compounds of interest in metabolism. *Meth. Biochem. Anal.*, **1**, 367–8.

Eggins, H. O. W. & Coursey, D. G. (1964). Thermophilic fungi associated with Nigerian oil products. *Nature* (*London*), **203**, 1083–84.

Hunter, I. R., Ferrel, R. E. & Houston, D. F. (1956). Free amino acid of fresh and aged parboiled rice. *J. Agric. Fd. Chem.*, **4**, 874–75.

Lawal, R. O. (1979). *The effect of a traditional food preparation technique on the nutritive value of the fruit of* T. africana. MPhil thesis, University of Ibadan, Nigeria.
Mace, M. E. (1963). Histochemical localisation of phenols in healthy and diseased banana roots. *Physiol. Plant*, **16**, 915–25.
Moore, S. & Stein, W. H. (1948). A modified ninhydrin reagent for the photodetermination of amino acids and related compounds. *J. Biol. Chem.*, **176**, 367–68.
Neish, A. C. (1964). Biosynthetic pathways of aromatic amino compounds. *Ann. Rev. Plant. Physiol.*, **11**, 58–80.
Nelson, N. (1944). A photometric adaptation of the Somogyii method for determination of glucose. *J. Biol. Chem.*, **15**, 375–80.
Okafor, N. (1966). Non-Pathogenic microbiology in Nigeria—A review. *W.A. Journal of Biol. appl. Chem.*, **9**(1), 4–13.
Ramaswamy, S. & Rege, D. V. (1975). Complexes of phenols with amino acids. *J. Fd. Sci. Technol.*, **13**, 24–26.
Shaheen, A. B., El Dash, A. A. & El. Shirbeeny, A. E. (1975). Effect of parboiling of rice on the rate of lipid hydrolysis and deterioration of rice bran. *Cereal Chem.*, **52**, 1–8.
Sowbhagya, C. M. & Bhattacharaya, K. R. (1976). Lipid auto oxidation in rice. *J. Fd. Sci.*, **41**, 1018–23.