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Full Length Research Paper

Sensory and nutritional quality characteristics of powdered 'Kunun-zaki': A Nigerian fermented cereal beverage

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Four types of 'kunun-zaki' produced in this study (millet + malted rice, millet + malted rice + starter culture, millet + wheat + malted rice, millet + wheat + malted rice + starter culture) were freeze-dried and evaluated for chemical (pH, titratable acidity); nutritional and sensory quality attributes and compared with the freshly prepared one. Changes in chemical and sensory quality of the powdered 'kunun-zaki' were evaluated during storage (6 months). The results show that there was no significant difference ($p > 0.05$) in the overall acceptability and mineral contents of the products; however, marginal differences occurred ($p < 0.05$) in pH, titratable acidity (% lactic acid), proximate and amino acids content. Furthermore, the powdered 'kunun-zaki' did not show any sign of deterioration as the overall quality acceptability of all the products were scored favourably (1.4 - 2.7; 7-point hedonic scale) throughout the storage period. The result of this study shows that the use of freeze-drying technique had extended the shelf-life of 'kunun-zaki' by 6 months.

Key words: Starter culture, 'Kunun-zaki', freeze-drying, shelf-life study, cereals.

INTRODUCTION

'Kunun-zaki' is fermented non-alcoholic cereal beverage whose popularity in Nigeria is due to its characteristic sweet-sour taste typical of other lactic acid bacterial fermented foods of African origin such as mahewu and baganiya (Dirar, 1993; Efiuvwevwere and Akoma, 1995). However, the short shelf-life (24 - 48 h) of this product is of major concern to its manufacturers and consumers (Efiuvwevwere and Akoma, 1997; Inyang and Dabot, 1997). Attempt has been made by various workers to extend the shelf-life of 'kunun-zaki' up to two weeks using combinations of heat treatment and chemical preservatives (Efiuvwevwere and Akoma, 1997, Inyang and Dabot, 1997). One of the greatest problems militating against shelf-life extension of 'kunun-zaki' beyond two weeks is the high moisture content (88 - 92%) associated with this product (Edward-Iniatimi et al., 1988; Akoma et al., 2002; Elmahmood and Doughari, 2007) therefore long term preservation of 'kunun-zaki' would be un-achievable as long as the moisture content of the product remains high.

Obanewo and Zidon (2003) reported extending the shelf-life of 'kunun-zaki' by two months. These workers produced powdered 'kunun-zaki' using fluidized bed drying technique and noted that the reconstituted powdered 'kunun-zaki' did not differ significantly with freshly prepared 'kunun-zaki' in sensory quality attributes. The shelf-life of many food products is determined by their sensory shelf-life; therefore, consumers' overall acceptability rating of a food product could determine if such a food would still be acceptable after a certain storage time (Gimenez et al., 2008). Therefore, consumers' assessment of a food product during storage could be an appropriate tool for determining the products' shelf-life.

Freeze-dried foods have many advantages since over 98% of the water content has been removed through sublimation. Freeze-dried foods are extremely lightweight and because of its low moisture content are relatively

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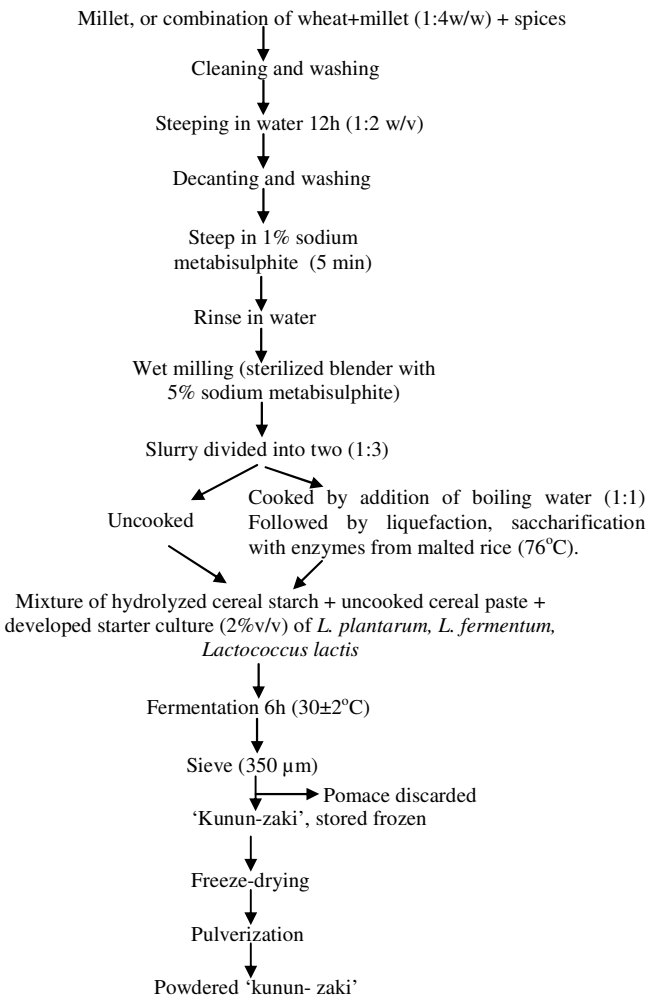

Figure 1. Flow diagram for the production of powdered 'Kunun-zaki' using freeze-drying technique.

contamination-free; yeasts and other pathogenic organism are unable to grow (Kennedy and Cabral, 1993): the original nutritional and sensory quality characteristic is maintained (Chaucer Foods, 2009; Freeze-dry Foods, 2009; Mountain House Foods, 2009). Furthermore, freeze-dried foods can be stored at room temperature without deterioration or spoilage so long as rehydration is prevented for 6 months to 25 years, depending on the packaging materials used (Mountain House Foods, 2009). The objective of this paper is to produce powdered 'kunun-zaki' using freeze-drying technique and evaluate its sensory and nutritional quality attributes during storage.

MATERIALS AND METHODS

Preparation of ground malted rice paste

Paddy rice (*Oryza sativa* Faro 37) obtained from National Cereal Research Institute (NCRI) Badeggi, Nigeria was soaked in tap water (1:2w/v) for 12 h and then drained. The drained grains were couched by covering them with moist cloth for 4 - 5days at ambient temperature (30±2°C) to germinate and then dried in the sun for 3 days. The dried malted rice were surface sterilized using 1% sodium metabisulphite solution for 5 min following which it was washed in tap water and ground to paste.

Development of starter culture

Three species of lactic acid bacteria (*Lactobacillus plantarum*, *L. fermentum* and *Lactococcus lactis*) previously isolated from fermenting 'kunun-zaki' by Agarry et al. (2010) was developed. I ml each of the pure culture of the organism in sterile saline suspension (equivalent to a No. 2 McFarland turbidity standard) was transferred to a 50 ml Hydrolyzed Cereal Starch-broth (HCS broth: 500 g gelatinized cereal starch was hydrolyzed at 76°C with 200 g ground malted rice to which 2 g of soy bean flour was added and sterilized at 121°C for 10 min). This was incubated for 12 h following which it was transferred to another 200 ml HCS-broth and subsequently incubated at ambient temperature (30±2°C) for 12 h

Pre-fermentation processing of cereal

One kilogram (1 kg) of cereal: millet (*Pennisetum typhoideum*) or combinations of wheat (*Triticum aestivum*) + millet (1:4w/w) depending on the type of 'kunun-zaki' to be produced (millet + malted rice, millet + malted rice + starter culture, millet + wheat + malted rice and millet + wheat + malted rice + starter culture), was steeped in 2 l of tap water (1:2w/v) for 24 h at ambient temperature. After 24 h of steeping, the grain was washed, drained and surface sterilized using 1% sodium metabisulphite (1:2w/v) together with spices (ginger, 6 g; black pepper, 2 g; clove, 2 g) for 5 min following which it was further washed and ground to paste using laboratory blender (laboratory blender was sterilized with 5% sodium metabisulphite for 5 min and rinsed with water).

Liquefaction and saccharification of gelatinized cereal starch

Two kilograms of cereal paste was divided into two unequal portions (1:3v/v). The larger portion was gelatinized at 76°C by the addition of boiling water (1:1v/v) and immediately, 600 g of ground malted rice was added and stirred vigorously for 2 - 3 min to allow for liquefaction and saccharification of the gelatinized cereal starch. The hydrolyzed cereal starch was cooled to 50°C and subsequently divided into 2 portions.

Production of 'kunun-zaki' using starter culture (controlled fermentation)

A portion of the hydrolyzed cereal starch was mixed with a 12 h starter culture (2%) and 100 g of uncooked cereal paste; this was mixed thoroughly for 1 min before allowing it to ferment for 6 h at ambient temperature following which it was sieved (Figure 1), packaged and stored frozen.

Production of 'kunun-zaki' without the addition of starter culture (uncontrolled fermentation)

The remaining portion of the hydrolyzed cereal starch was mixed with 100 g of uncooked cereal paste for 1 min and allowed to ferment for 6 h at ambient temperature following which it was sieved, packaged and stored frozen.

Production of powdered 'kunun-zaki'

The 'kunun-zaki' produced in this study was freeze-dried using LABCONCO freeze-drying system (LABCONCO Corporation USA; Model: 7759037). The freeze-dried products were pulverized, packaged in polyethylene bags, sealed (Impulse Sealer, model ME-200H, Maker Electric Co., Ltd, Japan) and stored at ambient temperature in an air-tight plastic container to prevent re-absorption of moisture.

Storage stability studies

The freeze-dried 'kunun-zaki' was produced between the 4th and 6th of September 2009 following which it was evaluated bimonthly for its sensory and chemical quality changes for 6 months.

Reconstitution of powdered 'kunun-zaki'

Thirty grams (30 g) of powdered 'kunun-zaki' was reconstituted with 90 ml of warm water (about 40°C) and stirred for 60 s.

pH and titratable acidity

The pH of freshly prepared and reconstituted 'kunun-zaki' was determined in triplicates using pH meter (TECPEL pH meter, model 705) after standardization with pH 4 and pH 7 buffers (BDH, England). The titratable acidity of freshly prepared and reconstituted 'kunun-zaki' was determined in triplicates by titrating 10 ml of the sample with 0.1 N sodium hydroxide to phenolphthalein end point (pink). The titratable acidity (% lactic acid) was calculated for each sample as described by Field (1977). Also, the pH and titratable acidity of the powdered 'kunun-zaki' during storage was determined.

Proximate analysis

The moisture content, crude protein, crude fat and ash contents of the 'kunun-zaki' samples (liquid and powdered) were determined in triplicates as described by AOAC (1990).

Mineral analysis

The mineral contents (calcium, iron, magnesium, potassium and phosphorous) of 'kunun-zaki' (liquid and powdered) samples was determined in triplicates as described by AOAC (1990). Iron, magnesium and calcium were determined using Atomic Absorption Spectrophotometer (Buck Scientific, USA; Accusy 211); while potassium and phosphorus were determined using Jenwa Flame Photometer (UK, PF P7) and Jenwa Colorimeter (UK, Spectronic, 20) respectively.

Amino acid analysis

The amino acid profiles of 'kunun-zaki' (liquid and powdered) produced in this study was determined in triplicates using the methods described by Spackman et al. (1958) and AOAC (2006). The 'kunun-zaki' samples were dried to a constant weight, defatted, hydrolyzed and evaporated in a rotary evaporator and loaded into the Technicon Sequential Multi-sample Amino acid Analyser (TSM; Technicon Instrument Co. Ltd, UK).

Organoleptic analysis

The overall quality acceptability of freshly prepared and the reconstituted 'kunun-zaki' produced in this study (millet + malted rice, millet + malted rice + starter culture, millet + wheat + malted rice, millet + wheat + malted rice + starter culture) were evaluated by 10-member taste panellists comprising of some trained students and lecturers who are familiar with the product using a 7-point hedonic scale (where 1 = like extremely; 2 = like very much; 3 = like slightly; 4 = neither like nor dislike; 5 = dislike slightly; 6 = dislike very much and 7 = dislike extremely) as described by Larmond (1977). The same sets of 10-member taste panellists were used throughout the storage period to evaluate the sensory quality attributes (appearance, taste, aroma and overall acceptability) of the products.

Statistical analysis

Mean differences in pH, titratable acidity, proximate, amino acids, mineral and overall quality attributes of the freshly prepared and the reconstituted 'kunun-zaki' were computed statistically (t-test) using 2006 Statistical Packages for Social Sciences (SPSS) for Windows version 15.0 (SPSS, 2006). Mean differences in pH, titratable acidity and sensory quality attributes of the products during storage were computed (analysis of variance) using the same package.

RESULTS

pH, titratable acidity and sensory quality of powdered 'kunun-zaki'

As shown in Table 1, there was no significant differences ($p > 0.05$) in the pH of freshly prepared and reconstituted 'kunun-zaki' produced with the addition of starter culture to millet or combinations of millet + wheat + malted rice; however, significant difference ($p < 0.05$) occurred in the rest products (Table 1). The titratable acidity of freshly prepared 'kunun-zaki' were lower than those of the reconstituted products and these differed ($p < 0.05$). The overall sensory acceptability of the four products (reconstituted versus freshly prepared) as shown in Table 1 were not significantly different ($p > 0.05$).

Nutritional quality of powdered 'kunun-zaki'

The amino acid profile, proximate and mineral content of freshly prepared and reconstituted 'kunun-zaki' are shown in Table 2. There was no significant difference ($p > 0.05$) in the amino acid content of both product (liquid or powdered) produced using combinations of millet + wheat + malted rice, millet + malted rice + starter culture in the all the 17 amino acids evaluated, however, differences occurred ($p < 0.05$) in the histidine, proline and glycine contents of the 'kunun-zaki' produced using combinations of millet + malted rice (Table 2). Similarly, the ether extract and ash content of this products: millet + wheat + malted rice + starter culture; millet + malted rice respectively differed (Table 2). There was a marked reduction in the moisture content of the freeze-dried

Table 1. Chemical and sensory quality attributes of liquid and powdered 'kunun-zaki'.

Analysis/Product	'Kunun-zaki' type[1,2]	
	Powdered	Liquid
pH		
Millet + wheat + malted rice	3.34 ± 0.01[b]	3.65 ± 0.02[a]
Millet + malted rice	3.27 ± 0.01[a]	3.81 ± 0.01[b]
Millet + wheat + malted rice + starter culture	3.53 ± 0.02[a]	3.58 ± 0.01[a]
Millet + malted rice + starter culture	3.61 ± 0.02[a]	3.52 ± 0.03[a]
Titratable acidity (% lactic acidity)		
Millet + wheat + malted rice	1.319 ± 0.004[b]	0.585 ± 0.001[a]
Millet + malted rice	1.116 ± 0.001[b]	0.560 ± 0.001[a]
Millet + wheat + malted rice + starter culture	0.857 ± 0.004[b]	0.600 ± 0.001[a]
Millet + malted rice + starter culture	0.887 ± 0.003[b]	0.475 ± 0.001[a]
Overall quality acceptability[3]		
Millet + wheat + malted rice	2.6 ± 0.2[a]	2.7 ± 0.33[a]
Millet + malted rice	2.4 ± 0.3[a]	2.3 ± 0.33[a]
Millet + wheat + malted rice + starter culture	1.3 ± 0.2[a]	1.3 ± 0.33[a]
Millet + malted rice + starter culture	1.5 ± 0.2[a]	1.7 ± 0.67[a]

[1]Each value is the mean ± standard error of triplicate determinations.
[2]Different letters within the same row are significantly different (t-test; $p < 0.05$).
[3]Each value is the mean ± standard error of 10-member panellist; using 7 point hedonic scale, where 1 = like extremely, 2 = like very much, 3 = like slightly, 4 = neither like nor dislike, 5 = dislike slightly, 6 = dislike very much and 7 = dislike extremely.

products (Table 2). Such a reduction was more pronounced in the 'kunun-zaki' produced using combinations of millet + malted rice + starter culture (86 to 8.18%) and this was significantly different ($p < 0.05$). There were no significant difference ($p > 0.05$) in the mineral content in all the products whether liquid or powdered (Table 2).

pH, titratable acidity and sensory quality attributes of powdered 'kunun-zaki' during storage

Changes in pH and titratable acidity of the powdered 'kunun-zaki' during storage is shown in Table 3. There was no significant difference ($p > 0.05$) in pH of 'kunun-zaki' produced with the combinations of millet + wheat + malted rice+starter culture throughout the storage period; differences occurred in the rest products in pH and titratable acidity within the same period however, these were minimal.

The changes in sensory quality of powdered 'kunun-zaki' during storage are shown in Table 4. The overall quality acceptability of the product produced using millet + malted rice (2.4 - 2.5), millet + wheat + malted rice + starter culture (1.3 - 1.4) did not differ ($p > 0.05$) throughout the storage; however, the overall quality acceptability of the remaining products differed ($p < 0.05$).

DISCUSSION

'Kunun-zaki' is a lactic acid bacterial fermented non-alcoholic cereal beverage with limited shelf-life. The high moisture content (88 - 92%) of the product (Edward-Iniatimi et al., 1988; Akoma et al., 2002) and the poor sanitary practices associated with its production (Elmahmood and Doughari, 2007) could account for its short shelf-life (24 – 48 h) which has been a source of concern to its manufacturers and consumers (Efiuvwevwere and Akoma, 1997). Freeze-drying drastically reduced the moisture content of the powdered 'kunun-zaki' produced in this study and this was evident in the mark reduction of its weight (data not shown but summarised as a footnote in Table 2).

The sensory quality attributes of the reconstituted 'Kunun-zaki' did not differ ($p > 0.05$; Table 1) when compared with the freshly prepared one. Although differences occurred in pH and titratable acidity ($p < 0.05$) in all the products, such differences were however minimal (Table 1) and could be attributable to the fact that 'kunun-zaki' was stored for 2 months after production before freeze-drying. Other studies report that freeze-drying techniques combines the best processing methods as it preserves the freshness and colour of frozen foods with the shelf-life stability and convenience qualities attributes of dehydrated foods (Chaucer Foods, 2009; Mountain House Foods, 2009). The results of this study

Table 2. Mean comparison of nutrient content of liquid and powdered 'kunun-zaki' produced using developed starter culture.

	'kunun-zaki' type[1,2,3]							
	Wheat + malted rice		Millet + malted rice		Millet + wheat + malted rice + starter culture		Millet + malted rice + starter culture	
Analyses	**Powdered**	**Liquid**	**Powdered**	**Liquid**	**Powdered**	**Liquid**	**powdered**	**liquid**
Amino acids (g/100 g protein)								
Lysine	2.68±0.01^{a}	2.73±0.06^{a}	2.95±0.05^{a}	3.02±0.02^{a}	3.31±0.01^{a}	3.25±0.06^{a}	3.70±0.05^{a}	3.72±0.07^{a}
Histidine	1.72±0.02^{a}	1.76±0.02^{a}	2.28±0.03^{a}	2.60±0.01^{b}	2.25±0.02^{a}	2.27±0.01^{a}	2.34±0.01^{a}	2.39±0.01^{a}
Arginine	3.82±0.02^{a}	3.78±0.03^{a}	4.38±0.01^{a}	4.39±0.01^{a}	4.21±0.01^{a}	4.22±0.02^{a}	4.80±0.01^{a}	4.81±0.02^{a}
Aspartic acid	5.68±0.02^{a}	5.54±0.04^{a}	6.14±0.08^{a}	6.18±0.03^{a}	5.66±0.14^{a}	5.82±0.02^{a}	7.10±0.03^{a}	7.33±0.03^{a}
Threonine	3.21±0.01^{a}	3.19±0.01^{a}	3.23±0.01^{a}	3.24±0.02^{a}	3.11±0.01^{a}	3.14±0.02^{a}	3.51±0.01^{a}	3.55±0.05^{a}
Serine	3.52±0.02^{a}	3.48±0.03^{a}	3.91±0.01^{a}	3.92±0.02^{a}	3.59±0.01^{a}	3.61±0.01^{a}	4.04±0.04^{a}	4.19±0.01^{a}
Glutamic acid	15.10±0.10^{a}	15.20±0.20^{a}	14.19±0.01^{a}	14.22±0.02^{a}	13.59±0.01^{a}	13.61±0.03^{a}	15.75±0.05^{a}	15.91±0.01^{a}
Proline	4.22±0.02^{a}	4.26±0.02^{a}	4.19±0.01^{a}	4.27±0.01^{b}	4.16±0.01^{a}	4.17±0.01^{a}	4.39±0.01^{a}	4.46±0.02^{a}
Glycine	3.77±0.01^{a}	3.79±0.01^{a}	4.39±0.02^{a}	4.31±0.01^{b}	3.79±0.01^{a}	3.88±0.02^{b}	4.64±0.04^{a}	4.77±0.02^{a}
Alanine	5.02±0.02^{a}	5.08±0.01^{a}	5.29±0.02^{a}	5.28±0.01^{a}	5.09±0.02^{a}	5.14±0.01^{a}	5.35±0.01^{a}	5.38±0.02^{a}
Cystine	1.35±0.01^{a}	1.39±0.01^{a}	1.59±0.03^{a}	1.58±0.02^{a}	1.71±0.01^{a}	1.72±0.01^{a}	2.02±0.02^{a}	2.04±0.01^{a}
Valine	4.29±0.01^{a}	4.31±0.03^{a}	4.59±0.02^{a}	4.58±0.01^{a}	4.69±0.01^{a}	4.71±0.01^{a}	4.77±0.01^{a}	4.80±0.02^{a}
Methionine	1.43±0.03^{a}	1.46±0.01^{a}	1.54±0.01^{a}	1.56±0.01^{a}	1.51±0.01^{a}	1.55±0.01^{a}	1.70±0.02^{a}	1.69±0.01^{a}
Isoleucine	3.51±0.01^{a}	3.57±0.02^{a}	3.49±0.01^{a}	3.51±0.01^{a}	3.50±0.02^{a}	3.52±0.01^{a}	4.02±0.02^{a}	4.13±0.01^{a}
Leucine	6.31±0.01^{a}	6.33±0.01^{a}	7.01±0.01^{a}	7.02±0.01^{a}	7.01±0.01^{a}	7.03±0.01^{a}	6.81±0.01^{a}	6.92±0.01^{a}
Tyrosine	2.85±0.01^{a}	2.83±0.01^{a}	2.62±0.02^{a}	2.67±0.01^{a}	2.49±0.01^{a}	2.51±0.01^{a}	3.03±0.03^{a}	3.07±0.01^{a}
Phenylalanine	4.01±0.01^{a}	4.03±0.01^{a}	4.69±0.01^{a}	4.71±0.01^{a}	4.78±0.01^{a}	4.79±0.01^{a}	4.59±0.01^{a}	4.61±0.01^{a}
Proximate content (%)								
Carbohydrate	89.90±0.11^{a}	90.01±0.13^{a}	88.71±0.00^{a}	88.61±0.02^{b}	87.98±0.03^{a}	87.21±0.23^{a}	87.51±0.01^{a}	87.54±0.05^{a}
Ether extract	3.90±0.01^{a}	3.95±0.01^{b}	7.25±0.01^{a}	7.31±0.02^{a}	8.59±0.01^{a}	8.64±0.01^{a}	5.69±0.01^{a}	5.76±0.01^{a}
Ash	4.43±0.03^{a}	4.35±0.01^{a}	2.99±0.02^{a}	2.90±0.01^{b}	2.93±0.01^{a}	2.89±0.01^{b}	2.91±0.02^{a}	2.92±0.03^{a}
Crude protein	1.11±0.01^{a}	1.09±0.01^{a}	1.16±0.01^{a}	1.14±0.01^{a}	1.08±0.01^{a}	1.07±0.01^{a}	1.05±0.01^{a}	1.03±0.03^{a}
Moisture content	9.38±0.03^{a}	86.9±0.03^{b}	9.15±0.05^{a}	85.7±0.03^{b}	9.35±0.05^{a}	84.6±0.03^{b}	8.18±0.03^{a}	86.0±0.03^{b}
Mineral content (mg/100 ml)								
Phosphorus	1.16±0.02^{a}	1.20±0.01^{a}	1.18±0.01^{a}	1.21±0.01^{a}	1.05±0.01^{a}	1.07±0.01^{a}	1.23±0.01^{a}	1.26±0.01^{a}
Calcium	8.17±0.01^{a}	8.22±0.02^{a}	5.21±0.05^{a}	5.20±0.05^{a}	9.71±0.09^{a}	9.73±0.13^{a}	6.77±0.01^{a}	6.78±0.08^{a}
Magnesium	55.00±1.00^{a}	54.50±0.50^{a}	30.10±0.10^{a}	30.20±0.10^{a}	60.35±0.15^{a}	60.68±0.33^{a}	34.15±0.35^{a}	34.55±0.05^{a}
Poatassium	157.00±0.20^{a}	157.35±0.15^{a}	146.00±0.00^{a}	145.86±0.05^{a}	217.00±0.20^{a}	216.70±0.70^{a}	186.55±0.35^{a}	186.60±0.40^{a}
Iron	52.50±0.20^{a}	52.78±0.23^{a}	48.55±0.05^{a}	48.58±0.08^{a}	75.60±0.30^{a}	75.78±0.23^{a}	51.38±0.23^{a}	51.63±0.38^{a}

[1]Each data is the mean + standard error of three determinations.
[2] Different letters within the same sub set row are significantly different (t-test; $p < 0.05$).
[3]11 l 'kunun-zaki' when freeze-dried weighed 1.9 kg.

Table 3. pH and titratable acidity of powdered 'kunun-zaki' during storage.

	Products/analysis[1,2,3]							
	Millet + wheat + malted rice		Millet + malted rice		Millet + wheat + malted rice + starter culture		Millet + malted rice + starter culture	
Storage time(months)	pH	TA	pH	TA	pH	TA	pH	TA
0	3.34±0.01^{ab}	1.319±0.004^{a}	3.27±0.01^{b}	1.116±0.001^{c}	3.53±0.02^{a}	0.857±0.004^{b}	3.61±0.02^{b}	0.887±0.003^{b}
2	3.28±0.04^{b}	1.178±0.029^{b}	3.30±0.01^{a}	1.120±0.001^{bc}	3.53±0.03^{a}	0.878±0.001^{a}	3.65±0.02^{ab}	0.900±0.001^{a}
4	3.32±0.06^{b}	1.217±0.001^{b}	3.30±0.04^{a}	1.123±0.002^{ab}	3.54±0.01^{a}	0.872±0.003^{a}	3.68±0.02^{a}	0.889±0.001^{b}
6	3.40±0.01^{a}	1.175±0.006^{b}	3.25±0.02^{a}	1.128±0.002^{a}	3.46±0.03^{a}	0.876±0.001^{a}	3.66±0.01^{a}	0.873±0.005^{c}

[1]Each data is the mean + standard error of three determinations.
[2]Different letters within the same column are significantly different ($p < 0.05$).
[3]TA: titratbale acidity (% lactic acid).

Table 4. Sensory quality attributes of powdered 'kunun-zaki' during storage.

	Products/sensory scores[1,2,3]			
	Millet + wheat + malted rice			
Storage time (months)	App	Tas	Aro	OA
0	2.5 ± 0.2^{a}	2.5 ± 0.2^{b}	2.7 ± 03^{a}	2.6 ± 0.2^{c}
2	2.6 ± 0.2^{a}	3.0 ± 0.2^{ab}	3.0 ± 0.3^{a}	3.4 ± 0.2^{a}
4	2.5 ± 0.2^{a}	3.0 ± 0.3^{ab}	2.9 ± 0.2^{a}	3.3 ± 0.03^{ab}
6	2.6 ± 0.2^{a}	3.3 ± 0.3^{a}	2.7 ± 0.3^{a}	2.7 ± 0.2^{bc}
	Millet + malted rice			
0	2.1 ± 0.3^{b}	2.6 ± 0.2^{a}	2.4 ± 03^{a}	2.4 ± 0.3^{a}
2	2.3 ± 0.2^{ab}	2.7 ± 0.2^{a}	3.0 ± 0.3^{a}	3.0 ± 0.2^{a}
4	2.6 ± 0.2^{ab}	3.0 ± 0.3^{a}	2.7 ± 0.2^{a}	2.6 ± 0.2^{a}
6	3.0 ± 0.3^{a}	3.0 ± 0.3^{a}	2.6 ± 0.3^{a}	2.5 ± 0.3^{a}
	Millet + wheat + malted rice + starter culture			
0	2.3 ± 0.3^{a}	1.4 ± 0.2^{a}	1.3 ± 0.2^{a}	1.3 ± 0.2^{a}
2	2.1 ± 0.1^{a}	1.5 ± 0.2^{a}	1.4 ± 0.2^{a}	1.4 ± 0.2^{a}
4	2.2 ± 0.1^{a}	1.3 ± 0.2^{a}	1.5 ± 0.2^{a}	1.5 ± 0.2^{a}
6	2.2 ± 0.1^{a}	1.5 ± 0.2^{a}	1.4 ± 0.2^{a}	1.4 ± 0.2^{a}
	Millet + malted rice + starter culture			
0	2.1 ± 0.3^{a}	1.8 ± 0.1^{a}	1.6 ± 0.2^{b}	1.5 ± 0.2^{b}
2	2.2 ± 0.1^{a}	1.7 ± 0.2^{a}	1.8 ± 0.2^{ab}	1.9 ± 0.2^{b}
4	2.1 ± 0.1^{a}	1.8 ± 0.2^{a}	1.8 ± 0.2^{ab}	2.0 ± 0.2^{ab}
6	2.4 ± 0.2^{a}	2.2 ± 0.2^{a}	2.2 ± 0.2^{a}	2.5 ± 0.2^{a}

[1]Each value is the mean ± standard error of 10-member panellist; using 7 point hedonic scale, where 1 = like extremely, 2 = like very much, 3 = like slightly, 4 = neither like nor dislike, 5 = dislike slightly, 6 = dislike very much and 7 = dislike extremely,
[2]Different letters within the same column are significantly different ($p < 0.05$).
[3]App: Appearance, Tas: Taste, Aro: aroma, OA: overall acceptability.

shows that the nutritional quality (amino acid, proximate and mineral content) of both freshly prepared 'kunun-zaki' and the powdered product did not differ ($p > 0.05$), hence there was no loss in the nutritional quality as a result of the freeze-drying process. Obanewo and Zidon (2003) produced powdered 'kunun-zaki' using fluidized bed drying technique and reported extending its shelf-life by 2 months. These workers observed that there was no significant difference in the sensory quality of both freshly prepared and powdered (reconstituted) 'kunun-zaki'

throughout the storage period. Since the consumer is in a position to decide when a food product remains wholesome during storage (Gimenez et al., 2008), the results of this study (Table 4) show that the overall quality acceptability scores for all the four products were favourable (1.4 to 2.7, below 3 in a 7-point hedonic scale) throughout the storage period thereby indicating the products' wholesomeness. Similarly, minimal changes were observed in pH and titratable acidity (Table 3) in all the products throughout the storage period. The result of this study has shown that use of freeze-drying technique has extended the shelf-life of 'kunun-zaki' by up to 6 months. If properly packaged, powdered 'kunun-zaki' could be exported and this may encourage the large scale production of 'kunun-zaki'.

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