Nutritional Composition, Health benefits and Utilization of Fonio (*digitaria exili*) Grains: A Review.

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Abstract

Fonio is a traditional cereal which has often occupied a marginal position among other cereals in most West African countries where it is cultivated. Adequate knowledge on the chemical and nutritional properties, as well as health benefits of fonio is required in its processing and maximum utilization. In this review, the chemical and nutritional characteristics of fonio were identified and compared with those of other major cereals like maize, rice, millet and sorghum. Fonio cereals compared favourably well with these other cereals.

Key words: Fonio, utilization, cereal, health benefits.

1.0 Introduction

The cereal grains of economic importance are the cool-season crops mainly wheat, barley, oats, and rye and the warm-season cereals like rice, maize, sorghum and millet (Ghatge, 2012). Fonio (Plate 1) is one of the ancient African crops, possibly the oldest West African crop as its cultivation seems to have started about 7,000 years ago (Gari, 2002). The first references to Fonio as food are reported from the mid-14th century (Cruz *et al.,* 2011). Significant cultivation is in West Africa from Chad to Cape Verde, South Mali, in Western Burkina Faso, Eastern Senegal, Northern Guinea, in North-Eastern Nigeria as well as in the South of Niger, where the plant supplies the staple food for several million people.

Fonio is an annual, erect herbaceous plant which reaches heights from 30 to 80 cm. The ears consist of two to five narrow part ears, which are up to 15 cm long. The spikelets comprise a sterile flower and a fertile flower, the latter of which gives rise to the fonio grain. Some varieties can already be harvested 42–56 days after sowing. Other ripen more slowly, usually in 165–180 days (Cruz *et al.,* 2011).

It is additionally referred to as hungry millet or hungry *koos*. In Senegal it is called *fundi*, *findi*, *eboniaye* or *efoleb*. Other local African names include *fonyo*, *fundenyo*, *foinye* (*Fulani*), *Fini*

(*Bambara*), *Acha*, *iburu*, *aburo* (Nigerian), *findo* (Gambia), *afio-warun*, *ipoga*, *ova* (Togo), *Fani*, *feni*, *foundé* (Mali), *foni* (Burkina Faso), *pende*, *kpendo*, *founié*, *pounié* (Guinea), *podgi* (Benin), *pom*, *pohin* (Ivory Coast) (Cruz *et al.*, 2011).

This paper aims to provide useful information of fonio (*Digitaria exilisis*) grains (its nutritional composition, health benefits and utilization).

Plate 1: Samples of fonio seed (Source: Irving and Jideani, (1997))

2.1 Chemical and Nutritional Composition of Fonio Grains

The proximate and chemical composition of fonio grain are presented in (Table 2.1). It should be noted that these values refer to the whole or dehusked grains.

2.1.1 Energy value

The energy value of fonio grains was not very much studied in literature. Jideani and Akingbala, (1993) reported a value of 19400 KJ/kg (Table 2.1). This result was higher than that reported for other cereals such as rice (18091 KJ/kg), maize (16982 KJ/kg) and sorghum (16245 KJ/kg) by Saldivar (2003).

2.1.2 Carbohydrates

The carbohydrates of fonio grains can also have many uses in industrial sector and their contents ranged from 67.1 to 91 % with a mean value of 79.05 % (Table 2.1). Nitrogen-Free Extract (NFE) or method by difference was used by all authors to determine the fonio carbohydrate contents. The lowest carbohydrate content was reported by Saldivar (2003) while the highest value was obtained by Jideani and Akingbala (1993).

2.1.3 Starch

Starch is the most abundant carbohydrate in fonio grains as in other cereals and the main provider of calories. Cruz *et al*., (2011) reported a starch content of 68% for fonio grains (Table 2.1). This starch percentage of the fonio grains was lower than that reported for sorghum and rice which was in average of 73.8 and 77.2% respectively. Starch is normally composed of one-quarter amylose, with the remaining three quarters being amylopectin but proportions varied generally according to species. Jideani and Akingbala,(1993) determined amylose content of fonio grains, procured from a local market in Nigeria, by the method described by Robyt and Bemis(1967) and they obtained 28 % of amylase.

2.1.4 Soluble Sugars

Soluble sugars were generally in very small quantities in the cereal grains and their concentration varied according to botanical species. The detected sugars in measurable quantities in the cereal grains were mainly saccharose, raffinose, stachyose, glucose and fructose. Some of these sugars, essentially the saccharose, glucose and fructose (Table 2.1), were also identified in fonio grains and their average soluble sugar content was 1% (Cruz *et al*., 2011).

2.1.5 Fibres

Fibre constituted of lignin and polysaccharides which are fraction of a consumed food and not degraded in the gut. Crude fibre contents reported for fonio grains were in the range of 0.41-11.3 % with a mean value of 5.85 % (Table 2.1). The lowest value (0.41 %) of crude fibre content was reported by Jideani and Akingbala (1993) while the highest value (11.3 %) was reported by Saldivar (2003). The high variation in the crude fibre contents of fonio grains could also be attributed to environmental influences, geographical location, agronomic and genetic factors on the one hand and to different analytical methods on the other hand.

Table 2.1 Proximate, chemical and nutrient composition of fonio grains

Composition		**Fonio**		**References**
	Min	Average	Max	
Energy value (KJ/Kg)		19400		Jideani and Akingbala (1993)
Carbohydrates (%)	67.1	79.05	91	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Starch (%)		68		Cruz et al (2011)
Amylose (%)	22.1	22.05	28	Cruz et al (2011), Jideani and Akingbala (1993), Jideani et al (1996)
Soluble sugar (%)		1		Cruz et al (2011)
Glucose (%)				Cruz et al (2011)
Fructose (%)				Cruz et al (2011)
Saccharose (%)	0.7	0.75	0.8	Cruz et al (2011)
Crude fiber (%)	0.41	5.85	11.3	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Protein (%)	5.1	8.05	11	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Albumins		3.5		Jideani et al (1994a)
Globulins		1.8		Jideani et al (1994a)
Prolamins		5.5		Jideani et al (1994a)
Glutelins		14		Jideani et al (1994a)

Lipids (%)	1.3	3.25	5.2	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Ash (%)	1	3.5	6	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Vitamins				
Thiamins (mg/100g)	0.3	0.39	0.48	Serna Saldivar (2003), Fliedel et al (2004)
Riboflavin (mg/100g)	0.05	0.07	0.1	Serna Saldivar (2003), Fliedel et al (2004)
Nicotinic acid (mg/100g)		3		Serna Saldivar (2003),

Source: Carbiner *et al*., (1960), Temple and Bassa (1991), Jideani *et al*., (1994b), Fliedel *et al*., (2004), Chukwu and Abdul-Kadir (2008).

2.2 Proteins and Amino Acids

The main source of protein for the human diet comes from cereal grains because they constitute the basic food in many developing countries. Protein contents of fonio grains ranged from 5.1 % (Fulcher *et al*., 1981) to 11 % (Fliedel *et al*., 2004) with a mean value of 8.05 % (Table 2.2). Protein content of fonio average was in lower than values reported by Saldivar (2003) for sorghum, millet and rice. Literature is limited on different protein fraction of fonio grains; only Jideani *et al*.,(1994a) investigated the percentage of each protein fraction of fonio grains in various Osborne fractions. Fonio possessed also the four protein fractions, frequent in most cereals, mainly albumin (3.5 %), globulin (1.8 %), prolamin (5.5 %) and glutelin (14%).

2.4 Vitamins

Vitamins are essential organic molecules needed in very small amounts for cellular metabolism. Cereals are considered like important sources of B vitamins, except B12 or cobalamin17. Very few authors have studied the vitamin contents of fonio grains (Table 2.1). The fonio grains contained also the B complex vitamins mainly thiamin. The content of which ranged from 0.3 to 0.48 mg/100 g (average: 0.39 mg/100 g) and riboflavin the value of which ranged between 0.05 - 0,1 mg/100 g (average: 0.07 mg/100 g). Nicotinic acid or PP vitamin has been found in concentrations (3 mg/100g) higher than the other vitamins in fonio grains according to the results reported by Serna Saldivar (2003).

Table 2.2 Amino acid composition of Fonio grains

Amino acid (%)	**Fonio (g per 16g)**			**Fonio (Mol %)**	**Fonio (%)**
	Min	Average	Max	Average	Average
Essential					
Phenylalanine	2.34	3.72	5.1	3.1	0.47
Histidine	1.33	1.71	2.1	1.4	0.17
Isoleucine	1.37	2.68	4	3.2	0.28
Leucine	4.4	7.1	9.8	8.8	0.91
Lysine	1.9	2.25	2.6	1.3	0.19
Methionine	2.98	4.3	5.6	3.7	0.34
Threonine	1.89	2.94	4	4.9	0.34
Tryptophan	0.9	0.92	0.95	-	0.16
Valine	2.34	4.07	5.8	6.1	0.52
Non essential					
Aspartic acid	3.5	5	6.5	7.2	0.68
Glutamic acid	6.9	13.55	20.2	18.2	2.16
Alanine	4.2	6.6	9	11.4	1.24
Arginine	1.3	2.55	3.8	2.1	0.93
Cysteine	2.8	2.9	3	2.5	0.07

Glycine	1.9	2.55	3.2	6.5	0.08
Proline	3.2	5.15	7.1	7.2	0.51
Serine	2.1	3.6	5.1	7.9	0.49
Tyrosine	0.91	2.25	3.6	2.2	0.23

Source: Carbiner *et al*., (1960), Temple and Bassa (1991), Jideani *et al*., (1994b), Fliedel *et al*., (2004), Chukwu and Abdul-Kadir (2008).

2.5 Minerals

Most of the authors used atomic absorption spectrophotometry to determine the mineral elements contained in the fonio ash. Major mineral elements in the fonio grains were magnesium, phosphorus and potassium. Table 2.3 shows the mineral composition of fonio grains.

Table 2.3: Mineral composition of Fonio grains

Minerals	**Fonio**			**References**
	Min	Average	Max	
Macroelements (%)				
Calcium (Ca)	0.0067	0.018	0.03	Irving and Jideani (1997), Cruz et al.,(2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Phosphorus (P)	0.09	0.17	0.25	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Potassium (K)	0.02	0.14	0.26	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Sodium (Na)	0.05	0.017	0.03	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Magnesium (Mg)	0.07	0.46	0.85	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993),

				Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Sulphur (S)		0.16		Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Microelements (ppm)				Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Iron (Fe)	36	84.8	133.6	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Copper (Cu)	1.5	8.25	15	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Manganese (Mn)	21.6	25.8	30	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Zinc (Zn)	30	36.15	42.3	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),

Source: Jideani and Akingbala (1993).

Table 2.3 showed that Ca content ranges from 0.0067 to 0.03 %; P content varies between 0.09 and 0.25 %; K value ranges from 0.02 to 0.26 %; Na reported is in the range of 0.005-0.03 %; Mg content varies between 0.07-0.85; S content is in average 0.16 %; Fe level is 36-133.6 ppm; Cu value is 1.5-15 ppm; Mn level is 21.6-30 ppm and Zn content is 30-42.3 ppm.

2.6 Potential health benefits of Fonio

Fonio is more than just an interesting alternative to the more common grains. The grain is also rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate,

which is associated with reduced cancer risk (Coulibaly *et al*., 2011). These health benefits have been partly attributed to the wide variety of potential chemopreventive substances, called phytochemicals, including antioxidants present in high amounts in foods such as fonio (Izadi *et al*., 2012).

2.7 Utilization of fonio

Fonio have good grain qualities suitable for processing. Processing of the grain for many end uses involves primary (wetting, dehulling and milling) and secondary (fermentation, malting, extrusion, glaking, popping and roasting) operations. Being a staple and consumed at household levels, processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs (Obilana and Manyasa, 2002; Hamad, 2012).

3.0 Conclusion

Fonio is still the staple food for millions of poor people in Africa and Asia. Like many other cereals, fonio is high in carbohydrate energy content and nutritious, making it useful component of dietary and nutritional balance in foods. Combination of fonio with other sources of protein would compensate the deficiency of certain amino acids such as lysine. Successful improvement of these attributes would be a crucial key to expand the spectrum of utilization of fonio. Future trends should focus on the consumption of fonio cereals due to its abundant nutritional and health benefits.

References

Carbiener R., Jaeger P. and Busson F., (1960). Etude de la fraction protidique de la grain de fonio Digitaria exilis (Kippist) Stapf, une proteine exceptionnellement riche in methionine, Ann Nutrition Alimentation, 14 165-169

Chukwu O. and Abdul-kadir A.J., (2008). Proximate Chemical Composition of Acha (Digit aria exilis and Digitaria iburua) Grains, Journal of Food Technology 6, 214-216

Coulibaly, A., B. Kouakou and J. Chen. (2011). Phytic acid in cereal grains: structure, healthy or harmful ways to reduce phytic acid in cereal

Cruz J-F., Beavogui F. and Drame D., (2011), Le fonio, une céréale africaine. Agricultures tropicales en poche. Quae / Cta / Presses agronomiques de Gembloux. Versailles, France. 175p.

Fliedel G., Ouattara M., Grabulos J., Dramé D. and Cruz J. (2004). Effet du blanchiment mécanique sur la qualité technologique, culinaire et nutritionnelle du fonio, céréale d'Afrique de l'Ouest. In :

Brouwer Inge D., Traoré Alfred S. and Trèche S., (ed.) Voies alimentaires d'amélioration des situations nutritionnelles en Afrique de l'Ouest : Le role des technologues alimentaires et des nutritionnistes : actes du 2e Atelier international, Ouagadougou, 23-28 nov. 2003. Ouagadougou: Presses universitaires de Ouagadougou, Burkina Faso, 599-614

Fulcher R.G., O'Brien T.P. and Wong S.I., (1981). Microchemical detection of niacin, aromatic amine and phytin reserves in cereal bran, Cereal Chem. 58, 130-135

Gari J.A., (2001). Review of the African millet Diversity. Paper for the international workshop on fonio, food scarcity and livelihood among the rural poor in West Africa. IPGRI/IFAD, Bamako, Mali, 19-22 November, 2001.

Ghatge N.S., (2012). Food Intake Pattern of Malnourished Preschool Children after Supplementation of Soyaladoo, International Research Journal of Social Sciences, 1(3), 36- 40

Hamad, S. H. (2012). The microbial quality of processed date fruits collected from a factory in Al-Hofuf City, Kingdom of Saudi Arabia. Emir. J. Food Agric. 24(2):105–112.

Irving D.W., and Jideani I.A., (1997). Microstructure and composition of Digitaria exilis Stapf (acha): a potential crop, Cereal Chem., 74(3), 224-228.

Izadi, Z., Nasirpour, A. Izadi, M and Izadi, T. (2012). Reducing blood cholesterol by a healthy diet, Int. Food Res.J.19(1):29-37.

Jideani I.A. and Akingbala J.O., (1993). Some physicochemical properties of acha (Digitaria exilis) and iburu (Digitaria iburua), J. Sci. Food Agric., 63, 369-374

Jideani I.A., Owusu R.K. and Muller H.G., (1994a). Proteins of acha (Digitaria exilis Stapf): Solubility fractionation, gel filtration, and electrophoresis of protein fractions, Food Chemistry, 51, 51-59

Jideani I.A., Takeda Y. and Hizukuri S., (1996). Structures and Physicochemical properties of starches from acha (Digitaria exilis), iburu (D. iburua) and tamba (Eleusine coracana), Cereal Chem., 73, 677-685

Obilana, A.B. and Manyasa, E. (2002). Millets. In: P.S. Belton and J.R.N. Taylor (Eds.). pp. 177-217. Pseudo cereals and less common cereals: Grain properties and Utilization potential. Springer-Verlag: New York.

Robyt J.F. and Bemis S. (1967). Use of the autoanalyser for determining the blue value of the amylose-iodine complex and total carbohydrate by phenol-sulfuric acid, Anal Biochem., 19 56-60

Serna Saldivar S.O., (2003). Cereals/Dietary Importance. In: Caballero B, Trugo L and Finglas (Eds) Encyclopedia of Food Sciences and Nutrition: Academic Press, London, UK, 1027-1033

Temple V.J. and Bassa J.D., (1991). Proximate chemical composition of 'Acha' (Digitaria exilis) grain, J. Sci. Food Agric. 56, 561-563.