Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2390-2393
Received: 25-07-2020
Accepted: 27-08-2020

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Physical, functional, nutritional, phytochemical and antioxidant properties of kodo millet (*Paspalum scrobiculatum*)

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Abstract
Kodo millet (*Paspalum scrobiculatum*) is a nutritious grain and is also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian crown grass. Physico functional properties revealed that kodo millet was dark grey in colour before dehulling and light yellow in colour after dehulling with a mean size of 1.66±0.09 mm. The mean hydration capacity of the grains was 1.81±0.57g/1000 seeds, with an index of 34.98±0.31 per cent. Swelling capacity and swelling idex of the grain were 1.2±0.1ml/1000 g seeds, and 31.8±0.62 per cent. The increase in weight and volume were 184.8±0.26 and 249.83±0.28 per cent respectively with a swelling power of 3.28±0.03 g/g and solids loss to an extent of 14.02±0.38 per cent. The mean macro nutrient composition of kodo millet for moisture, protein, fat, crude fiber and ash were 7.92±0.05per cent, 7.7±0.05g, 4.48±0.52g, 6.12±0.10g, 1.96±0.05g and mean micro nutrients calcium, phosphorous, iron, zinc, copper, manganese and magnesium content were 39.63±0.76 mg, 378.65±1.04mg, 3.55±0.32 mg, 2.08±0.20mg, 1.56±0.07mg, 2.97±0.14 mg/100g and 91.06±0.64 mg/100g respectively. Mean Phytic acid, polyphenol, tannin content, and antioxidant activity of kodo millet were 223.5 to 226.5 mg/g, 143±0.5 mg CE/100g, 5.04±0.01%. or 50.4 TAE/100g and 80.56±1.25% or 24.64±0.38 mg AAE/100 g.

Keywords: Physical, functional, nutritional composition, Kodo millet, phytochemical, antioxidant activity

Introduction
Millets are small-seeded grasses that are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture, grown throughout the world that belong to the family Poaceae of the mono-cotyledon group. As per the FAOSTAT, global millet production for the year 2016 was 30.35 million tons. Indian millet production is ~10 million tons and in the small millet production is 467 thousand tons (Himanshu *et al*., 2018) [5]. Millets are unique because of their richness in calcium, dietary fibre, polyphenols, carbohydrates (70-80%) and protein (9-14%). It is a gluten-free cereal and also rich in phytochemicals which help to lower cholesterol level and reduced cancer risk due to its phytate content (Shadang and Jaganathan, 2014) [14]. Millets are usually subdivided into major millets (sorghum and pearl millet) and minor millets (finger millet, barnyard millet, little millet, kodo millet, foxtail millet and proso millet).
Once a poor man's staple, now adorns the plates of affluent and health conscious people. One of such ancient millet grains is kodo millet, a native tropical Africa, believed to be domesticated in India about 3000 years back (De Wet *et al.*, 1983) [15]. Kodo millet is cultivated over an area of 1.96 lakh ha with total production of about 0.84 lakh tons and with productivity of 429 kg/ha during the year 2015-16 (Rao *et al*., 2017) [17]. Kodo millet (*Paspalum scrobiculatum*) is a nutritious grain and is also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian crown grass. The local names of kodo varies from region to region and it is known as Harka in Kannada. Nutritionally Kodo millet a fair source of protein, which is highly digestible and is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions (Deshpande *et al.*, 2015) [16]. The carbohydrate content is low and slowly digestible. Hence, the present study is undertaken to study the physical, functional, nutritional and nutraceutical properties of kodo milet.

Materials and Methods
Procurement of Kodo millet: Kodo millet was procured from the local farmers of Gopalanahalli of Chikkanayakanahalli taluk of Tumkur district of Karnataka, India. The grains were cleaned and dehulled in Millet Processing unit of Farmers Grower's Association, Gopalanahalli of Tumkur district.

The dehulled grains were cleaned in one lot and used for the study. All the estimations were carried out in triplicates.

Physical properties of Kodo millet: Kodo millet samples were assessed for physical characteristics such as size, shape, colour, thousand grain weight (g), thousand grain volume (ml), bulk density (g/ml) were analyzed using standard procedure.

Functional properties of Kodo millet: Kodo millet samples were assessed for functional properties such as Hydration capacity (g/1000 seeds) and Swelling capacity (ml/1000 seeds) by Dhingra *et al.* (1992) [6], Hydration index (%) and Swelling index (%) by Kantha *et al.* (1986) [7]. Cooking characteristics such as the cooked weight (g), Gain in weight after cooking (%), Cooked volume (ml), Gain in volume after cooking (%), Cooking time (min), Swelling power (g/g), Solubility (%) and Solid loss (%) were analyzed using standardized procedure. Swelling power and per cent solubility of grains was assessed according to the Methods used by Schoch (1964) [8].

Nutritional properties of kodo milet: All analysis were done by following the AOAC (1980) [9] official protocols. Moisture was determined from sample weight loss after drying at 110° C for 4 h. Protein content was determined by Kjeldahl method. The Soxhlet method was used for total fat determination. Crude fiber was estimated by treatment of sample first with acid and subsequently with alkali. The loss in weight was the crude fibre content. Carbohydrate and energy by difference method. Ash by muffle furnace, micronutrients iron, zinc, manganese and copper (AOAC, 1980) [9] by using Atomic Absorption Spectrophotometer, phosphorous by Adelowo *et al*., 2016 [11] method and calcium and magnesium (Heau *et al.,* 1965) [10] by titration method. All samples were analyzed in triplicates.

Phytochemical and antioxidant properties of kodo millet
Kodo millet were subjected to phytonutrient analysis like total antioxidant activity (Kang and Saltveit, 2002), total Polyphenols (Sadasivam and Manickam, 1991) [12], phytic acid (Sadasivam and Manickam, 1991) [12] and tannin content (Ranganna, 2005) [13] were analyzed in triplicate by using standardized procedure.

Results and Discussion
Physical characteristics of kodo millet are presented in Table 1. The whole kodo millet before dehulling was dark grey in color. The dehulled raw millet grains were ellipsoidal in shape and light yellow in colour. The mean size of the kodo millet was 1.66±0.09 mm with a range between 1.58 to 1.89 mm. The mean thousand grain weight was 4.29±0.08 g with a range between 4.20 to 4.37 g. The thousand grain volume of kodo millet ranged from 3.99 to 4.00 ml with a mean of 3.99±0.005 ml. The bulk density of the grain was 1.05 to 1.09 ml with a mean of 1.07±0.02 ml. The present study is in accordance with the study conducted by (Reddy *et al.*, 2019) [1] the results showed that thousand kernel grain, thousand grain volume and bulk density observed in kodo millet 4.15 ± 0.31g, 4.24 ± 0.75ml and 0.97 ± 0.04 g/ml. Kodo millet is light yellow in color small seed prior to dehulling. After dehulling, the seed size is further reduced, with thousand grain weight, volume and density of 2.8g, 1.2ml and 1.84 respectively (Muragod *et al.*, 2019) [3].

Table 1: Physical properties of Kodo millet

Parameter	Characteristic/quantity
Shape	Ellipsoidal
Whole grain colour	Dark grey
Colour (dehulled)	Light yellow
Size (mm)	1.66±0.09
Thousand grain weight (g)	4.29±0.08
Thousand grain volume (ml)	3.99±0.005
Bulk density	1.07±0.02

Table-2 shows the functional properties of the millets. The mean hydration capacity of the grains was 1.81±0.57g/1000 seeds, with an index of 34.98±0.31 per cent. Swelling capacity of the grain was 1.2±0.1ml/1000 seeds, with an index of 31.8±0.62. Cooking quality of the grain is an important criterion to assess the consumer acceptability. The kodo millet grains required 14 mins to get cooked. Weight and volume after cooking were 308.93±0.45 g and 349.66±0.57ml. ml, respectively. The increase in weight and volume were 184.8±0.26 and 249.83±0.28 per cent respectively. The grains exhibited a swelling power of 3.28±0.03 g/g. The solubility of the grains was 5.71±0.90 per cent. The cooking of grains resulted in loss of solids to an extent of 14.02±0.38 per cent. The findings are in conformity with the findings of Muragod *et al.* (2019) [3] and Reddy *et al*. (2019) [1] the results revealed that hydration index was observed maximum in kodo millet (36.16 ± 1.02 per cent) followed by sorghum (35.59± 0.21per cent) and pearl millet (23.41± 0.97per cent). kodo millet had hydration capacity of 1.44 ± 0.13 g/1000 kernels, swelling capacity 2.44 ± 0.03 ml/1000kernels and swelling index of 61 ± 1.13 percent.

Table 2: Functional properties of Kodo millet

Parameter	Characteristic/quantity
Hydration capacity (g/1000 seeds)	1.81±0.57
Hydration index (%)	34.98±0.31
Swelling capacity (ml/1000 seeds)	1.2±0.1
Swelling index (%)	31.8±0.62
Cooked weight (g)	308.93±0.45
Gain in weight after cooking (%)	184.8±0.26
Cooked volume (ml	349.66±0.57
Gain in volume after cooking (%)	249.83±0.28
Cooking time (min)	14
Swelling power (g/g)	3.28±0.03
Solubility (%)	5.71±0.90
Solid loss (%)	14.02±0.38

Nutrient composition of kodo millet provide essential macro and micro nutrients depicted in table 3. Moisture content of kodo millet ranged from 7.89 to 7.99 percent with a mean of 7.92±0.05 per cent. Protein content of the grain ranged from 7.65 to 7.85 g with a mean of 7.7±0.05 g per 100g. The mean fat content in the grain was 4.48±0.52 g with the values ranging from 4.12 to 5.04 g per 100g of the sample. Mean crude fibre and total ash content was 6.12±0.10 and 1.96±0.05 g per 100g with a range of 6.00 to 6.20 g and 1.90 to 2.00 g per 100g respectively. The computed carbohydrate content in the millet ranged from 71.11 to 72.24 g per 100g with a mean of 71.80±0.60 g per 100g. The calorific value as estimated by computation was 358.61±2.54kcal/100g of the grain sample. Micro nutrient composition is shown in table 3. The mean calcium content of kodo millet was 39.63±0.76 mg per 100g, mean phosphorous content and iron content were 378.65±1.04 and 3.55±0.32 mg per 100 g. The mean zinc, copper and manganese content were 2.08±0.20, 1.56±0.07, and 2.97±0.14

mg/100g, respectively. The mean magnesium content was 91.06±0.64 mg/100g of the sample. The kodo millet grain is composed of 8 % protein. Kodo millet is an excellent source of fiber (9%), as opposed to rice (0.2%), and wheat (1.2%). Moisture, protein, fat, ash and crude fiber content of kodo millet flour of present investigation were found to be similar to results of kodo millet flour reported by Thilagavathi *et al.* (2015) [4]. Kodo millet contains 66.6g of carbohydrates and 353 kcal per 100g of grain, comparable to other millets. It also contains 1.4% fat and 2.6% minerals. The iron content in kodo millet ranges from 25.86ppm to 39.60ppm (Chandel *et al.*, 2014) [18]. Nutrient composition of carbohydrate, moisture, fiber, protein and fat is 64.3g, 11.2%, 8.3g, 8.1g and 1.3g respectively, minerals like phosphorus, calcium and Iron is 16mg, 32mg and 0.5mg respectively ((Muragod *et al.*, 2019) [3].

Table 3: Nutrient composition of Kodo millet

Nutrients	Quantity (g/100g)
Macronutrients	
Moisture (%)	7.92±0.05
Protein (g)	7.7±0.05
Fat(g)	4.48±0.52
Ash (g)	1.96±0.05
Crude Fibre (g)	6.12±0.10
Carbohydrate (g)	71.80±0.60
Energy (Kcal)	358.61±2.54
Micronutrients	
Calcium (mg)	39.63±0.76
Phosphorous (mg)	378.65±1.04
Iron(mg)	3.55±0.32
Zinc (Mg)	2.08±0.20
Magnesium(mg)	91.06±0.64
Copper(mg)	1.56±0.07
Manganese(mg)	2.97±0.14

Phytochemical and antioxidant properties of kodo millet is given in Table 4. Phytic acid content of the kodo millet ranged between 223.5 to 226.5 mg/g wih a mean values of 225±1.5mg/g. Mean polyphenol content of the grain was 143±0.5 mg catechol equivalent/100g with the values ranging from 143 to 144.05 mg CE/100g. Tannin content of the kodo millet ranged between 5.03 to 5.05% or 50.3 to 50.5 Tannic Acid Equivalent (TAE)/100 g with a mean of 5.04±0.01%. or 50.4 TAE/100g. Mean antoxidant activity of kodo millet was 80.56±1.25% or 24.64±0.38 mg Ascorbic Acid Equivalent (AAE)/100 g ranging from 79.62 to 81.99% or 24.36 to 25.08 mg Ascorbic Acid Equivalent (AAE)/100 g. Studies had reported that bound polyphenols (1% HCl extractable) were highest in kodo millet (81.64±0.15), followed by foxtail (11.59 ± 0.23), little millet (9.64±0.28). The phytate content of common millet varieties range between 170 and 470 mg/100 g (Himanshu *et al.*, 2018) [5]

Table 4: Phytochemical and antoxidant properties of Kodo millet

Phytonutrients	Quantity
Phytic acid (mg/g)	225±1.5mg
Polyphenols (mg/100g)	143±0.5
Tannin	
(%)	5.04±0.01
mg TAE/g	50.46±0.15
Antioxidant Activity	
(%)	80.56±1.25
mg AAE/100g	24.64±0.38

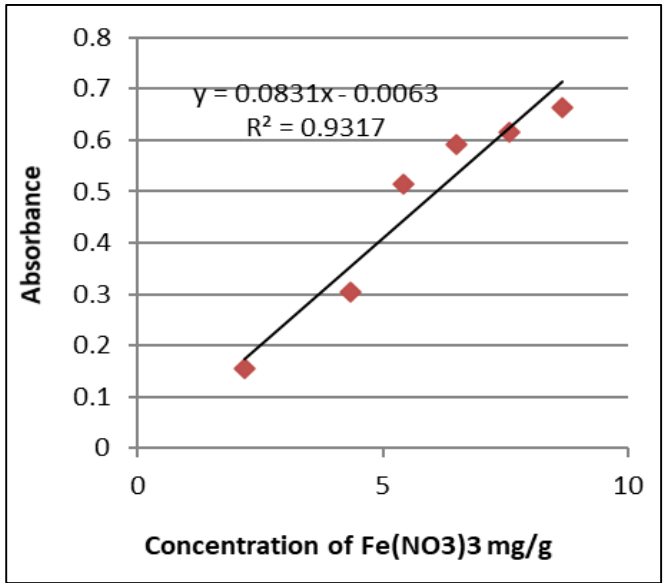

Fig 1: Standard graph for estimation of phytic acid

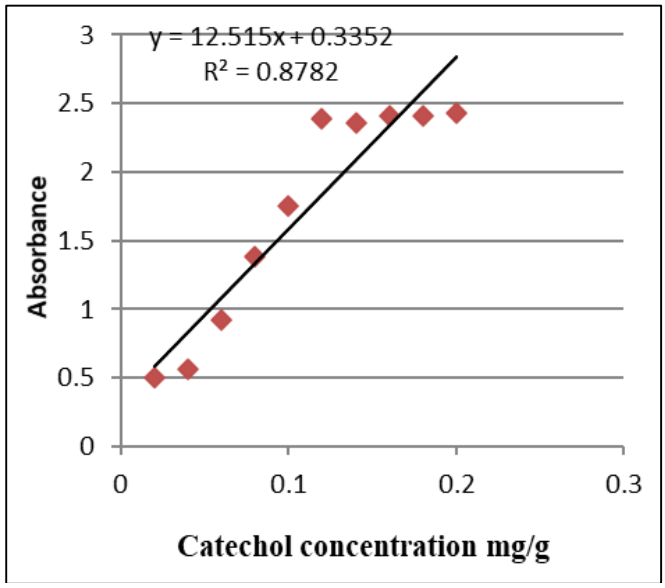

Fig 2: Standard graph for estimation of polyphenols

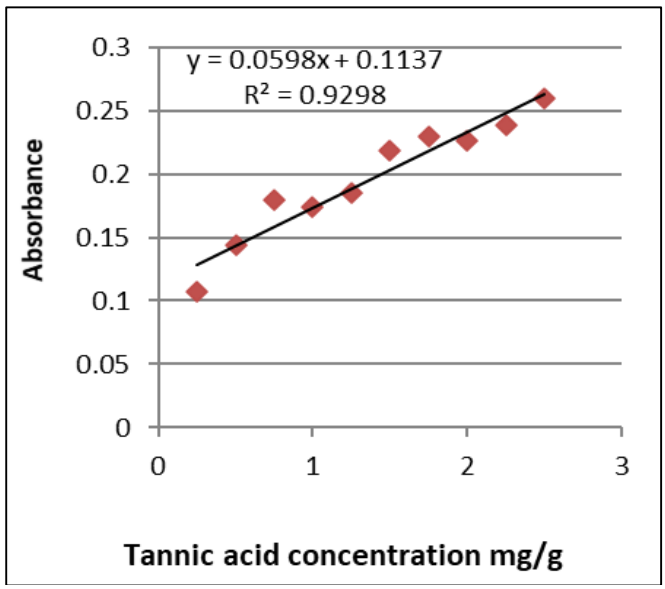

Fig 3: Standard graph for estimation of tannic acid

Conclusion

The study shows that kodo millet is rich in fibre, magnesium, phytic acid, polyphenols, tannin and antioxidants. Thus, the consumption of kodo millet can deliver health benefits. It is required to develop varieties of functional foods from kodo millet and promote utilization among population.

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