Original Research Article

"OPTIMIZATION OF POPPING PARAMETERS AND NUTRITIONAL PROFILING OF KODO MILLET POPS"

Abstract

Aims:This study investigates the optimization of popping parameters to enhance the nutritional profile of Kodo millet pops. Popping is a thermal processing technique widely used to transform whole grains into expanded, edible snacks. This process involves the application of heat to dry grains, causing rapid moisture expansion within the kernel. The sudden increase in internal pressure leads to the rupture of the grain's outer hull, resulting in the characteristic "pop" and expansion of the kernel into a light, crispy texture. Comparing minor millets in popped form highlights their nutritional richness and potential as healthy snacks. Popping enhances their digestibility, texture, and flavor, making them competitive with traditional grains like wheat and maize in terms of nutritional value and consumer appeal.

Studydesign: Experimental design

PlaceandDurationofStudy:The present study was conducted During 2023-2024 at Department of Foods and Nutrition, Post Graduate and Research Centre (PGRC), Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad (India).

Methodology: Kodo millet analyzedforphysicalparametersviz.Popping capacity, Bulk density, True density, Expansion ratio and popped ratio.FunctionalpropertiesofKodo millet grainssuchas Water absorption capacity,watersolubilityindex,oilabsorptioncapacity;andnutritionalpropertieslikemoisture,fat,ash,crudefiber, carbohydrates,protein , energy, Starch; Minerals like Sodium, potassium, Iron, Zinc, Calcium.

Results: The analysis revealed that in Kodo millet pops, physical parameters such as popping capacity, true density, and bulk density decreased. The popped ratio decreased notably for KM29 (14%, 18%, 22%), while the expansion ratio showed a decrease with increased moisture content. Functional properties like water solubility index and water absorption capacity significantly increased ($p \leq 0.05$), whereas oil absorption capacity decreased significantly in KMC2514 (6.48%) and KMM2914 (78.70%).There was a significant decrease ($p \leq 0.05$) in moisture content for KMM2914 (42.8%) and KMC2514 (50.5%), ash content for KMM2914 (7.6%) and KMC2514 (3.84%), crude fiber for KMM2914 (16.7%) and KMC2514 (15.6%), protein for KMM2914 (4.16%) and KMC2514 (0.41%), fat for KMC2514 (31.4%) and KMM2914 (30.81%), starch for KMM2914 (0.17%) and KMC2514 (0%), and energy for KMC2514 (5.73%) and KMM2914 (6.3%), whereas carbohydrate content increased significantly ($p \leq 0.05$).Mineral analysis showed significant increases ($p \leq 0.05$) in calcium, iron, zinc, and sodium content, while potassium content decreased significantly ($p \leq 0.05$) in KMM2914 (50.57%) and KMC2514

(51.7%).

Keywords:Kodo millet, Machine popping, Conventional popping, Physical, functional, Nutritional parametersof kodo millet pops**.**

INTRODUCTION

The word name "millet" is derived from the French word "mile," which meaning "thousand," a handful of millets must contain thousands of grains (1). Minor millets are small coarse of grains belonging to the group of forage grass called millet, belongs to the family Poaceae; most of the genera belongs to the sub-family Panicoideae, that can grow in extreme ecological conditions. Minor millets are an important traditional food with tremendous nutritional and medicinal application but, less concern about the importance of minor millets among the people (2).

Kodo millet (*Paspalum scrobiculatum L*.) was domesticated in India almost 3000 years ago. It is found across the old world in humid habitats of tropics and subtropics. It is a minor grain crop in India, and an important crop in the Deccan plateau. Its cultivation in India is generally confined to Gujarat, Karnataka, Chhattisgarh, Eastern Madhya Pradesh and parts of Tamilnadu.Kodo grains contain 8.35% protein, 1.45% fat, 65.65% carbohydrate and 2.95% ash. It may be considered as nutri-cereal. Nutritionally it is comparable with other common cereals and in somerespect it is superior to rice and wheat.The grain is recommended as a substitute for rice to the patients suffering from diabetes disease. Kodo grains provide cheap proteins, minerals and vitamins to poor people(3).

Popping is a simultaneous starch gelatinization and expansion process, during which grains are exposed to high temperatures for short time. During this process, superheated vapour produced inside the grains by instantaneous heating, cooks the grain and expands the endosperm suddenly, breaking out the outer skin (4).

In the past, popping and puffing were used to extend shelf life, improve organoleptic qualities, and make it easier to incorporate ingredients into ready-to-eat meals(5). Popping millet is becoming increasingly popular as a snack and as an ingredient for different formulations in baby foods due to its ready-to-eat, lighter and crispness characteristics, nutritional quality and increased palatability (6).The study was designed to optimize popping characterstics and physicofunctional and nutritional profiling of kodo millet. The popping constitutes an interest for food industries and the results of this study will provide information in order to produce good-quality poppedkodo millet.

MATERIALS AND METHODS

The present study was conducted during 2023-2024 at Department of Foods and Nutrition, Post Graduate and Research Centre (PGRC), Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad (India).

Pre-conditioning of grain:

Grain Procuring: The kodo millet was procured from the market, after which it was cleaned and graded.

Soaking: The cleaned and graded grain samples were soaked in water for 2hrs, then they were tray dried at 60°C for 15 minutes until desired moisture is obtained.

Moisture: The moisture of the grain was monitored by using Mini Gae plus moisture tester.

Popping: Then the preconditioned grain was then popped by using conventional and hot air popping method at different temperature and moisture levels as given in Table 1.

The popping technologiesused: Conventional method (Sand roasting):In sand roasting method, pre-conditioned kodo millet grains were exposed to hot sand, while temperature of sand is about 230°C to 250°C (4).

Machine popping method (Technocrats popping machine):The popping machine was designed by Indian Institute of Food Processing Technology, Thanjavur, Tamil Nadu, purchased from Technocrats was used. The popping experiments were conducted using the experimental high temperature short time (HTST) machine popping.

Process parameters: The process variables for machine popping were temperature and initial grain moisture content were optimized keeping hot-air velocity as constant to obtain the best yield and quality of kodo millet pops.

Table 1. Processing parameter of kodo millet pops

Sl. No	Sample	Temp ofconventional pops	Temp of machine pops	Moisture (%)
1.	Kodo millet (*Paspalumscrobiculatum*)	230 ˚C	290 ˚C-300 ˚C	14,18 & 22
		240 ˚C	300 ˚C-310 ˚C	14,18 & 22
		250 ˚C	310 ˚C-320˚C	14,18 & 22

Physical parameters: Popping capacity, bulk density(7), true desnity (8).expansion ratio**,** popped ratio **(**9) was estimated for the control(kodowhole grain), conventional popped and machine popped samples.

Sensory evaluation of Kodo millet pops : The sensory analysis was conducted in a sensory evaluation laboratory. Semi trained panel members (15) from the Foods and Nutrition Department at Post Graduate and Research Centre, PJTSAU, Rajendranagar, Hyderabad, were selected as panelmember for the study. They were given written instructions and asked to evaluate the products for acceptability in terms of appearance, color, texture, taste, flavour, crispness and overall acceptability using a 9-point hedonic scale, where 1= dislike extremely, 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like, nor dislike; 6 = like slightly; 7 = like moderately and 8 = like very much 9= Like extremely. The samples were presented in plates coded with three - digit numbers in individual booths in sensory evaluation lab. Panelists rinsed their mouth with water after testing each sample.

Functional parameters: Water absorptioncapacity (WAC),watersoulbilty index(WSI), oil absorption capacity(OAC)(10;11) were analysed for selected samples.

Nutritional composition:moisture (12), ash (12), protein (13), fat (12), carbohydrate (14), energy (15) and crude fiber (16), minerals like sodium, potassium, zinc, iron and calcium (17) were analyzed by following standard methods.

Statistical analysis: All experiments were performed three times. All the data were presented as mean ± standard deviation of the mean. The data was analyzed using MS Excel and Indostat software. The results are presented in the form of mean and standard deviation.The data of different sensory characteristics, physical properties and functional properties was subjected to analysis of variance (ANOVA) and the means were compared by Turkey test at a 5% level of significance (18).

RESULTS AND DISCUSSION

Table 2. Popping capacity of kodo millet (%)

Sample	Popped	Semi popped	Unpopped
Conventional			
KC2314	$14.00^{c}\pm1.00$	$24.33^{gh}\pm0.58$	$61.67^{c}\pm0.58$
KC2318	$12.00^{de}\pm1.00$	$19.33^{j}\pm1.15$	$68^{b}\pm1.00$
KC2322	$10.00^{fg}\pm1.00$	$30.00^{cde}\pm1.00$	$60.00^{cde}\pm2.00$
KC2414	$16.00^{b}\pm1.00$	$24.33^{gh}\pm0.58$	$59.67^{cde}\pm1.53$
KC2418	$11.67^{def}\pm1.53$	$28.33^{ef}\pm0.58$	$60.00^{cde}\pm2.00$
KC2422	$11.00^{ef}\pm1.00$	$31.00^{cd}\pm1.00$	$58.00^{e}\pm1.00$
KC2514	$10.00^{fg}\pm1.00$	$32.00^{c}\pm1.00$	$58.67^{de}\pm1.15$
KC2518	$9.00^{g}\pm1.00$	$11.33^{k}\pm0.58$	$79.67^{a}\pm1.53$
KC2522	$6.00^{h}\pm1.00$	$41.67^{b}\pm0.58$	$52.33^{f}\pm0.58$
Machine			
KM2914	$18.67^{a}\pm1.15$	$21.33^{ij}\pm1.15$	$60.00^{cde}\pm0.00$
KM2918	$13.33^{cd}\pm1.15$	$50.00^{a}\pm2.00$	$36.67^{h}\pm1.15$
KM2922	$10.67^{efg}\pm1.15$	$30.67^{cde}\pm1.15$	$58.67^{de}\pm1.15$
KM3014	$16.67^{b}\pm1.15$	$43.33^{b}\pm1.15$	$40.00^{g}\pm0.00$
KM3018	$11.33^{ef}\pm1.15$	$30.00^{cde}\pm2.00$	$58.67^{de}\pm1.15$
KM3022	$10.67^{efg}\pm1.15$	$22.00^{hi}\pm2.00$	$67.33^{b}\pm1.15$
KM3114	$13.33^{cd}\pm1.15$	$26.00^{fg}\pm2.00$	$60.67^{cd}\pm1.15$
KM3118	$12.00^{de}\pm0.00$	$23.00^{hi}\pm3.61$	$66.00^{b}\pm2.00$
KM3122	$10.67^{efg}\pm1.15$	$28.67^{de}\pm1.15$	$60.67^{cd}\pm1.15$
Mean	12.05	28.74	59.25
S.E	0.41	1.23	1.28
C.D	1.83	2.54	2.10
C.V (%)	9.17	5.33	2.13

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not differ significantly at ($p\leq 0.05$).

KC2314:Conventional popping of kodo millet 230°C with14% moisture.
KC2318: Conventional popping of kodo millet 230°C with18% moisture.
KC2322: Conventional popping of kodo millet 230°C with 22% moisture.
KC2414: Conventional popping of kodo millet 240°C with14% moisture.
KC2418: Conventional popping of kodo millet 240°C with18% moisture.
KC2422: Conventional popping of kodo millet 240°C with 22% moisture.
KC2514: Conventional popping of kodo millet 250°C with14% moisture.

KM2914:Machine popping of kodo millet 290°C with14%
KM2918:Machine popping of kodo millet 290°C with 18%
KM2922:Machine popping of kodo millet 290°C with 22%
KM3014:Machine popping of kodo millet 300°C with14%
KM3018:Machine popping of kodo millet 300°C with18%
KM3022:Machine popping of kodo millet 300°C with 22%
KM3114:Machine popping of kodo millet 310°C with14%

KC2518: Conventional popping of kodo millet 250°C with18% moisture.
KC2522: Conventional popping of kodo millet 250°C with 22% moisture.
KM3118:Machine popping of kodo millet 310°C with18%
KM3122:Machine popping of kodo millet 310°C with 22%

Physical parameters:

The data on popping capacity of kodo millet grain are presented in Table 2. The popping percentage in conventional method ranged from 6± 1.00% (KC2522) to 16± 1.00%(KC2414) where as in machine it was 10.67±1.15% to 18.67±1.15%(KM2922 and KM3122).The results indicated that in both the methods, as the moisture content is increased the percentage of popping decreased.The highest popping percentage was at 290°C temperature with 14% moisture and lowest popping percentage wasat 250°C temperature at 22% moisture content. When compare to conventional method, unpopped grains were less in machine method. At 290°C with 18% of moisture the unpopped grains (36.67±1.15%) and 300°C with 14% of moisture it was 40.00 ± 0.00%.Hence it can be concluded that popping capacity is more in machine method when compare to conventional method (Table 2).

Table 3. Physical parameters of kodo millet

Sample	Bulk density(g/L)	Truedensity (%)	Expansionratio (ml/100g)	Poppedratio (g/100g)
kw	0.76^{a}±0.00	1.67^{a}±0.58	-	-
Conventional				
KC2314	0.14^{fg}±0.00	0.67^{d}±0.00	0.97^{e}±0.02	0.383^{h}±0.01
KC2318	0.16^{cd}±0.00	0.56^{d}±0.09	0.81^{f}±0.02	0.32^{i}±0.01
KC2322	0.16^{c}±0.00	0.54^{d}±0.00	0.65^{hi}±0.02	0.433^{d}±0.04
KC2414	0.14^{fg}±0.00	0.10^{d}±0.00	1.15^{cd}±0.04	0.403^{efgh}±0.02
KC2418	0.15^{fg}±0.01	0.70^{cd}±0.52	0.8^{fg}±0.04	0.4f^{gh}±0.02
KC2422	0.17^{b}±0.00	1.00^{bc}±0.00	0.66^{hi}±0.02	0.42^{def}±0.01
KC2514	0.15^{de}±0.01	0.53^{d}±0.00	0.646^{hi}±0.07	0.413^{defg}±0.01
KC2518	0.15^{ef}±0.01	0.54^{d}±0.01	0.6^{i}±0.03	0.203^{j}±0.02
KC2522	0.16^{cd}±0.00	0.99^{bc}±0.00	0.423^{j}±0.03	0.476^{c}±0.01
Machine				
KM2914	0.10^{j}±0.00	1.00^{b}±0.00	1.833^{a}±0.06	0.4^{fgh}±0.00
KM2918	0.12^{i}±0.00	1.00^{b}±0.00	1.13^{d}±0.09	0.62^{a}±0.01
KM2922	0.14^{gh}±0.00	1.00^{b}±0.00	0.76^{fg}±0.09	0.413^{defg}±0.01
KM3014	0.10^{j}±0.00	1.01^{b}±0.00	1.63^{b}±0.06	0.6^{b}±0.00
KM3018	0.12^{i}±0.00	0.99^{bc}±0.00	0.903^{e}±0.06	0.413^{defg}±0.01
KM3022	0.14^{fg}±0.00	0.99^{bc}±0.00	0.72^{gh}±0.03	0.426^{de}±0.01
KM3114	0.11^{j}±0.00	0.99^{bc}±0.00	1.21^{c}±0.10	0.393^{gh}±0.01
KM3118	0.13^{h}±0.00	0.68^{d}±0.00	0.9^{e}±0.00	0.34^{i}±0.02
KM3122	0.16^{cd}±0.01	0.43^{d}±0.00	0.663^{hi}±0.03	0.406^{efgh}±0.01
Mean	0.1732	0.8094	0.9119	0.4156
S.E	0.188	0.0479	0.0487	0.0126
C.D	0.0815	0.30180	0.08955	0.02586
C.V (%)	2.841	22.518	5.919	3.750

Note: Values are expressed as mean ± standard deviation of three determinations. Means within the same column followed by a common letter do not differsignificantly at ($p \leq 0.05$).

KC2314: Conventional popping of kodo millet 230°C with14% moisture.
KC2318: Conventional popping of kodo millet 230 °C with18% moisture.
KC2322: Conventional popping of kodo millet 230°C with 22% moisture.
KC2414: Conventional popping of kodo millet 240°C with14% moisture.
KM2914:Machine popping of kodo millet 290°C with14%
KM2918:Machine popping of kodo millet 290°C with 18%
KM2922:Machine popping of kodo millet 290°C with 22%
KM3014:Machine popping of kodo millet 300°C with14%

KC2418: Conventional popping of kodo millet 240°C with18% moisture.	KM3018:Machine popping of kodo millet 300°C with18%
KC2422: Conventional popping of kodo millet 240°C with 22% moisture.	KM3022:Machine popping of kodo millet 300°C with 22%
KC2514: Conventional popping of kodo millet 250°C with14% moisture.	KM3114:Machine popping of kodo millet 310°C with14%
KC2518: Conventional popping of kodo millet 250°C with18% moisture.	KM3118:Machine popping of kodo millet 310°C with18%
KC2522: Conventional popping of kodo millet 250°C with 22% moisture.	KM3122:Machine popping of kodo millet 310°C with 22%
KW- kodo whole grain.	

Bulk density: Bulk density was highest in KW (0.76±0.00g/L) then all the experimental samples. The bulk density in conventional and machine popping ranged from 0.10±0.00g/L (KM2914) to 0.17±0.00g/L (KC2422)(Table 3). It was observed that in all temperatures, as the moisture content was increasing the bulk density of pops was increased. The highest bulk density is observed at 240°C temperature 22% moisture (0.17±0.00g/L) (Table 3). The volume of puffing depends on the bulk density of rice. As the grain weight increases, bulk density will be decreased but volume will be increased. In puffing operation, the volume of puffing is depends on the bulk density of grain (19).

True density: True density of kodo whole grain was highest (1.67±0.58%) when compare to both popping methods ranged from KC2414 (0.10±0.00%) toKM2914, KM2918, KM29222 (1.00±0.00%)(Table 3).In conventional at 230°C with increase of moisture true density was decreased (0.67% to 0.54%) when compared to 240°C and 250°C as the moisture increased, true density was decreased. In machine at 290°C temperature as the moisture increases true density remains constant when compare to 300°C and 310°C temperature the moisture increases true density has been decreased (Table3).

Expansion ratio: The expansion ratio in conventional method ranged from 0.423±0.03ml/g (KC2522) to 1.15± 0.04ml/g (KC2414) were as in machine it was 0.663±0.03ml/g (KM3122) to 1.833±0.06ml/g (KM2914)(Table 3).The results indicated that in both methods as moisture content is increases the expansion ratio was decreased. The highest expansion ratio was 290°C with14 % of moisture and lowest expansion ratio at 250°C with 22% of moisture. The volume of puffingdepends on the bulk density of grain. Higher density results in higher expansion ratio (19).

Popped ratio: The results indicated that popped ratio in all the temperatures, (except 290°C with moisture of 14%, 18%, 22%) as the moisture content was increased, popped ratio increased at 14% but decreased at 18% and again increased at 22% moisture. The popped ratio in conventional method ranged from 0.203±0.02 g/100g (KC2518) to 0.476±0.01 g/100g(KC2522) were as in machine it was 0.34±0.02g/100g(KM3115) to 0.62±0.01g/100g (KM2918) (Table 3).The highest popped ratio (0.62±0.01g/100g) was at 290°C with 18%moisture and lowest (0.203±0.02g/100g) at 250°C with 18% moisture.

Based on highest popping capacity and popping ratio the samples KMC1423, KMC1424, KMC1425, KMM1429, KMM1430, KMM1431 were selected for analysing functional properties and sensory evaluation(Table 2 and Table 3).

Table 4. Sensory scores of kodo millet pops

Sample	Appearance	Colour	Flavour	Taste	Texture	Crispiness	Overall Acceptability
KMC1423	$7.40^{ab} \pm 0.74$	$7.33^{a} \pm 0.62$	$7.53^{ab} \pm 0.64$	$7.40_{a} \pm 0.63$	$7.47^{a} \pm 0.64$	$7.60^{a} \pm 0.51$	$7.53^{ab} \pm 0.52$
KMC1424	$7.40^{ab} \pm 0.73$	$7.33^{a} \pm 0.62$	$7.53^{ab} \pm 0.64$	$7.40^{a} \pm 0.63$	$7.47^{a} \pm 0.64$	$7.60^{a} \pm 0.51$	$7.53^{ab} \pm 0,52$
KMC1425	$7.33^{ab} \pm 0.72$	$7.27^{a} \pm 0.88$	$7.20^{bc} \pm 0.86$	$7.40^{a} \pm 0.83$	$7.47^{a} \pm 0.83$	$7.60^{a} \pm 0.99$	$7.60^{ab} \pm 1.06$
KMM1429	$7.53^{a} \pm 0.74$	$7.40^{a} \pm 0.91$	$7.67^{a} \pm 0.62$	$7.73^{a} \pm 0.59$	$7.53^{a} \pm 0.83$	$7.60^{a} \pm 0.74$	$7.87^{a} \pm 0.52$
KMM1430	$7.27^{ab} \pm 0.74$	$7.33^{a} \pm 0.62$	$7.40^{ab} \pm 0.64$	$7.40^{a} \pm 0.63$	$7.40^{a} \pm 0.64$	$7.27^{ab} \pm 0.51$	$7.53^{ab} \pm 0.52$
KMM1431	$6.93^{b} \pm 0.88$	$7.07^{a} \pm 0.70$	$6.93^{c} \pm 0.80$	$7.33^{a} \pm 0.82$	$6.87^{a.} \pm 0.64$	$7.13^{b} \pm 0.52$	$7.20^{b} \pm 0.56$
Mean	7.31	7.28	7.38	7.44	7.36	7.46	7.54
S.E	0.08	0.08	0.08	0.08	0.08	0.77	0.07
C.D	0.56	0.50	0.43	0.46	0.45	0.46	0.46
C.V%	10.53	9.55	8.16	8.51	8.41	8.57	8.40

Note: values are expressed as mean ± standard deviation of three determinants

Means within the same column followed by a common letter do not differ significantly at ($p \leq 0.05$).

KMC1423 - Kodo millet conventional (230 °C with 14% of moisture)
KMC1424 - Kodo millet conventional (240 °C with 14% of moisture)
KMC1425 - Kodo millet conventional (250 °C with 14% of moisture)
KM1429:Kodo millet Machine(290°C with14%moisture)
KM1430:kodo millet machine (300°C with 14% moisture)
KMC1431:Kodo millet machine(310 °C with 14% of moisture)

Sensory scores of kodo millet pops : The sensory evaluation of appearance ranged from 6.93 ± 0.889 (KMM1431) to 7.53 ± 0.74 (KMM1429), color ranged from 7.07 ± 0.70 (KMM1431) to 7.40 ± 0.91 (KMM1429), flavor ranged from 6.93 ± 0.80 (KMM1431) to 7.67 ± 0.63 (KMM1429), taste ranged from 7.33 ± 0.82 (KMM1431) to 7.73 ± 0.59 (KMM1429) (Table 4), and texture ranged from 6.87 ± 0.64 (KMM1431) to 7.53 ± 0.83 (KMM1429).Among these attributes, appearance, color, flavor, taste, and texture exhibited their narrowest range at 310°C temperature with 14% moisture, while their widest range was observed at 290°C temperature under the same moisture conditions. Sensory attributes for appearance, color, flavor, texture, and taste remained consistent at 230°C and 240°C but decreased at 250°C, 300°C, and 310°C temperatures. Crispiness increased notably at 290°C, remained stable at 230°C, 240°C, 250°C, and 290°C, and showed further increases at 300°C and 310°C temperatures. Overall acceptability was highest at 290°C temperature with a score of 7.87 ± 0.52 and lowest at 310°C temperature with a score of 7.20 ± 0.56(Table 4).

Based on the popping ratio and sensory evaluation, best accepted sample KW, KMC1425, KMM1429 were used for further analysed for functional and nutritional properties. the KM1425(Kodo millet conventional 14% moisture with 250°Ctemperature andkodo millet machine 14% moisture 290°C temperature can be denoted as KMC and KMW).

Table 5.

Sample	Functional parameters		
	WAC (g/100g)	WSI (%)	OAC (g/100g)
KMW	1.16[c]±0.01	1.15[c]± 0.01	1.08[b]± 0.01
KMC	3.85[b]± 0.01	2.65[b]± 0.01	1.01[c]± 0.01
KMM	4.16[a]± 0.02	2.76[a]± 0.01	1.93[a]± 0.01
Mean	3.06	2.19	1.34
S.E	0.47	25.82	0.14
C.D	0.13	0.002	0.01
C.V (%)	0.01	0..0005	0.

Functional parameters of kodo millet pops

Note: values are expressed as mean ± standard deviation of three determinants**.**

Means with same column followed by a common letter do not differ significantly at (p ≤0.05).

KMM–Machine popping of Kodo millet pops KMW - Whole grain of Kodo millet

KMC-Conventionalpoppingof Kodomillet pops

Functional parameters: The data of functional parameters of kodo millet samples (whole grain, conventional pops, and machine pops) were statistically analysed and presented in Table 5 and the percentage change in experimental sample when compared with control were presented in Figure 1.

Water absorption capacity (WAC): The results showed that KMM2914 (4.16 ± 0.02 g/100g) had more WAC than KMC2514 (3.85± 0.01 g/100g), followed by KMW (1.16 ±0.01g/100g).There was significant($p \leq 0.05$) increased in KMM2914 (231.8%), KMC2514 (258.6%) when compared to control (KMW) (Figure 1).(20) reported that water absorption capacity of Maize - pop corn flour was 1.73 ±0.3%.

Water solubilty Index (WSI): The water solubility index of KMM2914 (2.76 ± 0.01%), KMC2514 (2.65± 0.01%) was increased when compared to control(1.15 ± 0.01%).The increase of WSI was 140%(KMM2914) and 130.43%(KMC2514),when compared to the control KMW (Figure 1).stated that water solubility index of puffed rice was 4.69 ± 0.16% white rice was 1.39 ± 0.07%(21).

Oil absorption capacity (OAC): It was found that KMM2914 (1.93 ± 0.01g/100g) had a higher OAC where asKMC2514 (1.01± 0.01g/100g) had lower when compare to KMW. There was an78.70% increase of OAC in KMM2914 and 6.48%decrease in KMC2514 of oil absorption capacity with respect to control (Figure 1).(20) reported that showed that oil absorption capacity of maize flour was (0.63 ±0.02g/100g).

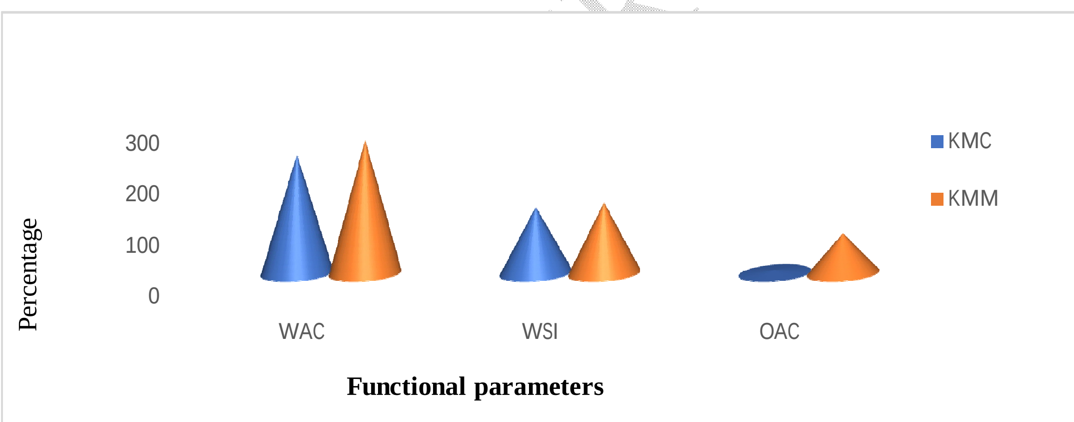

Figure 1. The percentage changes in the functional parameters of kodo millet experimental samples to control.

WAC :Water absorption capacity
WSI : Water solubilty Index
OAC : Oil absorption capacity
KMC: Kodo millet conventional pops
KMM :Kodo millet machine pops

Table 6. Nutritional composition of kodo millet pops (g/100g)

Sample	Moisture	Ash	Crude fiber	Carbohydrate	Protien	Fat	Starch	Energy Kcal/100g
KMW	9.25[a]±0.01	2.60[b]±0.01	8.80[a]± 0.01	71.13±0.0.01	8.41[a]± 0.01	3.25[a]± 0.06	5.60[a]± 0.16	349[b] ±0.41
KMC1425	4.57[c]±0.01	2.50[c]±0.01	7.43[a]± 0.01	73.71±0.01	8.06[a]± 0.01	2.10[c]± 0.12	5.60[a]± 0.16	329[a] ±0.58
KMM1429	5.29[b]±0.01	2.80[a]±0.00	7.33[a]± 0.01	72.99±0.01	8.16[a]± 0.01	2.11[b]±0.06	5.59[a]± 0.15	327[a] ±0.30
Mean	6.37	2.633	7.853	78.94	8.21	2.48	5.59	335s
S.E	0.728	0.043	1.324	4.69	0.156	0.912	0.4965	0.0212
C.D	0.031	0.017	1.115	0.45	0.854	2.118	2.002	0.0831
C.V (%)	0.219	0.297	9.389	0.04	4.657	19.458	18.271	0.479

Note: values are expressed as mean ± standard deviation of three determinants

Means with same column followed by a common letter do not differ significantly at ($p \leq 0.05$).

KMW - Whole grain of Kodo millet

KMC1425 - Conventional popping of Kodo millet pops

KMM1429– Machine popping of Kodo millet pops

Proximate composition of kodo millet pops.

Moisture: Moisture content of KMW (9.25±0.02%), which was significantly ($p \leq 0.05$) more than the KMM (5.29± 0.01%) and KMC samples (4.5±0.01%) (Table 6). In KMW 42.8% decreases of moisture content was observed, whereas in KMC 50.5% decrease was observed(Figure 2).(22) reported that moisture contentof popped maize flour (4.78% ± 0.20) and popped sorghum flour was (5.53 ± 0.32%).

Ash: KMM, KMC and KMW showed significant difference ($p<0.05$).The ash content of KMM was 2.80±0.00g/100g is greater than KMC (2.50±0.0100g/100g) and KMW. In KMM 7.6% increase of ash content observed,where as in KMC 3.84% decreases when compared with control (Figure 2). The findings of ash content of puffed rice was1.36 ± 0.220g/100g (23)

Crude fiber: The crude fiber content of KMC (7.43 ± 0.060g/100g) and KMM (7.33 ± 0.030g/100g) had less than KMW(8.80 ± 0.200g/100g) Table 6. In KMC 15.56% decrease of crude fiber was observed where as in KMM 16.7% decrease compared to control (Figure 2).(20) reported that crude fiber content of Maize- pop corn flour was 6.74±0.020g/100g.

Carbohydrate: The carbohydrate content of KMC (73.71±0.120g/100g) (Table 6) was significantly higher ($p<0.05$) than the KMM(72.99±0.080g/100g) and KMW (71.13±0.00g/100g) with an increase of KMC 3.62% and KMM 2.61%in (Figure 2).(23) reported carbohydrate contents on puffed rice was 83.28 ± 0.38g/100g.

Protien: KMM(8.16± 0.03g/100g) and KMC (8.06± 0.03g/100g) showed no significant difference compared to the KMW (8.41± 0.04g/100g). In KMM4.16% decrease of protein content was observed where as inKMC 0.41% was observed (Figure 2).(22)stated on popped sorghum flour of protein content was 8.49 ± 0.16g/100g.

Fat:KMC(2.10± 0.12g/100g) and KMM (2.11± 0.06g/100g) showed no significant difference compared to the KMW (3.05±0.02g/100g),In KMC 31.14% decreases of fat content and in KMM 30.81%was observed.(Figure 2).

Starch: The starch content of KMW (5.60± 0.16g/100g), KMC (5.60± 0.16g/100g) and KMM (5.59± 0.15g/100g) found that there is no significant difference, with a decrease of KMM 0.17% and KMC 0.00% when compared to control.(Figure 2).

Energy: The energy content of KMC(329Kcal/100g) and KMM(327Kcal/100g),showed no significant difference with the control (349Kcal/100g). In KMM 6.3% decrease of energy was observed, where as in KMC 0% was observed(Figure 2).

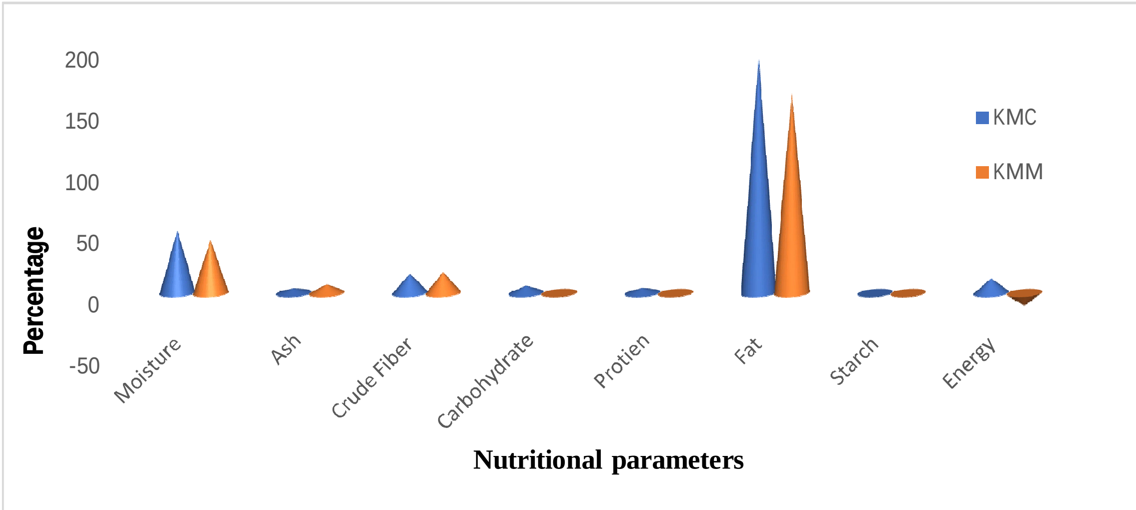

Figure 2. The percentage change in the Nutritional parameters of kodo millet compared with control.

Note:

KMC1425 : Kodo Millet Conventional pops250°C with 14% moisture.

KMM1429: Kodo millet machine pops 290°C with 14% moisture.

Table 7. Minerals composition kodo millet (mg/100g).

Sample	Calcium	Iron	Zinc	Potassium	Sodium
KMW	0.25^{c} ± 0.01	0.02^{b}± 0.01	2.23^{c}± 0.01	4.35^{a}±0.01	0.11^{c}±0.01
KMC1425	0.26^{b}±0.01	0.03^{a}±0.01	2.65^{b}±0.01	2.10^{c}±0.01	0.12^{b}±0.01
KMM1429	0.27^{a}±0.01	0.03a±0.01	2.72^{a}±0.01	2.15^{b}±0.01	0.13^{a}±0.11
Mean	0.26	0.026	2.5	2.8	0.12
S.E	0.001	0.013	0.011	0.014	0.011
C.D	0.002	0.001	0.003	0.001	0.004
C.V (%)	0.05	0.04	0.484	0.001	0.367

Note: values are expressed as mean ± standard deviation of three determinants

Means with same column followed by a common letter do not differ significantly at (p ≤0.05).

KMW - Whole grain of Kodo millet

KMC -Conventional popping of Kodo millet pops250°C14% moisture

KMM1429-Machine popping of kodo millet pops at 290°Cwith 14 % moisture

Calcium: The results indicated in Table 7 that calcium content of KMM(0.27±0.01mg/100g) and KMC (0.26±0.01mg/100g) was significantly (p ≤0.05)more when compared to KMW (0.25 ± 0.01mg/100g), with a increase of 8%KMM and 4% of KMC (Figure 3).

Potassium: The results indicated in Table 7 that potassium content of KMM(2.15 ±0.01mg/100g) and KMC(2.10 ±0.01mg/100g) was significantly (p ≤0.05)greater when compared to KMW(4.35±0.01mg/100g), with a increase of 5.07%KMM and 51.7% of KMC (Figure 3).

Sodium: The sodium content of KMM (0.13±0.11mg/100g), followed by KMC (0.12±0.01mg/100g) and KMW (0.11±0.01mg/100g. In Figure 3, it was graphyically illustrated that, there was a increase of KMM 8%and KMC 4% when compared to control.

Iron: The iron content of KMM(0.03±0.01mg/100g) and KMC (0.03±0.01mg/100g) was greater than KMW (0.02± 0.01mg/100g) was significantly (p ≤0.05), The iron content of KMM 50% and KMC50% significant difference is greater than control (Table 7).

Zinc: The results in Table 7indicated that KMM (2.72±0.01mg/100g) and KMC (2.65±0.01mg/100g) had significantly greater (p ≤0.05)when compared **to** KMW **(**2.23± 0.01mg/100g).In KMC 18% decrease of zinc content, where as in and KMM 21% increase was observed (Figure 3).

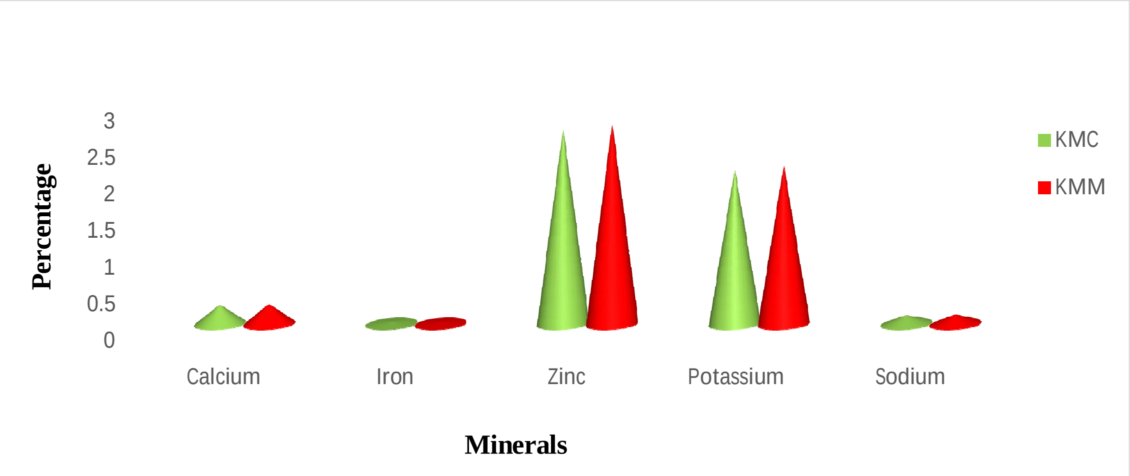

Figure 3. The percentage changes in the Mineral content of kodo millet experimental samples to control.

Note:

KMC1425- Kodo millet pops conventionalat 250°C with 14% moisture

KMM1429- Kodo millet pops machine 290°C with 14% moisture

Conclusion :

The analysis of Kodo millet pops revealed significant changes across various parameters, reflecting the effects of processing on their physical, functional, and nutritional attributes. Physically, decreases were observed intrue density, and bulk density, indicating alterations in the structural integrity of the millet grains upon popping. while the expansion ratio showed a decrease with higher moisture content, affecting the overall texture and volume of the pops. The ideal temperature for conventional popping and machine popping is 250°Cand 290°C with 14% moisture.

Functionally, there were notable increases in the water solubility index and water absorption capacity, suggesting improved water interaction properties post-processing. Conversely, oil absorption capacity decreased significantly in KMC2514 (6.48%) and KMM2914 (78.70%), which could influence the sensory attributes and shelf-life stability of the pops.

Nutritionally, significant decreases were observed in moisture content for KMM2914 (42.8%) and KMC2514 (50.5%), as well as in ash, crude fiber, protein, fat, starch, and energy contents. In contrast, carbohydrate content increased significantly.

Mineral analysis revealed significant increases in calcium, iron, zinc, and sodium content, which are beneficial for overall nutritional value. However, potassium content decreased notably in KMM2914 (50.57%) and KMC2514 (51.7).

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