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Grain Popping of Some Egyptian Rice Cultivars as Affected by Temperature and Sample Weight

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ABSTRACT

The optimum temperature and sample weight of popping for some Egyptian rice cultivars were determined by using new technique depending on invented electric local equipment. Results of both seasons revealed significant variance among cultivars for most studied characters. The superior values for weight of popped, popping %, expansion ratio, and least values for density were noticed with Giza 178 rice cultivar in 2021 and 2022 seasons. However, the superior values for weight of popped, popping % and expansion ratio. While, the lowest value for density was recognized with 190^{o}C in 2021 and 2022 seasons. Superior values for weight after popping were recognized with 190 and 210 ^{o}C in both study seasons respectively. Furthermore, the superior values for popping%, expansion ratio, and lowest values for density were noticed by using 40 g sample weight in both study seasons. Furthermore, the superior values for weight after popping and weight of popped rice were noticed with Giza 178, 190 ^{0}C and 45g sample weight in both study seasons. However, superior values for popping % and expansion ratio while lowest values for density were indicated with Giza 178 and using 40 g sample weight at 190 ^{0}C in both study seasons. Moreover, data declared that the least values for popping %and expansion ratio. while, the highest values for density were indicated with Sakha 101 rice cultivar and 45 g sample weight at 170 ^{0}C in both seasons. Economic value of Giza 178 was enhanced as considerd lower price than other Japonica types in market.

Keywords: Rice, Temperature, Sample weight, Popping %, Expansion ratio.

INTRODUCTION

Designing snack foods is considered a complicated process to meet consumers' expectations and search for unique products that appeal to a wide variety of people. Creating products as snacks requires variations and specific technology to improve the resulting snacks' health image. Popped rice is a cheap, simple and fast method that can be prepared by dry heat application to obtain snack products with great benefit. Bhat Upadya *et al.*, 2008 revealed that popped rice could be prepared by roasting rice kernels with hull on a hot pan at suitable temperature that converted to steam, and 135 psi pressure (at 170 ^{o}C), causing kernel ruptures and leads to expansion by 6-8 times of its original volume. Eating whole rice grain is so healthy as it contains numerous nutrients including minerals, fibers, vitamins and phytochemicals (Maisont and Narkrugsa 2010). Snack products such as popped rice prepared from whole rice kernels with hulls is one of the important healthy products that are consumed in breakfast food as its rich source of carbohydrates and provide the requirement of 60 to 70 % of total energy needs. The popping quality of cereals is influenced by various factors such as cultivar difference, physical and chemical properties of grain, moisture content, bran content, type of endosperm, and method of popping (Hoke *et al.* 2005, Mizra *et al.* 2014, Joshi *et al.* 2014). Paddy rice containing optimum moisture content between 14 and 15% produces superior popping % that could be achieved by great expansion value which is considered one of most quality parameters. The optimum moisture content for expansion of popped rice is governed by vapor pressure inside the kernels before popping however, low moisture content decreases popping % (Song and Eckhoff 1994). Shimoni *et al.* 2002 stated that low popped volume could be obtained by excess moisture content. Popping of rice is influenced greatly by moisture content, and other factors that affect popping in rice are not well studied unlike in maize, where several physico-chemical properties of the kernel are well studied (Dofing *et al.*, 1990; Mohamed *et al.*, 1993; Tian *et al.*, 2001; Ceylan and Karababa, 2002). A common processing technique used to produce popped rice is obtained by iron-pan roasting. The Fe content significantly increased by popping while, a significant drop in carbohydrates was noticed which might be due to the percentage of amylose to amylopectin that leaching from the grains when starch swells. popped rice is primary snack product for novel functional foods that could optimize human health and is characterized by the absence of gluten that provides additional benefit for the celiac patient (Hameeda *et al.* 2023). (Khaled *et al.* 2015) revealed variation between rice cultivars for the popping ability by using different temperatures and various times for popping. Heating Giza 178 rice cultivar for sixty seconds; at 260 ^{0}C gave the highest results for popping percentage in both seasons and results obtained from the interaction revealed that increasing heating time from 40 to 60 seconds, at 260 ^{0}C, may be valuable in the case of the two cultivars Giza 178 and E. yasmine since both cultivars showed superior increment in expansion ratio accompanied with an increase popping %. These two characteristics are important for the popping rice industry since they lead to an increase in yield. On the other hand, Giza 182 variety showed low response to increasing heating time in popping %. Short glutinous and E. yasmin rice cultivars recorded the desirable values for popping %, expansion and

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density compared to other varieties and, declared that the optimum temperature was 180 Celsius for all the studied traits. Moreover, the best sample weight was 40 gm to obtain superior popping %. Increasing the popping temperature could accelerate both melting of rice kernels and evaporation of water in rice as this melting renders the rice grain elastic and expandable whereas, the evaporation exerts the pressure needed for expansion (Dalia 2021). Abd El Salam (2006) showed that the optimum conditions for producing popped rice with the best yield were Giza 178 variety with 14% moisture content, three hundred Celsius heating temperature, 60 seconds and 50 grams weight of paddy rice. For maximizing popping % paddy should contain moisture content between 14 and 15% beside the time of heating is a sensitive parameter also in popping percentage as compared to power level (Swarnakar *et al.*, 2014). Therefore, this study was conducted to determine the influence of temperature and sample weight on popping ability and expansion of some Egyptian rice cultivars.

MATERIALS AND METHODS

Two experiments were performed at Grain Quality Labs; Rice Technology Training Center (RTTC), Field Crop Research Institute, Alexandria, Egypt, to study the influence of temperature, sample weight and their interaction on popping ability and expansion of rice cultivars. Newly harvested certified seeds in 2021 and 2022 growing seasons of eleven rice cultivars namely Giza 177 Sakha 101, Sakha 102, Sakha 103, Sakha 104, Sakha105, Sakha106, Sakha107 (Japonica types), and Giza 178 (Indica-Japonica type) and Giza 182 and Egyptian yasmin (Indica types) were provided by Rice Research Program, Field Crops Research Institute, Agriculture Research Center, Sakha Kafr, El-Sheikh, Egypt. A split-split plot design with three replicates was used in both seasons. The main plots were devoted to rice cultivars and the sub plots occupied four temperature levels (170, 190, 210 and 230 ^{o}C) whereas the sub-sub plots were assigned to three different weight samples (35, 40 and 45 g). The characters were measured on 14 % moisture content basis and fixed time 60 seconds. The studied popping characters were weight after popping (excluding loss in moisture), weight of popped rice (g), popping percentage (%), expansion ratio and density (g/cm^3). Popped and unpopped grains separated using a USA standard testing sieve (No. 6 Fischer Scientific co. Pitsburgh, PA). The popping percentage calculated as mentioned by Swarnakar *et al.* 2014 as follows: Popping % = weight of popped kernels / weight after popping X 100. Expansion ratio was the ratio of the volume of the popped kernels without the husk to that of whole brown rice obtained from 25 g paddy (Murugesan and Bhattacharya, 1989). Density was determined as described by Delost-Lewis *et al.* (1992). Cooking and eating quality characters for some Egyptian rice cultivars were determined. Amylose content was assessed by the improved methodology announced by Juliano 1971; gel consistency was estimated by Cagampang *et al.* 1973 and Gelatinization temperature (spreading and clearing) was recorded according to little *et al.* (1958). Protein content was estimated for brown rice, according to the standard Micro – Kjeldahl methodology. Then, the assessed nitrogen content was multiplied by a factor of 5.95 to estimate the crude protein content. The elongation ratio was estimated, according to Azeez and Shafi (1966).Cooking and eating quality charcters for the studied rice cultivars are mentioned in table 1

Table 1. Cooking and eating quality characters for some Egyptian rice cultivars during 2021 and 2022 harvested Seasons.

	Amylose content %		Gel consistency (G.C) mm		Gelatinization temperature (spreading)		Gelatinization temperature (clearing)		Protein content %		Elongation %	
Cultivars	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
G. 177	18.41	18.68	93.52	93.84	4.15	4.38	4.30	4.56	7.68	7.40	57.11	57.35
G.178	19.23	19.51	91.22	91.75	4.30	4.56	3.81	3.98	8.37	8.19	58.22	59.36
S.101	18.21	18.44	95.31	94.87	5.16	4.78	4.13	3.82	8.26	8.13	57.36	57.59
S.102	18.56	18.78	93.50	93.29	4.92	4.75	4.25	4.12	8.42	8.25	57.20	56.90
S.103	18.70	18.49	94.36	93.88	5.11	4.86	3.77	3.59	8.50	8.29	57.35	57.11
S.104	19.11	18.83	94.21	94.39	5.31	5.14	3.81	3.68	8.58	8.34	56.30	56.58
S.105	19.20	19.38	94.66	94.89	5.16	4.88	4.10	3.74	8.61	8.48	55.88	56.10
S.106	18.84	19.15	93.18	93.72	5.11	5.29	3.66	3.50	8.41	8.57	55.51	55.70
S.107	19.32	19.11	94.33	94.60	5.38	5.57	3.74	3.55	8.53	8.44	55.76	55.53
G.182	22.26	22.44	85.66	86.47	4.14	4.33	3.50	3.36	8.71	8.63	61.50	61.28
E. yasmin	22.51	22.65	85.23	84.69	3.75	3.56	3.26	3.11	8.83	8.69	62.27	61.92

Factors affecting popping conditions were tested by electrical equipment designed and made locally. The equipment consisted of stainless-steel vessel which had the following physical dimensions: the internal diameter 23 cm, length 12 cm, internal volume 603.2 cm^3. The temperature in the popping vessel was monitored with a thermocouple connected to a voltage regulator. To prevent burning during popping or puffing, a stirrer with a fixed speed (80 rpm) was inserted from outside into the popping vessel. Analysis of variance was carried out according to Gomez and Gomez (1984) using SAS program, version 8.0. Means were compared using the least significant difference (LSD) at 0.05 level of probability.

RESULTS AND DISCUSSIONS

Popping properties:

Popping quality is always determined by calculating the expansion ratio. It is defined as ratio of the volume of the popped without husk to that of raw brown rice at a constant weight (Murugesan and Bhattcharya, 1989). Expansion ratio as well as other quality indices, have been found to depend on many factors, such as moisture content of rice, kernel size, shape and other physical properties of variety or genotype, harvesting and handling practices, drying conditions, kernel damage, kernel structure, amount and distribution of protein, starch composition, popping temperature, popping method, and several other unexplained factors (Srinivas and Desikachar 1973; Gokmen, 2004). However, among all these factors affecting expansion ratio, moisture content is the most critical factor, because it affects the rate and extent of pressure build up in starch granules (Hoseney *et al.*, 1983). Popping is a simultaneous starch gelatinization and expansion process, during which grains are exposed to elevated temperatures for a brief time. During this process, super-heated vapor produced inside the grains by instantaneous heating, cooks the grain and expands the endosperm suddenly breaking out the outer skin.

1- Effect of cultivars:

The studied rice cultivars performance in both seasons, are presented in tables (2 and 3). Data revealed that there were significant differences between rice cultivars for all studied characters in the two seasons. Giza 178 rice cultivar showed the highest significant values for weight of popped (34.30 and 32.98 g), popping % (93.88 and 92.76 %) and expansion ratio (9.53 and 9.72) while, it showed the lowest values for density (125.60 and 124.77 g/cm^3) in both study seasons, respectively. Furthermore, data in table 2 revealed that Giza 178 rice cultivar showed the highest significant value for weight after popping (36.51 gm) in 2021 season only. Moreover, Sakha 101 showed the lowest weight of popped rice (31.04 and 30.07 gm), popping (87.18 and 86.25%) and expansion (8.02 and 8.30) but it showed superior values for density (136.33 and 133.40 g/cm^3) in both study seasons, respectively. The lowest weight after popping (34.82 and 34.21 gm) were noticed with Sakha 105 rice cultivar in both study seasons respectively. Furthermore, the highest weight after popping (35.76 g) was noticed with E. yasmin rice cultivar in 2022 season only. This variance between cultivars might be due to partial gelatinization and percentage of amylose to amylopectin that leaching from the grains when starch swells and it might be due to genetic differences between cultivars in grain structure and endosperm characteristics. (Khaled 2017a, Khaled 2017b, Doaa *et al.,* 2018, Khaled *et al.,* 2020, Dalia 2021 and Hameeda *et al.* 2023). Moreover, the popping volume can relate to the genotype, method of expansion, grains physical attributes, and moisture content and the maximum volume popping occurred in the moisture content range from 15.5 % to 11.0 %, also the cereal grains bulk density after expansion decreased (Anne Allred-Coyle *et al.,*2000, Gökmen 2004 and Mariotti *et al.,* 2006).

2- Effect of temperature:

Increasing temperature from 170 to 230 ºC significantly affects all studied characters in both study seasons (Table 2 and 3). The highest values for weight of popped (33.39 and 33.26 g), popping % (92.41 and 94.05 %) and expansion ratio (8.87 and 9.36). While the lowest values for density (127.93 and 126.75 g/cm^3) were recognized with190ºC in 2021 and 2022 seasons, respectively. Superior values for weight after popping (36.14 and 36.11 gm) were recognized with 190 and 210ºC in 2021 and 2022 seasons respectively. However, the lowest values for weight after popping (34.74 and 34.28), weight of popped (31.51 and 29.41 gm), popping % (90.62 and 85.69 %) and expansion ratio (8.40 and 8.66) but the highest values for density (133.81 and 130.77 g/cm^3) were noticed with 170ºC in 2021 and 2022 seasons, respectively. This might be because increasing the heating temperature could accelerate both melting of rice kernels and evaporation of water from center of rice grain to surface. The melting renders the rice kernel elastic and expandable whereas, the evaporation of water from center of grain to outer surface exerts the pressure needed for expansion. Therefore, the expansion of rice increased with optimum heating temperature. Similar results were reported by (Hsieh *et al.,* 1989, Huff *et al.,*1992 and Khaled *et al.,* 2015).

3- Effect of sample weight:

Data presented in (Table 2 and 3) showed that sample weight affects all studied characters in both study seasons. The highest values for popping (93.15 and 91.55 %), expansion ratio (9.03 and 9.54) and lowest values for density (125.18 and 121.53 g/cm^3) were noticed by using 40 gm sample weight in both study seasons, respectively. Moreover, the superior values for weight after popping (44.42 and 43.76 gm) and weight of popped rice (40.52 and 39.69 gm) were noticed by using 45 grams sample weight in both study seasons respectively. Furthermore using 35 gm weight showed lowest values for weight after popping (25.84 and 25.23 gm), weight of popped (23.46 and 22.84 gm), popping (90.79 and 90.46 %), expansion ratio (8.38 and 8.59) while highest values for density (135.81 and 135.09 g/cm^3) in both study seasons, respectively. Superior values for popping and expansion by using 40 g sample weight might be due to regularity and uniform heat distribution in popping electric pan. While, using 45 grams sample weight gave low values and this might be due to the insufficient temperature for whole sample used. Moreover, the lowest values were declared by using 35 g sample weight and this might be due to the occurrence of popped burning.

Table 2. Mean values for weight after popping (g), weight of popped (g), popping percentage expansion ratio and density (g/cm^3) as affected by cultivars, temperature and sample weight in 2021 season.

Characters	Weight after popping (g)	Weight of popped (g)	Popping %	Expansion Ratio	Density (g/cm^3)
		Cultivars			
G. 177	34.84	31.88	91.14	8.18	132.32
G.178	36.51	34.30	93.88	9.53	125.60
S.101	35.52	31.04	87.18	8.02	136.33
S.102	35.27	32.35	91.46	8.62	131.65
S.103	35.35	32.56	91.81	8.59	129.97
S.104	35.38	32.14	90.98	8.68	128.53
S.105	34.82	32.21	92.61	8.72	130.85
S.106	35.07	31.94	91.21	8.26	134.80
S.107	35.08	32.18	92.21	8.60	132.10
G.182	35.83	33.53	93.32	9.17	129.20
E. yasmin	36.20	33.74	93.23	9.15	126.41
L.S.D $_{0.05}$	0.012	0.023	0.083	0.034	0.251
		Temp (^{0}C)			
170	34.74	31.51	90.62	8.40	133.81
190	36.14	33.39	92.41	8.87	127.93
210	35.63	32.83	92.10	8.80	129.37
230	35.27	32.39	91.79	8.69	131.65
L.S.D $_{0.05}$	0.186	0.227	0.086	0.035	0.164
		Sample weight (g)			
35	25.84	23.46	90.79	8.38	135.81
40	36.05	33.59	93.15	9.03	125.18
45	44.42	40.52	91.24	8.64	131.12
L.S.D $_{0.05}$	2.861	3.511	0.361	0.092	1.726

Table 3. Mean values for weight after popping (g), weight of popped (g), popping percentage expansion ratio and density (g/cm^3) as affected by cultivars, temperature and sample weight in 2022 season.

Characters	Weight after popping (g)	Weight of popped (g)	Popping %	Expansion Ratio	Densit (g/cm^3)
			Cultivars		
G. 177	34.35	31.48	91.76	9.08	132.40
G.178	35.53	32.98	92.76	9.72	124.77
S.101	34.97	30.07	86.25	8.30	133.40
S.102	34.79	31.48	90.14	8.88	130.25
S.103	34.68	31.71	91.55	9.09	128.08
S.104	34.97	31.57	90.07	9.18	126.77
S.105	34.21	31.00	90.47	8.66	128.85
S.106	34.45	31.38	91.26	8.72	130.42
S.107	34.62	31.59	91.35	9.17	129.96
G.182	35.19	32.38	91.89	9.62	125.05
E. yasmin	35.76	32.82	91.46	9.54	121.45
L.S.D $_{0.05}$	0.027	0.031	0.014	0.022	0.583
			Temp (^{0}C)		
170	34.28	29.41	85.69	8.66	130.77
190	35.33	33.26	94.05	9.36	126.75
210	36.11	32.88	93.13	9.31	127.42
230	34.80	31.79	90.71	9.25	128.24
L.S.D $_{0.05}$	0.048	0.214	0.115	0.127	0.642
			Sample weight (g)		
35	25.23	22.84	90.46	8.59	135.09
40	35.60	32.60	91.55	9.54	121.53
45	43.76	39.69	90.65	9.12	128.30
L.S.D $_{0.05}$	3.720	5.434	0.253	0.181	2.761

4- Interaction between cultivars, temperature, and sample weight:

Interaction between cultivars, temperature and sample weight showed highly significant differences on all studied characters in both seasons. (Tables 4,5,6,7,8).

Table 4. Mean values for weight after popping (g) as affected by the interaction between rice cultivars, temperature and sample weight in 2021 and 2022 seasons.

Cultivars	Temp (^{0}C)	Weight after popping (g)					
		2021			2022		
		Sample weight (g)					
		35	40	45	35	40	45
G. 177	170	24.39	35.24	42.72	23.82	34.89	42.41
	190	25.95	36.50	44.31	24.68	36.23	43.86
	210	25.21	36.09	43.60	24.22	35.85	43.45
	230	25.10	35.80	43.22	24.06	35.63	43.13
G.178	170	26.71	35.80	45.72	25.13	35.31	44.37
	190	27.31	37.31	46.78	26.65	36.14	45.72
	210	26.92	36.42	46.20	26.22	35.83	44.82
	230	26.80	36.11	46.03	26.03	35.60	44.53
S.101	170	24.70	35.41	44.20	24.17	35.05	43.75
	190	26.33	36.52	45.60	25.72	36.26	44.32
	210	25.90	36.20	45.13	25.35	36.02	44.11
	230	25.62	35.86	44.74	25.14	35.87	43.92
S.102	170	25.36	35.54	42.86	25.02	35.17	42.45
	190	26.76	36.62	44.79	25.95	36.22	43.70
	210	26.17	36.11	43.82	25.56	35.90	43.41
	230	25.90	35.82	43.51	25.33	35.72	43.07
S.103	170	25.13	35.11	43.72	24.70	34.83	43.42
	190	26.89	36.82	44.84	25.55	35.65	43.90
	210	26.14	36.31	44.18	25.28	35.42	43.71
	230	25.80	35.75	43.56	25.04	35.17	43.50
S.104	170	25.43	35.70	42.81	25.12	35.35	42.44
	190	26.90	36.95	44.65	26.43	36.29	43.60
	210	26.38	36.28	44.14	26.15	36.11	43.33
	230	25.76	36.02	43.56	25.82	35.84	43.19
S.105	170	24.72	34.63	43.26	24.21	34.21	42.88
	190	25.61	35.78	44.82	25.14	35.18	43.60
	210	25.28	35.31	44.31	24.86	34.90	43.29
	230	24.97	35.08	44.12	24.52	34.66	43.06
S.106	170	24.86	35.21	42.93	24.25	34.84	42.60
	190	25.93	36.85	44.56	25.43	35.72	43.35
	210	25.56	36.23	44.14	25.27	35.41	43.21
	230	25.21	35.75	43.61	25.05	35.28	42.94
S.107	170	24.51	35.71	42.72	24.13	35.31	42.39
	190	25.92	36.80	44.52	25.47	35.96	43.90
	210	25.46	36.43	44.18	25.21	35.72	43.61
	230	25.15	36.11	43.45	25.02	35.55	43.20
G.182	170	25.18	35.56	44.20	24.80	35.13	43.86
	190	26.95	36.92	45.63	25.46	36.40	45.17
	210	26.56	36.51	45.29	25.28	36.12	44.88
	230	26.19	36.17	44.83	24.96	35.86	44.41
E. yasmin	170	25.63	35.71	45.16	25.11	35.27	44.75
	190	26.95	36.97	46.57	26.57	36.55	45.50
	210	26.52	36.65	46.11	26.35	36.31	45.61
	230	26.31	36.22	45.65	26.12	35.89	45.29
L.S.D $_{0.05}$			0.038			0.016	

Table 5. Mean values for weight of popped (g) as affected by the interaction between rice cultivars, temperature and Sample weight in 2021 and 2022 seasons.

Cultivars	Temp (^{0}C)	Weight of popped (g)					
		2021			2022		
		Sample weight (g)					
		35	40	45	35	40	45
G. 177	170	21.20	31.12	39.15	20.51	30.28	38.2
	190	23.18	34.17	40.98	23.66	34.17	39.86
	210	22.51	34.03	40.26	23.31	34.03	39.22
	230	22.38	33.54	40.02	21.8	33.80	38.90
G.178	170	23.50	34.17	41.97	20.96	31.56	39.23
	190	25.86	36.12	44.49	25.3	35.14	44.30
	210	25.02	35.08	43.11	25.02	34.72	42.14
	230	24.51	34.89	42.84	24.84	32.39	40.11
S.101	170	20.56	32.11	35.24	19.87	30.79	33.18
	190	22.42	33.85	40.97	22.81	33.28	38.22
	210	21.74	33.14	39.73	22.27	32.84	37.55
	230	21.40	32.65	38.72	21.81	31.45	36.80
S.102	170	22.11	33.45	39.26	20.92	31.22	32.52
	190	23.81	34.62	40.65	23.13	34.11	41.70
	210	23.39	34.25	40.13	22.75	33.85	41.44
	230	23.05	33.81	39.66	22.57	32.42	41.09
S.103	170	22.64	32.87	40.54	21.22	30.66	33.28
	190	23.86	33.95	41.46	24.50	34.29	42.17
	210	23.50	33.51	41.13	24.11	32.87	41.86
	230	23.19	33.14	40.95	22.70	32.51	40.38
S.104	170	23.38	31.70	39.11	21.90	30.17	35.31
	190	24.95	32.86	40.85	24.41	33.82	41.66
	210	24.51	32.12	40.23	23.80	32.15	41.38
	230	24.20	31.97	39.74	22.52	31.73	40.03
S.105	170	22.81	32.28	39.85	20.70	30.62	34.82
	190	23.75	33.71	40.66	23.17	33.90	41.33
	210	23.41	33.42	40.21	22.80	32.29	40.17
	230	23.19	33.07	40.13	21.39	30.81	40.05
S.106	170	22.36	32.44	38.50	20.92	30.85	37.31
	190	23.98	33.85	40.12	24.55	33.52	40.96
	210	23.51	33.47	39.56	24.13	32.90	40.51
	230	23.17	33.12	39.21	22.7	32.49	40.17
S.107	170	23.20	32.50	38.56	21.43	30.12	35.60
	190	24.87	33.95	39.87	24.17	33.50	40.95
	210	24.35	33.41	39.51	23.90	33.17	40.70
	230	23.83	32.89	39.20	22.61	32.82	40.09
G.182	170	23.11	31.55	40.82	21.85	30.13	39.50
	190	24.86	35.90	43.17	24.19	34.03	43.60
	210	24.14	35.32	42.84	23.86	33.90	42.14
	230	23.75	34.66	42.26	22.45	32.50	40.41
E. yasmin	170	23.15	33.49	41.16	21.51	31.22	39.22
	190	25.48	35.90	42.97	25.12	34.26	43.52
	210	25.04	35.36	42.33	24.62	33.83	43.03
	230	23.66	34.68	41.68	22.20	33.65	41.76
L.S.D $_{0.05}$			0.013			0.021	

Table 6. Mean values for popping % as affected by the interaction between rice cultivars, temperature and Sample weight in 2021 and 2022 seasons.

Cultivars	Temp (^{0}C)	Popping %					
		2021			2022		
		Sample weight (g)					
		35	40	45	35	40	45
G. 177	170	86.92	88.31	91.64	86.10	86.79	90.07
	190	89.33	93.62	92.48	95.87	94.31	90.88
	210	89.29	94.29	92.34	96.24	94.92	90.26
	230	89.16	93.69	92.60	90.61	94.86	90.19
G.178	170	87.98	95.45	91.80	83.41	89.38	88.42
	190	94.69	97.88	95.10	94.93	97.23	96.89
	210	92.94	96.32	93.31	95.42	96.90	94.02
	230	91.46	96.62	93.07	95.43	90.98	90.07
S.101	170	83.24	90.68	79.73	82.21	87.85	75.84
	190	85.15	92.69	89.85	88.69	91.78	86.24
	210	83.94	91.55	88.03	87.85	91.17	85.13
	230	83.53	91.05	86.66	86.75	87.68	83.79
S.102	170	87.18	94.12	91.60	83.61	88.77	76.61
	190	88.98	94.54	90.76	89.13	94.17	95.42
	210	89.38	94.85	91.58	89.01	94.29	95.46
	230	89.00	94.39	91.15	89.10	90.76	95.40
S.103	170	90.09	93.62	92.73	85.91	88.03	76.65
	190	88.73	92.21	92.46	95.89	96.19	96.06
	210	89.90	92.29	93.10	95.37	92.80	95.77
	230	89.88	92.70	94.01	90.65	92.44	92.83
S.104	170	91.94	88.80	91.36	87.18	85.35	83.20
	190	92.75	88.93	91.49	92.36	93.19	95.55
	210	92.91	88.53	91.14	91.01	89.03	95.50
	230	93.94	88.76	91.23	87.22	88.53	92.68
S.105	170	92.27	93.21	92.12	85.50	89.51	81.20
	190	92.74	94.21	90.72	92.16	96.36	94.79
	210	92.60	94.65	90.75	91.71	92.52	92.79
	230	92.87	94.27	90.96	87.23	88.89	93.01
S.106	170	89.94	92.13	89.68	86.27	88.55	87.58
	190	92.48	91.86	90.04	96.54	93.84	94.49
	210	91.98	92.38	89.62	95.49	92.91	93.75
	230	91.91	92.64	89.91	90.62	92.09	93.55
S.107	170	94.66	91.01	90.26	88.81	85.30	83.98
	190	95.95	92.26	89.56	94.90	93.16	93.28
	210	95.64	91.71	89.43	94.80	92.86	93.33
	230	94.75	91.08	90.22	90.37	92.32	92.80
G.182	170	91.78	88.72	92.35	88.10	85.77	90.06
	190	92.24	97.24	94.61	95.01	93.49	96.52
	210	90.89	96.74	94.59	94.38	93.85	93.89
	230	90.68	95.83	94.27	89.94	90.63	90.99
E. yasmin	170	90.32	93.78	91.14	85.66	88.52	87.46
	190	94.55	97.11	92.27	94.54	93.73	95.65
	210	94.42	96.48	91.80	93.43	93.17	94.34
	230	89.93	95.75	91.30	84.99	93.76	92.21
L.S.D $_{0.05}$			0.026			0.014	

Table 7. Mean values for expansion ratio as affected by the interaction between rice cultivars, temperature and sample weight in 2021 and 2022 seasons.

Cultivars	Temp (^0C)	Expansion Ratio					
		2021			2022		
		Sample weight (g)					
		35	40	45	35	40	45
G. 177	170	6.82	7.54	8.34	7.59	8.47	9.02
	190	7.85	8.62	8.90	8.09	10.10	10.13
	210	7.42	9.27	8.62	7.78	9.78	10.32
	230	7.25	8.75	8.73	7.71	9.95	9.99
G.178	170	8.32	9.52	9.69	7.62	10.25	9.56
	190	10.20	10.75	10.43	9.23	10.93	10.70
	210	9.72	10.03	10.12	9.09	9.95	10.46
	230	8.03	9.11	8.35	8.90	9.80	10.25
S.101	170	8.12	8.45	6.92	8.27	8.53	6.74
	190	7.39	8.32	8.20	7.22	8.77	8.51
	210	7.27	8.07	8.27	7.68	8.52	8.48
	230	7.35	9.07	8.92	7.91	9.69	9.26
S.102	170	7.30	9.07	8.92	8.31	8.91	8.49
	190	7.82	9.32	8.50	7.96	9.75	9.47
	210	8.20	9.75	8.75	7.79	10.15	8.59
	230	7.95	9.52	8.44	8.10	10.20	8.82
S.103	170	8.12	8.70	9.15	8.17	8.97	8.29
	190	7.65	8.52	9.02	9.28	9.13	9.36
	210	7.50	8.45	9.47	8.75	9.81	8.96
	230	7.29	9.66	9.63	8.96	10.38	9.06
S.104	170	8.33	7.93	8.20	8.20	8.64	7.98
	190	8.95	8.14	8.55	9.56	9.71	8.87
	210	9.13	9.62	8.03	9.42	10.27	8.79
	230	9.52	9.85	8.12	9.47	10.31	9.08
S.105	170	8.83	8.64	8.87	7.90	8.73	8.88
	190	8.96	9.02	8.05	8.19	9.29	9.03
	210	8.45	9.33	8.20	7.49	9.34	8.74
	230	8.63	9.17	8.47	8.38	9.09	8.85
S.106	170	7.52	8.50	7.95	8.35	9.21	8.58
	190	8.61	8.33	8.33	8.95	9.01	8.51
	210	8.40	8.86	7.38	9.26	8.91	7.96
	230	8.21	8.93	8.15	9.10	8.92	7.93
S.107	170	9.24	8.05	8.41	10.01	9.33	8.15
	190	9.78	8.44	8.01	10.43	9.80	8.89
	210	9.50	8.26	7.83	8.12	8.96	8.71
	230	9.33	8.12	8.29	8.88	9.21	9.52
G.182	170	8.72	7.90	8.82	9.21	8.79	9.57
	190	9.03	10.21	9.51	9.41	10.36	10.04
	210	8.46	10.50	9.35	9.11	9.81	9.71
	230	8.25	10.11	9.17	9.79	9.89	9.75
E. yasmin	170	8.37	9.17	8.50	7.97	9.85	9.69
	190	9.56	10.25	9.32	9.98	10.35	10.07
	210	9.25	9.89	8.86	8.12	10.21	9.91
	230	8.18	9.77	8.71	8.44	10.07	9.82
L.S.D $_{0.05}$			0.041			0.025	

Table 8. Mean values for density as affected by the interaction between rice cultivars, temperature and Sample weight in 2021 and 2022 seasons.

Cultivars	Temp (^0C)	Density (g/cm^3)					
		2021			2022		
		Sample weight (g)					
		35	40	45	35	40	45
G. 177	170	146.50	133.36	140.20	143.52	130.23	137.21
	190	131.80	114.50	130.50	131.59	126.51	129.25
	210	133.20	124.60	133.40	141.28	120.65	128.58
	230	136.50	130.70	132.60	142.34	127.15	130.45
G.178	170	142.70	120.50	139.20	139.11	118.35	137.79
	190	120.60	110.33	118.50	133.81	105.68	121.20
	210	133.20	118.40	120.30	130.55	115.24	125.56
	230	142.50	114.20	126.70	138.34	108.65	122.98
S.101	170	135.60	133.30	146.70	131.36	118.87	147.82
	190	134.20	130.60	134.20	140.45	126.38	131.64
	210	145.50	132.10	135.10	141.26	127.62	130.62
	230	142.70	129.80	136.20	140.89	125.30	138.56
S.102	170	144.90	119.40	130.50	140.73	125.59	127.26
	190	131.30	125.20	133.60	137.52	121.91	128.47
	210	133.50	129.50	131.20	138.26	125.45	126.36
	230	140.40	127.20	133.10	136.67	125.69	129.16
S.103	170	131.30	125.40	127.40	127.53	122.65	129.54
	190	137.5	124.50	128.5	138.32	119.95	124.26
	210	142.2	124.82	126.21	140.68	128.87	124.38
	230	144.6	122.13	125.17	140.25	118.24	122.18
S.104	170	132.5	130.6	131.14	135.54	124.98	126.20
	190	126.3	125.2	134.5	133.62	121.74	128.23
	210	125.12	120.3	122.7	130.19	115.97	120.54
	230	137.8	123.1	133.1	134.47	119.36	130.38
S.105	170	134.6	127.5	130.3	140.54	125.78	129.58
	190	133.1	129.2	131.5	130.63	125.36	127.68
	210	136.7	126.3	133.2	142.25	122.45	128.29
	230	132.2	125.1	130.4	130.11	120.45	123.11
S.106	170	142.3	135.3	140.6	138.30	129.38	136.44
	190	133.6	130.2	131.5	129.68	125.54	128.24
	210	135.4	132.1	133.3	130.29	125.49	128.47
	230	137.5	130.6	135.2	135.24	125.26	132.68
S.107	170	138.2	128.8	135.1	140.24	123.39	130.28
	190	136.4	125.2	133.7	137.58	121.47	135.36
	210	133.1	123.6	130.2	135.28	118.21	130.15
	230	136.5	130.9	133.5	132.91	124.68	130.28
G.182	170	136.2	125.3	130.3	127.33	122.53	120.75
	190	136.5	124.5	125.2	138.59	118.56	122.24
	210	137.2	121.9	126.7	133.24	115.32	127.17
	230	139.1	119.6	128.1	133.77	114.78	126.56
E. yasmin	170	137.2	128.2	135.6	133.22	123.56	130.76
	190	122.5	116.5	120.5	115.63	112.23	114.36
	210	125.8	120.5	122.2	120.74	116.48	119.23
	230	139.3	117.1	131.5	130.24	115.78	125.36
L.S.D $_{0.05}$			1.021			0.874	

Data in these tables revealed that the superior values for weight after popping (46.78 and 45.72 g) and weight of popped (44.49 and 44.30 g) were noticed with Giza 178 and 190 0C and 45 g sample weight in both study seasons respectively. While the lowest values for weight after popping (24.39 and 23.82 g) and weight of popped rice (21.20 and 20.51 g) were detected with Giza 177 rice cultivar and 35 gm sample weight at 1700C. However, the superior values for popping (97.88 and 97.23%) and expansion ratio (10.75 and 10.93) while the lowest values for density (110.33 and 105.68 g/cm3) were indicated by using Giza 178 rice cultivar and 40 grams sample weight by heating for 190 0C in both study seasons respectively. Moreover, data declared that the lowest values for popping (79.73 and 75.84 %) and expansion ratio (6.92 and 6.74) while highest values for density (146.70 and 147.82 g/cm3) were indicated with Sakha 101 rice cultivar and 45 grams sample weight at 1700C in 2021 and 2022 seasons respectively. From the results, it became clear to us that using Giza178 rice cultivar at 190 degrees Celsius, and a 40 grams sample gave the highest results for popping and expansion and this might be since Giza178 rice cultivar is Indica/Japonica type has amylose content that is suitable for obtaining the highest popping rate with the previous conditions of temperature and sample weight.

CONCLUSION

Popping is an inexpensive and simple processing method that improves sensory qualities of cereals and nutrient composition in the processed product. Traditionally, popped products are prepared only during a few specific occasions. This type of home processed ready-to-eat snacks has great market potential as value added health products, convenient food, as consumer needs are changing towards more convenient foods as well as less refined or polished grains. The present study revealed variation between rice cultivars for the popping ability with variation in temperature and sample weight. That implies the need to optimize processing methods and factors which govern the popping characteristics of different cereal grains to get high popping yield, less un- popped kernels, and higher expansion volume. The present study indicated that using Giza 178 rice cultivar showed superiority in popping % and expansion ratio which are the most important factors of popping rice. Also, this study is considered a new method for using Giza 178 rice cultivar and to increase the economic value of this cultivar because of its lower price in market than other Japonica types. Further studies are needed to assess micronutrients availability, dietary fiber content, protein, and carbohydrate digestibility to develop value added health foods to meet the community nutritional problems. There is also need for technological development for popping of different cereals to accomplish the target of achieving consumer satisfaction.

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تفشيرحبوب بعض أصناف الأرز المصري نتيجة تاثير درجة الحرارة ووزن العينة

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الملخص

يهدف هذا البحث إلى تحديد درجة الحرارة ووزن العينة المثلى وتاثيرها على خصائص التفشير لحبوب بعض أصناف الأرز المصري باستخدام تقنية جديدة تعتمد على جهاز كهربائي محلي مبتكر. أظهرت نتائج الموسمين 2021 و 2022 اختلافات معنوية بين الأصناف لمعظم الصفات المدروسة. حيث أظهر الصنف جيزة 178 أعلى قيم معنوية لوزن الفشار ونسبة التفشير ونسبة التمدد بينما أظهر أدنى قيم للكثافة في موسمي الدراسة. ومع ذلك ، تم التعرف على أعلى قيم لوزن التفشير ونسبة التمدد بينما أدنى قيم للكثافة عند 190 درجة مئوية في موسمي 2021 و 2022. تم التعرف على اعلي القيم لوزن ارز الفشار عند 190 و 210 درجة مئوية في كلا الموسمين على التوالي. علاوة على ذلك ، لوحظ أعلى قيم للتفشير ونسبة التمدد وأدنى قيم للكثافة باستخدام وزن عينة 40 جم في موسمي الدراسة. ايضا لوحظ اعلي القيم لوزن ارز الفشار في صنف جيزة 178 مع 190 درجة مئوية و وزن عينة 45 جم في موسمي الدراسة. أما اعلي القيم لنسبة التفشير ونسبة التمدد و ادني قيم للكثافة مع صنف جيزة 178 وباستخدام وزن عينة 40 جرام عند 190 درجة مئوية في كلا موسمي الدراسة. كما أوضحت البيانات أن أدنى قيم نسبة التفشير ونسبة التمدد و أعلى قيم للكثافة في صنف أرز سخا 101 مع وزن العينة 45 جرام عند 170 درجة مئوية في كلا الموسمين. هذا بالاضافة الى تعظيم القيمة الإقتصادية لصنف الأرز جيزة 178نظراً لانخفاض سعره فى السوق المصرى عن باقى الأصناف اليابانية قصيرة الحبة.