Effect of Cooking Methods on Physical and Sensory Properties, Anthocyanins and Polyphenolic Compounds of Pigmented Rice Grains

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ABSTRACT

The objective of this research is to study the effect of three methods of rice cooking on four pigmented rice grains for their physical properities, sensory attributes, amylose content, total anthocyanin content (TAC) and polyphenol content (PC). Steaming cooked black rice (*Oryza sativa L. indica*) was the most darkness with L* value of 39.63. Steamed Egyptian jasmine white rice had the highest L* value (75.03). Red rice exhibited the lowest hardness in all cooking methods as (112.46, 97.65 and 82.19 N), while black rice possessed the best lowest stickiness in all cooking methods as (5.31, 4.18 and 4.08 N) for boiling, steaming and rice cooker, respectively. Black rice (23.76% amylose) which was classified as intermediate amylose rice (20-25%) before cooking kept intermediate after cooking by rice cooker as (21.56%). It could be seen that waxy rice belongs to moist and sticky rices after cooking as (amylose content 7.24%) was best cooked by boiling method. On the other hand, steamed black rice had the most preferred appearance (8.59), black rice which cooked by rice cooker was scored the highest accepted texture (8.04), while boiled black rice was the most accepted taste (9.04). Steamed Egyptian jasmine white rice was the highest accepted regarding aroma (8.69). Black rice contained the highest amount of naturally occurring anthocyanin content (TAC) as (235.68 – 290.78 mg/100 gm) after cooking, These findings indicate that cooking rice by steaming is the preferable cooking method where it caused the lowest losses in anthocyanin content. Polyphenol content (PC) differed significantly among the varieties. It was clear that all the methods of cooking caused a significant decrease in total polyphenols. It was found that cooking rice by steaming also was the best way for decreasing losses of polyphenol content for all rice varieties, Egyptian jasmine white rice, red, black and waxy rice as (25.54, 47.61, 71.22 and 29.34 mg GAE/g), respectively. The present study can guide in using steaming which was found to provide the most quality attributes for rice cooking in terms of physical quality, sensory properties with enhanced antioxidant compounds.

***Keywords:* Pigmented rice, red rice, black rice, amylose content, physical properties, sensory attributes, anthocyanins, phenolics.**

INTRODUCTION

Rice (*Oryza sativa* L.) is an economic crop, which is important in household food security, ceremonies, nutritional diversification, income generation and employment (Perez *et al.,* 1987). Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population and is mostly consumed as cooked rice as the primary dietary source of carbohydrate and energy. It is rich in carbohydrates, contains a moderate amount of protein, and is a source of the B vitamins namely, thiamin, riboflavin, and niacin (Hu *et al.,* 2004, Fresco, 2005, Denardin *et al.,* 2007). It is utilized mostly at the household level, where it is consumed as boiled or fried or ground rice with stew or soup. It is consumed as a staple food by over one-half of the world's population with approximately 95% of production in Asia (Bhattacharjee *et al.,* 2002). Rice is cooked by washing and boiling in water which leads to loss of some nutrients (Ihekoronye & Ngoddy, 1985, Perez *et al.,* 1987).

There are also diverse foods made from rice, such as bread, cakes, noodles, and other traditional foods prepared in homes across the world. Rice is a rich source of many bioactive compounds including phenolic compounds that have the potential to reduce the risk of disease, such as coronary heart disease and cancer and preventing oxidative damage of lipid and low-density lipoproteins (Qiu *et al.,* 2009). Rice is a major cereal crop in the developing world. Although widely consumed as white rice, there are many special cultivars of rice that contain pigments, such as black, red and brown rice. Their names refer to the kernel colour (black, red or purple) which is formed by deposits of anthocyanins in different layers of the pericarp seed coat and aleurone (Chaudhary, 2003).

Pigmented rice or coloured rice is distinguished by the rice grain having red brown or dark purple colour in its covering layers. Pigments, which are located in the aleurone layer of rice grain, have been reported as a mixture of anthocyanin compounds, which belong to the family of flavonoids (Yawadio *et al.,* 2007). Red rice had high phenolic and anthocyanin content (Itani & Ogawa, 2004). Anthocyanin pigments have been reported to be highly effective in reducing cholesterol levels in the human body (Lee *et al.,* 2008). Black rice has a number of nutritional advantages over common rice, such as a higher content of protein, vitamins and phenolics (Lee *et al.,* 2008).

The phenolic compounds have been found as a major active component for antioxidation. For pigmented rice, the main substance of phenolic compounds has been reported as anthocyanins (Iqbal *et al.,* 2005, Zhang *et al.,* 2006, Yawadio *et al.,* 2007).

In pigmented rice, there are naturally occurring colour substances that belong to the flavonoid group called anthocyanins (Sutharut & Sudarat, 2012). Anthocyanins in pigmented rice have been identified. They are cyanidin-3-glucoside and peonidin-3-glucoside (Hu *et al.,* 2004), malvidin, pelargonidin-3, 5-diglucoside, cyanidin-3-glucoside and cyanidin-3, 5-diglucoside (Zhang *et al.,* 2006), cyanidin-3-glucoside, pelargonidin-3-glucoside (Yawadio *et al.,* 2007).

It was found that the cooking was depended on rice types and rice eating culture. The study on the effect of cooking methods on several aspects occurring to rice would benefit the manufactures to produce high quality cooked rice and would also benefit to consumers to prepare the higher nutritional and eating quality of rice (Daomukda *et al.,* 2011). During cooking, the structure of rice, physical properties, chemical composition and nutritional quality are changed (Mahadevamma & Tharanathan 2007). Rice texture is a key indicator of rice quality as affecting cooked rice acceptance by consumers.

The present study was carried out to investigate the effect of cooking methods (boiling, steaming and rice cooker) on physical, sensory properties, amylose content, total anthocyanins and poly phynolic compounds of four rice genotypes (Egyptian Jasmine white rice, red rice (Yun Jing 23), black rice and waxy rice (*Ciasem*).

MATERIALS AND METHODS

Materials

Four local and exotic rice genotypes grains (Egyptian Jasmine, red rice (Yun Jing 23), black rice and waxy rice (*Ciasem*) were obtained from the Rice Research and Training Center (RRTC), Sakha, Kafr Elsheikh Governorate, Egypt.

Methods

Preparation of rice flour

Rice grains were dehusked using a rubber roller according to Rewthong *et al.,* (2011). Broken kernels were separated from the obtained dehusked grains. The dehusked grains were divided into 2 parts, one of them was ground using milling and sieved through a 100 micrometer sieve. Preparation of rice flour for analysis was done shortly before analysis, Pigmented rice flour samples were then vacuum packed in plastic bags and stored at 4°C until used. All experiments were done at least in triplicates, analytical results were expressed on a dry matter basis. The other part of milled rice was left for cooking methods.

Preparation of cooked rice

Rice was washed thoroughly in water at ambient temperature in order to clean and remove dust particles. Three cooking methods, boiling, steaming and rice cooker were used to prepare cooked rice as described by Rewthong *et al.,* (2011) with some modifications. In the case of boiling, rice grains were soaked in water (1:1) at ambient temperature for 10 min before boiling, rice was boiled for 12 min. In the case of cooking using rice cooker, the rice grains were directly cooked in water (1:1.5) for 18 min until the electric cooker was automatically turned off and simmered for 5 min to obtain completely cooked rice (Daomukda, *et al.,* 2011). For the steaming method, the rice grains were placed in a stainless steel bowl with the ratio of water to rice of 1.25:1 (w/w) and were cooked for 30 min until completely cooked rice was obtained and all cooking water was disappeared (Daomukda, *et al.,* 2011).

Colour of pigmented rice grain

The colour of rice grains and powder samples was measured with a Spectrophotometer (Minolta

CM-3500d). Colour measurements were expressed as tristimulus parameters, L*, a* and b*. L* indicates lightness (L* = 0 yields black and L* = 100 indicates diffuse white). a* indicates redness–greeness and b* indicates yellowness–blueness (Bao *et al.,* 2005).

Texture analysis

The textural properties of cooked rice grains were determined by a texture analyzer (Stable Micro System, TA.XT.Plus, Surrey, UK). The resulting force-deformation data were analyzed and the average values of hardness and stickiness were calculated according to Rewthong *et al*. (2011).

Sensory evaluation of pigmented cooked rice

Sensory evaluation of the cooked rice grain varieties was carried out by 20 untrained taste panelists (Ebuehi & Oyewole 2007). They were instructed to taste the rice samples. They were requested to express their feelings about the samples by scoring the following attributes: appearance, texture, taste, aroma and overall acceptability. Sensory scores were based on a nine point hedonic scale, where 1 is extremely dislike and 9 is extremely like (Watt *et al.,* 1989).

Determination of amylose content (AC) in pigmented rice grains

One ml of ethanol (95%) and 9 ml 1 N NaOH were added to 100 mg of flour. After mixing, the samples were heated for 10 min in a boiling water bath to gelatinise the starch. Samples were cooled down and transferred to a 100 ml volumetric flask and 5 ml of starch solution and 1 ml 1 N acetic acid were added. After addition of 2 ml iodine solution, the volume was adjusted to 100 ml with distilled water, mixed, and allowed to stand for 20 min. The absorbance was measured at 620 nm using a spectrophotometer (U-1100, Hitachi, Japan). The amylose content was determined from a previous standard curve of potato amylose (Juliano, 1985).

Determination of total anthocyanin content (TAC)

Total anthocyanin (TAC) content was determined using a spectrophotometric method reported by Abdel-Aal & Hucl (1999). Anthocyanins were extracted with acidified methanol (methanol and HCl, 85:15, v/v) with a solvent to sample ratio of 1:10. Absorbance was measured after centrifugation at 525 nm against a blank. Cyanidin 3-glucoside-chloride was used as standard pigment, and TAC were expressed as mg cyanidin 3-glucoside equivalent per 100 g flour.

Determination of total phenolic content (PC)

Whole meal flour (150 g) of each accession was extracted with 150 ml of a mixture of CH_3OH/H_2O/HCOOH (50:48.5:1.5) for 24 h at room temperature. The mixture was centrifuged at 2500 g for 15 min and the supernatant was collected and stored at 4°C (Gómez-Alonso *et al.,* 2007). Total polyphenols were assayed using the Folin–Ciocalteau method (Aguilar-Garcia *et al.,* 2007). Briefly, Folin-Ciocalteau reagent was diluted with water 1:9 (v/v), 60 µL of the sample extract were added to 2.5 mL of this reagent and after 2 min incubation at room temperature, 2 mL sodium carbonate solution (75 g/L) were added. The mixture was incubated for 15 min at 50°C and cooled quickly in an ice-wate ter bath. The absorbance at 760 nm was measured within 15 min by spectrophotometer (Libra S22, Biochrom, England). The standard curve was made using gallic acid. The obtained regression equation was y = 2.4646x-0.0228, (R2 = 0.9967). The results were expressed as gallic acid equivalent per dry matter (Ainsworth & Gillespie, 2007).

Statistical analysis

All the analyses were carried out at least in triplicates and expressed as mean and standard deviation (SD). Data were statistically analyzed by analysis of variance (ANOVA) and significant differences were identified by Duncan's Multiple Range test (P<0.05) (Steel & Torrie, 1980).

RESULTS AND DISCUSSIONS

Effect of cooking on colour parameters of pigmented rice grains

The results pertaining to colour parameters of pigmented rice grains such as Egyptian jasmine white rice, red, black and waxy rice (gm/100gm) are presented in Table (1).

For brightness, black rice had the most darkness after cooking by steaming where L* value was 44.92 followed by black rice in rice cooker as 42.96. The Egyptian jasmine white rice after steaming had the most lightness since L* value was 75.03 as compared with its counterpart before cooking. The values of a* and b* were in the range of 2.15 – 3.47 and 12.14 – 21.35, respectively. It

Table 1: Effect of cooking methods on colour parameters of pigmented rice grains

Cooking methods	Colour parameters		
	L*	a*	b*
Before cooking :			
Egyptian Jasmine white rice	78.53^{a}±0.36	2.69^{bc}±0.75	18.05^{b}±0.23
Red rice (Yun Jing 23)	54.26^{h}±0.28	3.47^{a}±0.54	15.92^{c}±0.50
Black rice (Oryza sativa L. indica)	50.12^{i}±0.64	2.34^{cd}±0.18	20.17^{a}±0.09
Waxy rice (Ciasem)	72.14^{c}±0.58	2.56^{c}±0.33	21.35^{a}±0.16
After cooking :			
Boiling :			
Egyptian Jasmine white rice	75.03^{b}±0.24	2.18^{d}±0.65	18.25^{b}±0.98
Red rice (Yun Jing 23)	51.19^{i}±0.35	3.45^{a}±1.01	15.27^{c}±0.68
Black rice (Oryza sativa L. indica)	47.36^{j}±0.87	2.31^{d}±0.34	18.56^{ab}±0.14
Waxy rice (Ciasem)	69.58^{d}±0.09	2.48^{c}±0.61	19.05^{a}±1.21
Steaming :			
Egyptian Jasmine white rice	68.54^{e}±0.78	2.56^{c}±0.18	15.34^{c}±0.85
Red rice (Yun Jing 23)	44.92^{k}±0.37	2.98^{b}±0.61	12.14^{d}±0.08
Black rice (Oryza sativa L. indica)	39.63^{l}±0.84	2.49^{c}±0.73	14.37^{cd}±0.39
Waxy rice (Ciasem)	61.15^{g}±0.41	2.99^{b}±0.84	14.91^{c}±0.62
Rice cooker :			
Egyptian Jasmine white rice	69.18^{d}±0.98	2.57^{c}±0.55	17.22^{bc}±0.53
Red rice (Yun Jing 23)	48.23^{j}±0.45	3.01^{b}±0.64	13.27^{d}±0.24
Black rice (Oryza sativa L. indica)	42.96^{k}±0.62	2.95^{b}±0.83	15.03^{c}±0.67
Waxy rice (Ciasem)	65.73^{f}±0.46	2.15^{d}±0.94	15.41^{c}±0.82

Each value is the mean ± SD
Mean values in each column having different subscript (a, b, c, d) are significantly different at P < 0.05.
Mean values in a column superscripted by the same letter are not significantly different at P < 0.05.

can be noted that a* value (3.45) of the boiled red rice was higher than that of the other rice varieties and b* value of the boiled black rice was 18.56 after cooking by boiling.

Because the rice varieties are different in colour, the colour parameters (L*, a* and b*) of rice grains showed large variations. L* values, which expresses the brightness, being in the range of 39.63 – 78.53 for all varieties before and after cooking by boiling, steaming and rice cooker. Black rice (*Oryza sativa L.* indica) cooked by steaming had the most darkness with L* value of 39.63. The low L* values were found in steamed cooked black rice, cooked black rice in rice cooker and boiled black rice being 47.36, 42.96 and 39.63, respectively comparing with black rice grain before cooking (50.12).

Textural properties of cooked rice varieties

Data in Table (2) show the textural characteristics of cooked rice obtained from the different cooking methods.

The hardness values of cooked rice ranged from 82.19 N to 123.07 N. The hardness of cooked rice by boiling method was higher than those by steaming and rice cooker method, where boiling Egyptian jasmine white rice was 123.07 N. These results are similar to those reported by Bett-Garber *et al.* (2001).

Table (2) shows that the cooking method affected the textural properties of cooked rice. The boiling method showed significantly higher values of hardness and stickiness than those of steaming and rice cooker methods. The description of different textural characteristics of cooked rice is related to the amount and components of leached starch (Tester & Morrison, 1990), which should be larger for the rice cooked by the rice cooker because the cooking time required (18 min) was longer than that of the boiling method (12 min), the longer cooking time resulted in the larger amount of leached starch (Chiang & Yeh, 2002).

In the red rice, the lowest hardness (82.19N) was noted when using rice cooker. The stickiness was nevertheless lower. However, the stickiness of boiling rice was higher than that of the other two methods, where black rice had the lowest stickiness in all cooking methods (5.31, 4.18 and 4.08 N) for boiling, steaming and rice cooker, respectively.

It was clear that the steaming method is the most preferable method for cooking rice varieties. These results are in agreement with those obtained by Payakapol *et al.* (2011).

Amylose content (AC) of pigmented cooked rice grains

Amylose contents of pigmented cooked rice grains (g/100g) are presented in Table (3).

Rice varieties were classified into five groups according to their amylose content: waxy (1–2%), very low (2–9%), low (10–20%), intermediate (20–25%) and high (25–33%) (IRRI, 2009). The

Table 2: Textural properties of cooked rice varieties

Cooking methods	Hardness values (N)	Stickiness values (N)
Boiling :		
Egyptian Jasmine white rice	$123.07^{a}\pm0.09$	$11.56^{a}\pm0.49$
Red rice (Yun Jing 23)	$112.46^{b}\pm0.54$	$6.98^{c}\pm0.86$
Black rice (Oryza sativa L. indica)	$114.50^{b}\pm0.33$	$5.31^{d}\pm0.15$
Waxy rice (Ciasem)	$110.27^{bc}\pm0.97$	$5.42^{d}\pm1.02$
Steaming :		
Egyptian Jasmine white rice	$108.72^{c}\pm0.64$	$9.13^{b}\pm0.36$
Red rice (Yun Jing 23)	$97.65^{e}\pm1.45$	$5.24^{de}\pm0.12$
Black rice (Oryza sativa L. indica)	$101.41^{d}\pm0.25$	$4.18^{e}\pm0.98$
Waxy rice (Ciasem)	$89.02^{g}\pm0.66$	$5.49^{d}\pm0.84$
Rice cooker :		
Egyptian Jasmine white rice	$102.78^{d}\pm0.61$	$8.63^{b}\pm1.14$
Red rice (Yun Jing 23)	$82.19^{i}\pm0.52$	$5.94^{d}\pm0.46$
Black rice (Oryza sativa L. indica)	$93.05^{f}\pm0.38$	$4.08^{e}\pm0.51$
Waxy rice (Ciasem)	$86.57^{h}\pm0.76$	$6.30^{c}\pm1.32$

Each value is the mean ± SD
Mean values in each column having different subscript (a, b, c, d) are significantly different at $P < 0.05$.
Mean values in a column superscripted by the same letter are not significantly different at $P < 0.05$.

Table 3: Amylose content (AC) of pigmented cooked rice grains

Cooking methods	Amylose content (%)	Amylose classification
Befor cooking :		
Egyptian Jasmine white rice	$15.08^{f}\pm0.29$	Low amylose
Red rice (Yun Jing 23)	$29.13^{a}\pm0.97$	High amylose
Black rice (Oryza sativa L. indica)	$23.76^{c}\pm0.46$	Intermediate
Waxy rice (Ciasem)	$7.52^{h}\pm0.84$	Very low amylose
After cooking :		
Boiling :		
Egyptian Jasmine white rice	13.58 ± 0.95	Low amylose
Red rice (Yun Jing 23)	$27.14^{b}\pm0.61$	High amylose
Black rice (Oryza sativa L. indica)	$18.54^{e}\pm0.11$	Low amylose
Waxy rice (Ciasem)	$7.24^{h}\pm0.40$	Very low amylose
Steaming :		
Egyptian Jasmine white rice	$11.65^{g}\pm0.43$	Low amylose
Red rice (Yun Jing 23)	$24.19^{c}\pm0.21$	Intermediate
Black rice (Oryza sativa L. indica)	$15.07^{f}\pm0.46$	Low amylose
Waxy rice (Ciasem)	$5.17^{i}\pm0.98$	Very low amylose
Rice cooker :		
Egyptian Jasmine white rice	$14.02^{f}\pm0.22$	Low amylose
Red rice (Yun Jing 23)	$29.01^{a}\pm0.36$	High amylose
Black rice (Oryza sativa L. indica)	$21.56^{d}\pm0.45$	Intermediate
Waxy rice (Ciasem)	$7.13^{h}\pm0.78$	Very low amylose

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Mean values in a column superscripted by the same letter are not significantly different at $P < 0.05$.

amylose content of rice is one of the most important criteria of rice quality in terms of cooking and pasting properties (Adu-Kwarteng *et al.,* 2003). Significant differences in amylose content within the tested pigmented rice varieties were found after cooking. Rice cooker kept the highest amylose content of the red rice (29.01).

Black rice (23.76% amylose) was classified as intermediate amylose rice (20-25%) according to the classification of IRRI (2009) before cooking. After cooking by rice cooker its AC was 21.56%, which would according to Adu-Kwarteng *et al.* (2003) dry and fluffy and retain its soft texture upon cooling. Therefore, intermediate amylose rice varieties are the most preferable ones.

Low amylose rice (10–20%) is moist and sticky after cooking. It can be seen that waxy rice belonging to this category has an amylose content 7.24%. Cooking by boiling and rice cooker methods are the best methods for waxy rice. The results obtained in the present study are in agreement with those obtained by Sompong *et al.* (2011).

It has been reported that the components of leached starch consist of amylose and amylopectin, at a different proportion (Ong & Blanshard, 1995 b). The amount of leached amylopectin is generally higher than that of leached amylose, the short-chain amylopectin is considered the main proportion of the leached starch. It is also recognized that amylose and short-chain amylopectin contribute to the hard and sticky texture of cooked rice, respectively (Ong & Blanshard, 1995a).

The rice cooked by steaming lost larger amounts of amylose and short-chain amylopectin resulting in its lower hardness and stickiness. All cooking methods investigated here caused reducing of amylose content in all cooked rice varieties. These results agree with those obtained by Jain *et al.,* (2007) and Rewthong *et al.* (2011).

Sensory attributes of cooked pigmented rice grains

The mean sensory scores of the cooked pigmented rice varieties are presented in Table (4).

It was noted that black rice cooked by steaming was the most preferable appearance among all cooked rice (8.59) followed by boiled red rice (8.36), while the lowest accepted appearance was 5.17 for Egyptian jasmine white rice followed by 6.31 for boiled waxy rice.

On the other hand, black rice which cooked by rice cooker scored the highest accepted texture (8.04), while boiled black rice possessed the most accepted taste (9.04). Steamed Egyptian jasmine white rice had the highest accepted taste (8.17) followed by 8.54 for boiled red rice. Steamed black rice and boiled red rice exhibited the highest overall acceptability (8.92) and (8.67), respectively. Waxy rice cooked in rice cooker had the lowest overall acceptability (7.11) followed by Egyptian jasmine white rice as (7.30). These results are similar to those reported by Ebuehi & Oyewole (2007) and Rewthong *et al.* (2011).

Although, sensory characteristics of cooked rice including appearance, texture, taste, aroma and overall acceptability were highly significant among all cooking methods, but generally, steaming was given higher preference scores followed by boiling than cooking rice by rice cooker which agree with Rewthong *et al*. (2011).

Total anthocyanin and poly phenolic compounds in pigmented cooked rice

The results pertaining to total anthocyanin and phenolic contents of pigmented cooked rice grains are presented in Table (5).

The evaluation of the total antioxidant capacity of pigmented rice varieties is getting more importance, since it has been found that phenolic compounds are one of the most effective antioxidants. The concept of the total antioxidant capacity, which describes the ability of different food antioxidants in scavenging preformed free radicals, has been suggested as a tool for investigating the health effects of antioxidant-rich foods (Sompong *et al.,* 2011).

The anthocyanins play an important role as they are responsible for the antioxidant activity in the pigmented-germinated rice samples (Maisont & Narkrugsa, 2010). The antioxidant capacity dependes on chemical structure of the substrates that react with the reagent. Adom & Liu (2002) reported that insoluble phenolics were the major contributors to the antioxidant capacity.

Table 4: Mean sensory scores of pigmented cooked rice grains

Cooked methods	Appearance	Texture	Tastes	Aroma	Overall acceptability
Boiling :					
Egyptian Jasmine white rice	$5.17^{d}\pm0.56$	$7.34^{b}\pm0.31$	$8.43^{c}\pm0.91$	$8.01^{c}\pm0.64$	$7.30^{c}\pm0.04$
Red rice (Yun Jing 23)	$8.36^{a}\pm0.06$	$7.15^{b}\pm0.59$	$8.65^{b}\pm0.77$	$8.54^{a}\pm0.22$	$8.42^{a}\pm0.15$
Black rice (Oryza sativa L. indica)	$8.25^{a}\pm0.36$	$7.94^{a}\pm0.11$	$9.04^{a}\pm0.39$	$8.93^{a}\pm0.18$	$8.67^{a}\pm0.36$
Waxy rice (Ciasem)	$6.31^{c}\pm0.82$	$7.86^{a}\pm0.82$	$8.72^{b}\pm0.58$	$7.64^{c}\pm0.99$	$7.37^{c}\pm0.94$
Steaming :					
Egyptian Jasmine white rice	$7.15^{c}\pm0.52$	$6.49^{c}\pm0.82$	$8.64^{b}\pm0.96$	$8.69^{a}\pm0.32$	$7.94^{b}\pm0.12$
Red rice (Yun Jing 23)	$8.33^{a}\pm0.48$	$7.65^{b}\pm0.98$	$8.71^{b}\pm0.43$	$8.50^{a}\pm0.86$	$8.63^{a}\pm0.27$
Black rice (Oryza sativa L. indica)	$8.59^{a}\pm0.25$	$7.98^{a}\pm0.65$	$8.19^{c}\pm0.37$	$8.34^{b}\pm0.58$	$8.92^{a}\pm0.35$
Waxy rice (Ciasem)	$7.46^{b}\pm0.64$	$6.34^{c}\pm0.18$	$7.47^{d}\pm1.04$	$8.01^{c}\pm0.24$	$7.43^{c}\pm0.64$
Rice cooker :					
Egyptian Jasmine white rice	$7.35^{b}\pm0.73$	$6.65^{c}\pm0.23$	$8.17^{c}\pm0.31$	$8.01^{c}\pm0.67$	$7.99^{b}\pm1.03$
Red rice (Yun Jing 23)	$7.88^{b}\pm0.69$	$7.58^{b}\pm0.47$	$8.68^{b}\pm0.22$	$8.03^{c}\pm0.10$	$8.31^{b}\pm0.48$
Black rice (Oryza sativa L. indica)	$7.69^{b}\pm0.82$	$8.04^{a}\pm0.21$	$8.05^{c}\pm0.08$	$7.98^{c}\pm1.45$	$8.12^{b}\pm0.67$
Waxy rice (Ciasem)	$7.05^{c}\pm0.14$	$6.51^{c}\pm0.09$	$6.59^{e}\pm0.46$	$7.14^{d}\pm0.53$	$7.11^{c}\pm0.29$

Each value is the mean ± SD
Mean values in each column having different subscript (a, b, c, d) are significantly different at $P < 0.05$.
Mean values in a column superscripted by the same letter are not significantly different at $P < 0.05$.

Table 5: Total anthocyanin and total phenolic compounds in pigmented cooked rice grains.

Cooking methods	Total anthocyanin (mg/100 g)	Total phenolics (mg GAE/g)
Before cooking :		
Egyptian Jasmine white rice	$3.08^{k}\pm0.56$	$28.06^{g}\pm0.33$
Red rice (Yun Jing 23)	$235.34^{d}\pm0.99$	$54.13^{c}\pm0.85$
Black rice (Oryza sativa L. indica)	$325.09^{a}\pm0.16$	$76.51^{a}\pm0.06$
Waxy rice (Ciasem)	$31.75^{h}\pm0.42$	$37.86^{f}\pm0.92$
After cooking :		
Boiling :		
Egyptian Jasmine white rice	$2.45^{m}\pm1.33$	19.05 ± 0.48
Red rice (Yun Jing 23)	$151.14^{g}\pm0.09$	$38.67^{f}\pm0.39$
Black rice (Oryza sativa L. indica)	$235.68^{d}\pm0.54$	$42.39^{e}\pm0.64$
Waxy rice (Ciasem)	$23.69^{j}\pm1.02$	$22.48^{i}\pm0.76$
Steaming :		
Egyptian Jasmine white rice	$2.95^{l}\pm0.91$	$25.54^{h}\pm0.17$
Red rice (Yun Jing 23)	$184.36^{e}\pm0.27$	$47.61^{d}\pm0.32$
Black rice (Oryza sativa L. indica)	$290.78^{b}\pm0.58$	$71.22^{b}\pm1.08$
Waxy rice (Ciasem)	$28.49^{i}\pm0.68$	$29.34^{g}\pm0.41$
Rice cooker :		
Egyptian Jasmine white rice	$2.60^{l}\pm0.83$	$21.78^{i}\pm0.25$
Red rice (Yun Jing 23)	$172.35^{f}\pm1.43$	$42.19^{e}\pm0.14$
Black rice (Oryza sativa L. indica)	$254.03^{c}\pm0.69$	$58.37^{c}\pm0.28$
Waxy rice (Ciasem)	$24.88^{j}\pm0.94$	$25.63^{h}\pm0.51$

Each value is the mean ± SD
Mean values in each column having different subscript (a, b, c, d) are significantly different at $P < 0.05$.
Mean values in a column superscripted by the same letter are not significantly different at $P < 0.05$.

All cooking methods investigated here caused significant decreases in the anthocyanin and these results are in agreement with those of Hiemori *et al.* (2009). Steaming method resulted in the greatest loss of anthocyanin content followed by rice cooker. From this result, the differences in grain colour could depend on the form of anthocyanin and rice genotypes (Escribano-Bailón *et al.,* 2004, Yawadio *et al.,* 2007).

Dark purple coloured rice varaities such as red and black rice grains had higher anthocyanin and polyphenol contents (325.09 and 235.34 mg/100g) and (76.51 and 54.13 mg GAE/g), respectively than waxy and Egyptian white rice as (31.75 and 3.08 mg/100 g) and (37.86 and 28.06 mg GAE/g), respectively. Similar results had been reported by Goffman & Bergman (2004) and Shen *et al.* (2009).

It was noted that the all investigated cooking methods caused significant decreases in the anthocyanin content. Cooking rice by boiling resulted in the greatest loss of total anthocyanin content (TAC) for all cooked rice varieties followed by rice cooker where boiled black rice had 235.68 mg/100g of TAC. On the other hand steamed black rice had 290.78 mg/100 g of anthocyanin content. Black rice contains the highest amount of naturally occurring anthocyanin content (235.68 – 290.78 mg/100 g) among the four varieties after cooking, which is agreeable with those reported by Sompong *et al.* (2011).

These findings indicate that cooking rice by steaming is the preferable cooking method where it caused the lowest losses in anthocyanin content. These results agree with those obtained by Hiemori *et al.* (2009), Tananuwong & Tangsrianugul (2012).

Polyphenols are the most effective antioxidative constituents in plant products consumed (Escribano-Bailón *et al.,* 2004). The highest level of poly phenolic contents of pigmented rice grains was found to be 76.51 mg GAE/g in black rice followed by 54.13 mg GAE/g in red rice. The lowest total phenolic content was 28.06 mg GAE/g which found in Egyptian jasmine white rice. There were significant differences among pigmented rice varieties (P<0.05). The higher amount of phytochemicals such as anthocyanin and phenolic compounds in pigmented rice varieties might contribute to their higher antioxidant activity. These results agree with those of Shen *et al.* (2009).

It was clear that all methods of cooking rice used in the present study caused a significant decrease in total polyphenols. It was found that cooking rice by steaming also was the best method in terms of lowering losses of total phenolic content (TPC) for all rice varieties, namely Egyptian jasmine white rice, red, black and waxy rice (25.54, 47.61, 71.22 and 29.34 mg GAE/g), respectively, followed by using rice cooker (21.78, 42.19, 58.37 and 25.63 mg GAE/g). These results are in accordance with those of Zhang *et al.* (2006).

Many studies have reported that black rice is more abundant in anthocyanin and other phenolic compounds compared to that of white rice (Rye *et al.,* 1998, Zhang *et al.,* 2006). These phytochemical compounds usually are accumulated in pericarp or bran of rice kernels (Sutharut & Sudarat, 2012).

CONCLUSION

The present research focuses on the effect of cooking rice methods (boiling, steaming and rice cooker) on physical properties, colour, sensory properties, amylose, total anthocyanins and poly phynolic contents of four rice genotypes (Egyptian Jasmine white rice, red rice, black rice and waxy rice.

Studying the effect of cooking methods of rice would benefit to produce high quality of cooked rice and for consumer to choose the best method which could have high potential in providing physical properties and antioxidant substances. Cooking rice grains caused change in the structure of starch, the physical properties, chemical compositions, and nutritional quality.

Plant pigments as well as other phytochemicals in grains have lately been attributed to positive nutritional properties, such as prevention of cardiovascular diseases and cancer. In this context, the phytochemical content and physical properties of Egyptian jasmine white rice, red, black and waxy rice were investigated after cooking. The present study can guide in using steaming which was found to provide the most desirable quality for rice cooking in terms of physical quality, sensory properties with enhanced antioxidant compounds.

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تأثير طرق الطهو على الخواص الطبيعية والحسية ومركبات الانثوسيانين والبولي فينولات لحبوب الأرز الملونة

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استهدف هذا البحث دراسة تأثير ثلاث طرق لطهو الأرز على أربعة أنواع من حبوب الأرز الملونة من حيث الخواص الطبيعية والحسية، محتوى الأميلوز، الأنثوسيانين والبولي فينولات. أظهر الأرز الأسمر المطهو بالبخار أعلى درجة لون بنسبة دكانة ٣٩,٦٣. وعلى الجانب الآخر كان أرز الياسمين المصري هو الأفتح في تركيز درجة اللون بواقع ٧٥,٠٣. كان الأرز الأسمر أقل صلابة في جميع طرق الطهو المستخدمة (١١٢,٤٦، ٩٧,٦٥ و ٨٢,١٩)، بينما كان الأرز الأسمر أفضل أدنى نسبة إلتصاق في جميع طرق الطهو بواقع (٥,٣١، ٤,١٨ و ٤,٠٨). أثناء الطهو بالسلق، البخار وجهاز طهو الأرز على الترتيب.

يتميز صنف الأرز الأسمر بأنه ذو محتوى معتدل من الأميلوز (٢٠–٢٥٪) بواقع (٢٣,٧٦٪) قبل الطهو وكذا بعد الطهو بواسطة جهاز طهو الأرز بواقع ٢١,٥٦٪. يتميز الأرز الشمعي بكونه الأكثر رطوبة ولزوجة بعد الطهو لإحتوائه علي (٧,٢٤٪) أميلوز مع كون طريقة الطهو بالسلق هي أفضل طريقة بالنسبة للأرز الشمعي. من ناحية أخرى، كان طهو الأرز الأسمر على البخار هو الأكثر تفضيلا (٨,٥٩)، في حين سجل الأرز الأسمر المطهو بجهاز طهو الأرز أعلى قبول للقوام (٨,٠٤)، في حين كان الأرز الأسمر المسلوق من حيث الطعم الأكثر قبولا (٩,٠٤) أما أرز الياسمين المطهو بطريقة البخار فكان الأفضل رائحة (٨,٦٩).

احتوى الأرز الأسمر على أعلى كمية من الأنثوسيانين بواقع (٢٣٥,٦٨ – ٢٩٠,٧٨ مجم/١٠٠جم) بعد الطهو، وتشير هذه النتائج إلى أن طريقة طهو الأرز بالبخار هي الأكثر تفضيلا حيث أنها تسببت في أدنى فقد في محتوى الأنثوسيانين. وقد اختلف المحتوى الكلي للفينولات إختلافاً كبيراً بين الأصناف حيث تسببت جميع طرق طهو الأرز في انخفاض معنوي في البولي فينول.

وقد وجد أن طهو الأرز بالبخار يعتبر أفضل وسيلة لخفض الفقد في محتوى الفينول لجميع الأصناف (أرز الياسمين، الأحمر، الأسمر والشمعي بواقع (٢٥,٥٤، ٤٧,٦١، ٧١,٢٢ و ٢٩,٣٤ ملجم حامض جاليك /جم)، على الترتيب. هذه الدراسة يمكن أن توجه إلى استخدام طريقة الطهو بالبخار التي وجد أنها تحسن معظم صفات جودة الطهو للأرز من حيث الخصائص الطبيعية والحسية مع تعزيز وجود المواد المضادة للأكسدة.