

## STIMULATING COMPOUNDS AFFECT THE GRAIN QUALITY CHARACTERISTICS AND THE NUTRITIONAL VALUE OF RICE (*ORYZA SATIVA*)

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**Abstract.** This investigation was carried out in the experimental farm and the grain quality laboratory of the Rice Research and Training Center, Kafr El-Sheikh Governorate, Egypt to determine the grain quality characteristics as well as the nutritional value after milling of three Egyptian rice genotypes (*Oryza sativa*) under foliar treatment with different stimulating compounds. A two-year field experiment was laid out in split-plot design with four replications in the 2017 and 2018 rice growing seasons. Rice genotypes were allocated in the main plot and stimulating compounds in the subplot. After harvesting, 150-gram from each plot was taken to study the following characteristics: hulling, milling, head rice, gelatinous temperature, kernel elongation, amylose content, protein content, carbohydrate content, lipids content, ash, phosphorus, potassium and energy composition. There were significant differences for most of the studied characteristics caused by genotype, stimulating compound and the interaction between the two factors. The results revealed that the grain quality characteristics and the nutritional value of Egyptian rice genotypes can be enhanced by the application of some stimulating compounds such as amino acids and NPK compound fertilizer.

**Keywords:** *milling recovery, cooking quality, amino acid, ascorbic acid, NPK*

### Introduction

Rice (*Oryza sativa*, L.) is considered to be one of the most important staple food crops in Egypt. It plays a critical role in Egyptian food security. Rice is mostly considered a starchy food, but since animal products can be scarce or expensive in Egypt, it is often the most important source of protein in Egyptians diet as well. The Egyptian rice varieties vary in grain quality characteristics as well as nutritional value after milling (Metwally et al., 2016). Those characteristics are not important only to the consumers but, they are important to the marketer and miller. The genotypic variations in grain quality and nutritional value of milled rice are mainly caused by the genetic, environmental and agronomical factors which have been reported as the main responsible for those variations. Singh et al. (2011) found genotypic variations among three Japonica rice cultivars on physicochemical, cooking and textural properties of milled grains. They found that amylose and protein contents of milled rice grains affected significantly the cooked grain quality. Anjum et al. (2007) indicated significant variation in cooking, chemical characteristics and mineral contents among four Pakistani rice cultivars therefore; differences can be exploited by the rice breeders in their hybridization.

Mohapatra and Bal (2006) studied the cooking quality and instrumental textural attributes of cooked rice for different milling fractions of three rice varieties. They

found that cooking qualities as well as textural attributes were found to be varied among the varieties. Frei and Becker (2005) reported that rice protein quality is determined by the amino acid composition and its digestibility. Rice protein quality is very high when compared to other crops. Rice has favorable amino acid compositions, a high amount of lysine and a high protein digestibility which makes it a fairly good source of protein in diets where animal protein is limited.

Several researchers have reported that the use of stimulating substances is one of the effective means of improving rice grain quality and enhancing the milled rice nutritional value. Pan et al. (2013) indicated that foliar application plant growth regulators (gibberellic acid, paclobutrazol, 6-Benzylaminopurine) enhanced yield, grain quality characteristics and antioxidant enzyme activities in super hybrid rice. Kamboj and Mathpal (2019) found that foliar application of plant growth regulators i.e. gibberellic acid cytokinin enhanced the translocation of zinc from vegetative parts to the grains of the rice. They also reported a favorable effect of plant growth regulators on protein content in milled grains due to the translocation of synthesized proteins towards grain by increasing longevity of leaves thus resulted in higher grain protein content.

Therefore, the main objective of this study is to test the grain quality characteristics and the nutritional value of three rice genotypes under foliar application different stimulating compounds.

## Materials and methods

At the Experimental Farm of RRTC (Rice Research & Training Center), Sakha, Kafrelsheikh Governorate, Egypt (31°5'17"N, 30°56'44"E altitude), a two-year field experiment was conducted to study the behavior of three rice genotypes treated with foliar application of different stimulating compounds. The selected tested genotypes were Sakha108, GZ9399 and GZ10154. Sakha108 is a newly registered variety while GZ9399 and GZ10154 are new promising genotypes. The parentage, type and origin of the studied genotypes are presented in *Table 1*.

**Table 1.** Parentage, type and origin of the rice genotypes

Genotype	Parentage	Type	Origin
Sakha108	Sakha 101/ HR5824-B-3-2-3 //Sakha 101	Japonica	Egypt
GZ9399	Giza178/IR65844-29-1-3-2-1	Indica/Japonica	Egypt
GZ10154	Sakha 105/Sakha 101	Japonica	Egypt

The soil of the experiment was clayey in texture, 8.15 and 8.12 pH, 1.06 and 1.04 dS/m EC, 1.46 and 1.39% organic matter, 23.91 and 24.51 mg kg<sup>-1</sup> available nitrogen, 15.45 and 14.12 mg kg<sup>-1</sup> available phosphorus, 346 and 357 mg kg<sup>-1</sup> available potassium in first and second season respectively.

The different stimulating compounds were control (distilled water), amino acids, NPK 20:20:20, ascobin, vulvic acid, humic acids, and potassium sulphate. Stimulating compounds were applied twice; 20 and 40 days after transplanting (DAT). Amino acid (27.38% mixed amino acids + 9% micronutrients + 2% magnesium), ascobin (13% citric acid, 25% ascorbic acid plus 62% organic materials) and humic acid (65% humic acid + 10% K<sub>2</sub>O) were applied at the rate of 1 g L<sup>-1</sup>. Vulvic acid (50% vulvic acid + 20% organic acid) was applied at 1 ml L<sup>-1</sup>. NPK (20-20-20) and potassium sulphate

(50% K<sub>2</sub>O) were applied at 2%. 500 letters per hectare was used as spray solution amount for all compounds.

Split-Plot Design with four replicates was used. Rice genotype and stimulating compound treatment were arranged as main plot and sub-plot, respectively. The plot size was 12 m<sup>2</sup>. Rice seeds were sown in nursery 2<sup>nd</sup> and 4<sup>th</sup> of May for 2017 and 2018, respectively. Transplanted was done after 28 days of sowing nurseries with three to four seedlings per hill, spaced 20 X 20 cm within and between rows. All plots received optimum culture practices.

Grain quality characteristics: milling recovery, gelatinization temperature, kernel elongation and amylose content was estimated according to Cruz and Khush (2000): 150 (g) cleaned rough rice at 14% moisture content was dehulled using an Experimental Huller Machine (Satake - Japan). The brown rice was separated and weighed then the hulling percentage was calculated. The brown rice was milled using MC GILL Rice Miller No.2. (S.K. Appliances – India). The total milled rice was weighed and milled rice percentage was calculated. Whole milled grains were separated from the total milled rice using a rice sizing device SKU: 61-220-50 (Seedburo – USA). The percentage of head rice was calculated.

Six grains of whole milled rice were placed in boxes containing 1.7% KOH and arranged so that the kernels do not touch each. The boxes were covered and incubated for 23 h at 30 °C. The appearance and disintegration of endosperm were graded visually according to the numerical scale of the gelatinization temperature. Kernel elongation was measured using the Micrometer, the length of five milled grains was measured (mm) and their average was determined for each treatment (before cooking). Grains were left in a test tube filled with 30 ml of distilled water for 30 min, then for another 10 min in 98 °C a water tub. After that, the tubes were placed in cold water until reaching room temperature. Grains were lifted from the distilled water, dried (by filter paper), and measured again by graph papers (after cooking). Kernel elongation percentage was calculated as the percentage of grain expanding before and after cooking.

Amylose content was determined by weighing accurately 100 mg of sample into 100 ml volumetric flask then carefully adding 1 ml of 95% ethanol and 9 ml 1 N Na OH. The mixture was heated for 10 min in a boiling water bath to gelatinize the starch; then cooled, and the content made up to volume 100 ml with water. Pipette 5 ml portion of the gelatinization starch solution, 1 ml of 1 N acetic acid, and 2 ml of iodine solution were added and made up to a volume of 100 ml with distilled water. The content was shaken and stands for 20 min before reading the transmission at 620 nm by Spectronic 1201 Spectrophotometer (Milton Roy, USA).

Protein, carbohydrate, lipids, ash, phosphorus and potassium determination in rice grain: Plant samples were taken from the grain after milling (50 g of milled rice). All plant samples were placed in paper bags and oven-dry at 70 °C for 48 h. Grain samples were ground to powder and digested according to the method of Chapman and Pratt (1961) before chemical analysis as follows: the nitrogen content of milled grains was determined by using the Microkieldahl method (Jackson, 1967) to calculate protein content. Total carbohydrate was calculated by difference as mentioned by Fraser and Holmes (1959). Lipids was determined according to A.O.A.C. (2000). The phosphorus content of milled grain was determined using Spectronic 1201 Spectrophotometer (Milton Roy, USA) following the procedures of Watanabe and Olsen (1965). The Potassium content of grain was determined using Elico CL378 Flame Photometer

(RHYS international LTD, India) according to Peterpurgski (1968) method. The energy composition was calculated according to A.O.A.C. (2000) and Singh and Singh (2019).

The data was subjected to analysis of variance (ANOVA), and the differences among treatments' means were compared by Duncan's Multiple Range Test ( $P < 0.05$ ) and multiple F. test according to Duncan (1955). The Simple correlation coefficient ( $r$ ) among the nutritional properties of milled rice grains was generated using pooled values of two seasons. All statistical analyses were done using Costat Statistical Software - CoHort Software.

## Results and discussion

There were marked differences in milling recovery characteristics due to genotype, stimulating compound and the interaction between the two factors (*Tables 2 and 3*). Sakha108 recorded the highest values of hulling percentage and head rice percentage. The highest percentage of milling was observed by the rice genotype GZ10154. The differences among rice genotypes may be due to the genetically inherited variants. Zhao et al. (2018) identified GS9 (Grain Shape Gene on Chromosome 9) gene by map-based cloning. GS9 regulates grain shape and hull thickness by altering cell division.

The application of different stimulating compounds enhanced significantly milling recovery characteristics. The highest percentages of hulling, milling and head rice were noted with foliar application of amino acid followed by NPK 20,20,20. Regarding the interaction effect between genotype and stimulating compound, the studied rice genotypes responded differently to the stimulating compound application. Sakha108 recorded the highest percentages of hulling and head rice under the amino acid foliar application. While the highest percentage of milling was recorded by GZ10154 rice genotype treated with amino acid. Pan et al. (2013) found that foliar application plant growth regulators improved the rice milling recovery characteristics. Gharieb et al. (2016) indicated that application of Ascobin (13% citric acid, 25% ascorbic acid and 62% organic materials) three times as foliar application increased hulling, milling and head rice percentages.

**Table 2.** *Hulling %, milling % and head rice % of the tested rice genotypes under foliar application of stimulating compounds*

Treatment	Hulling %		Milling %		Head rice %	
	2017	2018	2017	2018	2017	2018
<u>Genotype:</u>						
Sakha108	80.11a	80.05a	70.20b	69.73c	66.22a	65.41a
GZ9399	79.34c	79.13c	69.39c	70.21b	64.69b	63.97b
GZ10154	79.41b	79.34b	70.49a	71.43a	64.63c	63.27c
F test	*	**	*	*	*	*
<u>Stimulating compound:</u>						
Amino acid	80.13a	79.99a	70.62a	70.96a	65.66a	64.74a
NPK 20:20:20	79.97b	79.86b	70.42b	70.77b	65.50b	64.59b
Ascobin	79.82c	79.62c	70.26c	70.62c	65.33c	64.38c
Vulvic acid	79.61d	79.47d	70.04d	70.44d	65.19d	64.20d
Humic acid	79.45e	79.35e	69.85e	70.31e	65.04e	64.06e
Potassium sulphate	79.28f	79.19f	69.62f	70.14f	64.86f	63.87f
Control	79.10g	79.06g	69.40g	69.96g	64.70g	63.69g
F test	**	**	**	**	**	**
Interaction effect	**	**	**	**	**	**

**Table 3.** Hulling %, milling % and head rice % as affected by the interaction between rice genotype and stimulating compound

Stimulating compound	Rice genotypes					
	Sakha108	GZ9399	GZ10154	Sakha108	GZ9399	GZ10154
	2017			2018		
	<b>Hulling %</b>					
Amino acid	80.69 a	79.81 f	79.90 e	80.50 a	79.70 g	79.79 f
NPK 20:20:20	80.47 b	79.69 g	79.76 fg	80.38 b	79.58 i	79.63 h
Ascobin	80.29 c	79.50 i	79.69 g	80.16 c	79.20 l	79.51 j
Vulvic acid	80.11 d	79.34 j	79.40 j	80.03 d	79.02 m	79.38 l
Humic acid	79.93 e	79.22 k	79.21 k	79.95 e	78.93 n	79.17 l
Potassium sulphate	79.75 fg	79.01 l	79.09 l	79.70 g	78.81 o	79.06 m
Control	79.59 h	78.86 m	78.86 m	79.63 h	78.70 p	78.85 o
	<b>Milling %</b>					
Amino acid	70.80 b	70.00 j	71.07 a	70.21 k	70.70 h	71.98 a
NPK 20:20:20	70.61 d	69.83 l	70.82 b	70.02 m	70.55 i	71.76 b
Ascobin	70.45 f	69.66 m	70.68 c	69.89 n	70.39 j	71.60 c
Vulvic acid	70.20 h	69.44 o	70.50 e	69.70 o	70.20 k	71.42 d
Humic acid	70.02 j	69.19 p	70.34 g	69.57 p	70.07 l	71.29 e
Potassium sulphate	69.80 l	68.91 q	70.15 i	69.44 q	69.89 n	71.10 f
Control	69.58 n	68.70 r	69.92 k	69.30 r	69.68 o	70.90 g
	<b>Head rice %</b>					
Amino acid	66.70 a	65.19 h	65.11 i	64.50 h	65.90 a	63.83 l
NPK 20:20:20	66.55 b	64.96 k	65.00 j	64.38 i	65.74 b	63.65 m
Ascobin	66.41 c	64.80 l	64.80 l	64.11 j	65.60 c	63.44 n
Vulvic acid	66.25 d	64.70 m	64.63 n	63.95 k	65.42 d	63.25 o
Humic acid	66.10 e	64.53 o	64.49 p	63.80 l	65.27 e	63.13 p
Potassium sulphate	65.89 f	64.40 q	64.30 r	63.63 m	65.09 f	62.90 q
Control	65.70 g	64.30 r	64.10 s	63.47 n	64.91 g	62.70 r

The Gelatinous temperature, kernel elongation and amylose content were varied the rice genotypes by stimulating compounds application (Tables 4 and 5). GZ9399 recorded the highest values of gelatinous temperature and the lowest values of kernel elongation and amylose content. The highest amylose content and kernel elongation were observed by the rice genotype GZ10154. The variations among the studied genotypes in cooking qualities may be due to the differences in their shape, thickness and surface area. Mohapatra and Bal (2006) suggested that surface area and thickness of the rice grain are important factors in deciding the diffusion of water during cooking. GZ9399 has lower amylose content and higher gelatinous temperature and kernel elongation which suggests that amylose content plays a significant role in deciding the cooking quality of rice.

Starch is the main component of milled rice grain. It is made up of two starchy fractions: amylose and amylopectin. After cooking, rice grains with high amylose content are dry, fluffy, separate and hard, while those with low amylose content are glossy, soft and sticky. So, Amylose content is considered to be one of the most important predictors of the eating quality of cooked rice. Milled rice cultivars may be generally classified based on their apparent amylose content into waxy (1-2%), very low (2-12%), low (12-20%), intermediate (20-25%) or high (>25%) (Bao, 2012). Based on the results, the studied genotypes under the current study belong to low amylose content rice types that meet the Egyptian consumers' preferences. The significant variation in amylose content among the studied genotypes could be attributed to the genetic background of those varieties.

**Table 4.** Gelatinous temperature, kernel elongation and amylose % of the tested rice genotypes under foliar application of stimulating compounds

Treatment	Gelatinous temperature		Kernel elongation %		Amylose %	
	2017	2018	2017	2018	2017	2018
<u>Genotype:</u>						
Sakha108	6.35c	6.19b	58.01 b	57.95 b	18.10b	17.89b
GZ9399	7.42a	6.87a	78.47 a	78.26 a	16.80c	16.72c
GZ10154	6.47b	5.86c	57.80 c	57.72 c	18.59a	18.53a
F test	*	*	*	*	*	*
<u>Stimulating compound:</u>						
Amino acid	7.06a	6.74a	65.10 a	65.39 a	18.10a	18.00a
NPK 20:20:20	6.95b	6.57b	65.12 a	64.76 b	18.02b	17.90b
Ascobin	6.80c	6.56b	64.91 b	64.69 c	17.93c	17.82c
Vulvic acid	6.68d	6.29c	64.77 c	64.58 d	17.83d	17.71d
Humic acid	6.50e	6.15d	64.60 d	64.51 e	17.76e	17.63e
Potassium sulphate	6.19f	5.98e	64.49 d	64.38 f	17.64f	17.51f
Control	6.04g	5.86f	64.34 e	64.20 g	17.53g	17.44g
F test	**	**	**	**	**	**
Interaction effect	**	**	**	**	**	**

**Table 5.** Gelatinous temperature, kernel elongation and amylose % as affected by the interaction between rice genotype and stimulating compound

Stimulating compound	Rice Genotypes					
	Sakha108	GZ9399	GZ10154	Sakha108	GZ9399	GZ10154
	2017			2018		
	Gelatinous temperature					
Amino acid	6.80 g	7.47 a	6.92 f	6.67 cd	7.39 a	6.17 g
NPK 20:20:20	6.65 h	7.38 b	6.84 g	6.50 de	7.20 ab	6.03 gh
Ascobin	6.50 j	7.30 c	6.60 i	6.39 ef	7.07 b	6.23 fg
Vulvic acid	6.38 k	7.18 d	6.49 j	6.20 fg	6.85 c	5.84 hi
Humic acid	6.20 mn	7.02 e	6.30 l	6.03 gh	6.70 cd	5.72 ij
Potassium sulphate	6.01 o	6.41 k	6.17 n	5.84 hi	6.52 de	5.60 jk
Control	5.93 p	6.23 m	5.98 o	5.70 ij	6.41 ef	5.48 k
	Kernel elongation %					
Amino acid	58.33 ef	78.76 a	58.23 f	58.90 h	78.59 a	58.70 i
NPK 20:20:20	58.53 e	78.70 a	58.14 fg	58.00 j	78.50 b	57.80 m
Ascobin	58.13 fg	78.60 ab	58.00 gi	57.94 k	78.43 c	57.71 n
Vulvic acid	58.01 gh	78.49 b	57.81 hj	57.85 l	78.30 d	57.60 o
Humic acid	57.80 ik	78.40 bc	57.62 jl	57.80 m	78.21 e	57.53 p
Potassium sulphate	57.72 jk	78.26 cd	57.50 lm	57.70 n	78.00 f	57.45 q
Control	57.60 kl	78.08 d	57.35 m	57.50 p	77.80 g	57.30 r
	Amylose					
Amino acid	18.37 f	17.09 l	18.85 a	18.19 h	17.03 o	18.79 a
NPK 20:20:20	18.30 g	17.00 m	18.77 b	18.10 i	16.90 p	18.70 b
Ascobin	18.21 h	16.89 n	18.70 c	18.01 j	16.84 q	18.62 c
Vulvic acid	18.10 i	16.80 o	18.60 d	17.88 k	16.72 r	18.54 d
Humic acid	18.07 i	16.71 p	18.51 e	17.80 l	16.63 s	18.46 e
Potassium sulphate	17.89 j	16.63 q	18.42 f	17.70 m	16.50 t	18.35 f
Control	17.78 k	16.52 r	18.30 g	17.61 n	16.43 u	18.28 g

Foliar application of different stimulating compounds increased significantly gelatinous temperature, kernel elongation and amylose content. The highest values of gelatinous temperature, kernel elongation and amylose content were observed with the application of amino acid followed by NPK 20,20,20. Concerning the interaction effect between genotype and stimulating compound, GZ9399 recorded the highest values of gelatinous temperature and kernel elongation under the amino acid foliar application. While the highest percentage of amylose content was recorded by GZ10154 rice genotype treated with amino acid.

Data in *Tables 6* and *7* revealed significant differences among rice genotypes, stimulating compound and the interaction for protein, carbohydrate and lipids content percentage in both seasons. GZ10154 recorded the highest values of protein content and the lowest values of carbohydrate and lipids. The highest values of carbohydrate content were recorded by GZ9399. Lipids content was significantly higher in Sakha 108 than the other genotypes. Zhao et al. (2018) indicated that GS9 Gene on Chromosome 9 acts as a transcriptional activator to regulate rice grain protein content and appearance quality. Anjum et al. (2007) and Singh and Singh (2019) found genotypic variation in protein, carbohydrate and lipids content percentage among different rice varieties.

The application of different stimulating compounds increased significantly the contents of protein and lipids over control treatment. Foliar application of NPK recorded the highest values of protein content while amino acid foliar application produced the highest values of lipids content. There are highly significant differences in protein, carbohydrate and lipids content percentage with respect to genotype X stimulating compound interaction suggesting that the three rice genotypes responded differently to stimulating compound application. Foliar application of NPK to GZ10154 gave the highest content of protein. Application of amino acid to Gz9399 and Sakha108 recorded the highest values of carbohydrate and lipids respectively. Khan et al. (2016) found that application of plant growth regulators (gibberellic acid, indole acetic acid and kinetin) significant increase in soluble protein contents of two rice cultivars. These results found in accordance of Kamboj and Mathpal (2019).

**Table 6.** Protein, carbohydrate and lipids content % of the tested rice genotypes under foliar application of stimulating compounds

Treatment	Protein %		Carbohydrate %		Lipids %	
	2017	2018	2017	2018	2017	2018
<u>Genotype:</u>						
Sakha108	8.27b	7.41b	76.90b	77.92b	0.591a	0.557a
GZ9399	7.33c	6.49c	77.93a	78.94a	0.545b	0.516b
GZ10154	9.52a	7.81a	75.77c	77.72c	0.503c	0.491c
F test	*	*	*	*	*	*
<u>Stimulating compound:</u>						
Amino acid	8.91b	7.92b	77.05a	78.24ab	0.572a	0.552a
NPK 20:20:20	9.10a	8.32a	76.59d	77.60c	0.564b	0.539b
Ascobin	8.60c	7.50c	76.82bc	78.20b	0.556c	0.530c
Vulvic acid	8.39d	7.10d	76.80c	78.31ab	0.547d	0.521d
Humic acid	8.07e	6.89e	76.91a-c	78.34ab	0.539e	0.512e
Potassium sulphate	7.88f	6.58f	76.98ab	78.33ab	0.530f	0.503f
Control	7.68g	6.35g	76.91a-c	78.40a	0.518g	0.493g
F test	**	**	**	**	**	**
Interaction effect	**	**	**	**	**	**

**Table 7.** Protein, carbohydrate and lipids content % as affected by the interaction between rice genotype and stimulating compound

Stimulating compound	Rice genotypes					
	Sakha108	GZ9399	GZ10154	Sakha108	GZ9399	GZ10154
	2017			2018		
	Protein %					
Amino acid	8.72 g	7.76 l	10.25 b	8.03 e	6.94 l	8.80 b
NPK 20:20:20	8.91 f	7.99 k	10.41 a	8.28 c	7.24 j	9.44 a
Ascobin	8.50 i	7.47 n	9.83 c	7.68 f	6.68 o	8.13 d
Vulvic acid	8.27 j	7.38 o	9.51 d	7.30 i	6.50 q	7.51 g
Humic acid	8.05 k	7.06 p	9.09 e	7.12 k	6.13 r	7.41 h
Potassium sulphate	7.82 l	6.90 q	8.94 f	6.89 m	6.08 s	6.78 n
Control	7.64 m	6.78 r	8.62 h	6.61 p	5.84 t	6.60 p
Carbohydrate %						
Amino acid	77.04 de	78.29 a	75.82 hi	77.96 e-g	79.30 a	77.47 i
NPK 20:20:20	76.58 f	77.83 bc	75.36 k	77.46 i	78.70 c	76.63 j
Ascobin	76.94 e	77.97 bc	75.56jk	77.90 f-h	78.98 b	77.71 h
Vulvic acid	76.89 e	77.83 bc	75.67ij	78.02 d-g	78.87 bc	78.05 d-f
Humic acid	76.85 e	77.98 b	75.89gh	78.19 d	79.01 b	77.82 gh
Potassium sulphate	77.19 d	77.77 c	75.99gh	77.96 e-g	78.83 bc	78.22 d
Control	76.84 e	77.82 bc	76.08 g	78.13 de	78.89 c	78.18 d
Lipids %						
Amino acid	0.617 a	0.569 g	0.530 l	0.599 a	0.539 ef	0.518 h
NPK 20:20:20	0.610 b	0.560 h	0.524 m	0.578 b	0.530 g	0.510 i
Ascobin	0.600 c	0.553 i	0.515 o	0.570 c	0.521 h	0.500 j
Vulvic acid	0.591 d	0.546 j	0.504 p	0.556 d	0.515 hi	0.493 k
Humic acid	0.583 e	0.538 k	0.496 q	0.543 e	0.510 i	0.485 l
Potassium sulphate	0.575 f	0.530 l	0.485 r	0.533 fg	0.503 j	0.474 m
Control	0.563 h	0.520 n	0.471 s	0.521 h	0.497 jk	0.462 n

The ash, phosphorus and potassium contents in milled rice grains differed significantly among genotypes and stimulating compounds, with a significant interaction (Tables 8 and 9). Ash content was higher in GZ9399 followed by GZ10154 without any significant difference between them in the second season. Sakha 108 recorded the highest content of phosphorus and potassium. Similar variations pattern has been reported earlier for rice genotypes by Anjum et al. (2007) and Singh et al. (2011). Singh and Singh (2019) found a genetic diversity of five rice varieties in mineral contents of rice grains. Stimulating compounds foliar application increased the content of ash, phosphorus and potassium in milled rice grains compared to control. Amino acid foliar application produced the highest values of ash content. Phosphorus content was higher in NPK treatment compared with other treatments. Potassium sulphate treatment increased significantly potassium content over the other treatments.

Regarding the interaction effect, ash content was higher in GZ9399 under the application of amino acid in both seasons. Phosphorus content in Sakha 108 rice milled grain was higher with the foliar application of NPK. The application of potassium sulphate to Sakha 108 produced the highest content of potassium. Pan et al. (2013) reported that foliar application of different stimulating compounds could enhance the lodging resistance and increase root biomass and root activity to improve phosphorus and potassium accumulation in milled grains of two rice cultivars.

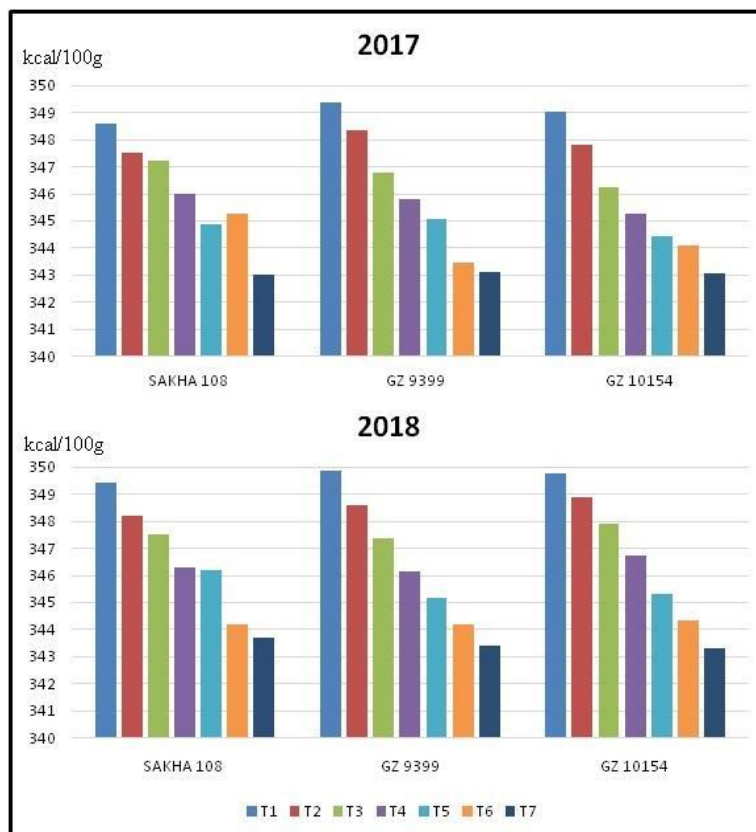
**Table 8.** Ash, phosphorus and potassium content % in milled rice grain of the tested rice genotypes under foliar application of stimulating compounds

Treatment	Ash %		Phosphorus %		Potassium %	
	2017	2018	2017	2018	2017	2018
<u>Genotype:</u>						
Sakha108	0.60 c	0.58 b	0.265 a	0.276 a	0.244 a	0.263 a
GZ9399	0.65 a	0.63 a	0.237 b	0.243 b	0.182 b	0.201 b
GZ10154	0.63 b	0.61 a	0.220 c	0.231 c	0.161 c	0.170 c
F test	*	*	*	*	*	*
<u>Stimulating comp.:</u>						
Amino acid	0.74 a	0.70 a	0.255 b	0.267 b	0.179 f	0.193 f
NPK 20:20:20	0.70 b	0.67 ab	0.262 a	0.274 a	0.213b 0.186	0.230 b
Ascobin	0.67 c	0.65 b	0.248 c	0.259 c	e	0.201 e
Vulvic acid	0.63 d	0.60 c	0.240 d	0.250 d	0.197 d	0.213 d
Humic acid	0.59 e	0.57 cd	0.233 e	0.243 e	0.205 c	0.221 c
Potassium sulphate	0.57 f	0.55 d	0.227 f	0.235 f	0.221 a	0.238 a
Control	0.51 g	0.51 e	0.219 g	0.225 g	0.168 g	0.184 g
F test	**	**	**	**	**	**
Interaction effect	**	**	**	**	**	**

**Table 9.** Ash, phosphorus and potassium content % in milled rice grain as affected by the interaction between rice genotype and stimulating compound

Stimulating compound	Rice genotypes					
	Sakha108	GZ9399	GZ10154	Sakha108	GZ9399	GZ10154
	2017			2018		
	Ash %					
Amino acid	0.72 c	0.77 a	0.75 b	0.69 ab	0.71 a	0.71 a
NPK 20:20:20	0.69 d	0.72 c	0.70 d	0.67 a-c	0.69 ab	0.66 a-d
Ascobin	0.65 ef	0.70 d	0.66 e	0.62 c-f	0.69 ab	0.64 b-e
Vulvic acid	0.64 fg	0.63 gh	0.62 hi	0.61 e-f	0.60 d-g	0.60 d-g
Humic acid	0.56 lm	0.61 ij	0.61 ij	0.55 gh	0.59 e-g	0.58 f-h
Potassium sulphate	0.54 n	0.60 j	0.58 k	0.53 h	0.58 f-h	0.55 gh
Control	0.42 o	0.57 kl	0.55 mn	0.42 i	0.55 gh	0.55 gh
	Phosphorus %					
Amino acid	0.281 b	0.251 g	0.235 j	0.291 b	0.263 g	0.248 k
NPK 20:20:20	0.289 a	0.258 e	0.241 i	0.298 a	0.271 e	0.253 i
Ascobin	0.274 c	0.243 h	0.229 k	0.285 c	0.254 h	0.240 m
Vulvic acid	0.260 d	0.236 j	0.220 m	0.278 d	0.243 l	0.230 o
Humic acid	0.255 f	0.230 k	0.214 o	0.270 f	0.235 n	0.224 q
Potassium sulphate	0.250 g	0.225 l	0.206 p	0.263 g	0.225 p	0.217 r
Control	0.241 i	0.217 n	0.200 q	0.251 j	0.216 s	0.210 t
	Potassium %					
Amino acid	0.230 f	0.162 o	0.145 q	0.245 f	0.185 n	0.150 s
NPK 20:20:20	0.260 b	0.201 i	0.180 l	0.281 b	0.220 i	0.190 m
Ascobin	0.235 e	0.174 m	0.150 p	0.254 e	0.190 m	0.159 r
Vulvic acid	0.243 d	0.185 k	0.163 o	0.268 d	0.200 k	0.171 q
Humic acid	0.252 c	0.193 j	0.171 n	0.275 c	0.209 j	0.179 o
Potassium sulphate	0.269 a	0.210 h	0.185 k	0.290 a	0.229 h	0.197 l
Control	0.221 g	0.150 p	0.134 r	0.234 g	0.174 p	0.145 t

Figure 1 shows that the amounts of energy vary significantly among the different genotypes. The amounts in GZ9399 and GZ10154 were slightly higher than Sakha108. These variations are mainly due to genetic diversity. The application of different stimulating compounds increased energy amount in milled rice grains. The application of amino acid recorded the highest composition of energy for the three rice genotypes. Data in Table 10 indicated that energy composition in milled rice grain had significant and positive correlations with each of lipids ( $p = 0.05$ ), ash ( $p = 0.01$ ) and phosphorus ( $p = 0.01$ ) concentrations in milled grains. These results explain the superiority of amino acid application.



**Figure 1.** Energy composition kcal/100 g of milled rice grains of the tested rice genotypes under foliar application of stimulating compounds. T1: Amino acid, T2: NPK 20:20:20, T3: Ascobin, T4: Vulvic acid, T5: Humic acid, T6: Potassium sulphate, T8: Control

**Table 10.** Simple correlation coefficient ( $r$ ) among the nutritional properties of milled rice grains (Pooled data of two seasons)

	Protein %	Carbohydrate %	Lipids %	Ash %	P %	K %	Energy
Protein %	1.000	-0.884**	0.497*	0.599**	0.153	-0.253	0.416
Carbohydrate %	-0.884**	1.000	-0.337	-0.194	0.194	0.262	0.055
Lipids %	0.497*	-0.337	1.000	0.563**	0.673**	0.344	0.505*
Ash %	0.599**	-0.194	0.563**	1.000	0.552*	-0.158	0.906**
P %	0.153	0.194	0.673**	0.552*	1.000	0.598**	0.765**
K %	-0.253	0.262	0.344	-0.158	0.598**	1.000	0.042
Energy	0.416	0.055	0.505*	0.906**	0.765**	0.042	1.000

## Conclusion

The foliar application of different stimulating compounds enhanced rice grain quality characteristics as well as the nutritional value of milled grains. The application of different stimulating compounds enhanced the translocation of assimilates to milled grains. Amino acid foliar application showed marked increases in the studied characteristics compared to other treatments. There were noticeable differences in grain quality characteristics and the nutritional value of milled grains among the studied genotypes. Finally, greater attention should be paid to grain quality characteristics in Egyptian rice production to meet Egyptian consumer preferences. Thus, more studies should be done to improve the grain quality characteristics of the Egyptian rice varieties.

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