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Effect of different levels of sulphur and nitrogen fertilizers on potato productivity, acrylamide formation and amino acids content in processed potatoes

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ABSTRACT

Potato is one of the most widespread vegetable crops in the world. In addition, potatoes have grown very extremely in recent years due to increased potato processing rates, especially in Egypt. As a result of some uncontrolled agricultural practices, mainly fertilization; this led to defects in processed potato products. Obtaining the highest possible potato productivity per unit of the cultivated area, as well as the high quality of the processed products, is the focus of this research. Four levels of sulphur fertilizer (zero, 100, 200 and 300 kg S/feddan = 4200 m^2) and two levels of nitrogen fertilizer (100 and 200 kg N/feddan) were applied to the growing potato plants. Seven pre-treatments were utilized on sliced potatoes before frying (without soaking; soaking in salt and acetic acid for 30 and for 60 min, respectively; soaking in salt and rosemary powder for 30 and for 60 min, respectively and soaking in salt, acetic acid and rosemary powder for 30 and for 60 min, respectively). Most of the studied vegetative growth characters and potato tuber yield (ton/Fed.) were improved by increasing sulfur fertilization levels from zero up to 300 kg / Fed. and / or increasing nitrogen fertilization levels from 100 kg up to 200 / Fed. during the two seasons. The best results for the vegetative growth traits and total tuber yield/Fed could be achieved from the application of 300 kg S/Fed. + 200 kg N/Fed. Levels of acrylamide in potato processed were significantly increased by increasing nitrogen fertilizer treatments from 100 up to 200 kg N/Fed. and / or increasing sulphur treatments from 100 kg up to 300 kg S/Fed. Soaking the potato slices before frying for 60 min. in a solution composed of salt + acetic acid + rosemary reduced the proportion of acrylamide formed in potato chips during the frying.

Keywords: potato, nitrogen, sulphur, potato yield, tubers quality, acrylamide, amino acids, potato processing.

Introduction

Potato (*Solanum tuberosum*, L.) belongs to family *Solanaceae* is one of the world's most important agricultural yields and it is consumed regular by millions of people from miscellaneous cultural experiences. Potato is one of the major staple foods in many developing countries. According to FAO the total world production of potatoes is 376,826,967 tons from an area of 19,246,462 hectares (FAOSTAT, 2016). The total potato production in Egypt is 5,029,022 tons from an area of 184,592 hectares. With this productivity Egypt ranked first in Africa (FAOSTAT, 2016).

Nitrogen remains one of the essential elements for plant development and is one of main components of proteins. It is an integral component of many compounds for example chlorophyll, nucleotides, alkaloids, enzymes, hormones and vitamins, etc. which is vital for plant growing processes (Brady and Weil, 2008). In potato production, the growth, development and yield of potato are mainly ruled by availability of major nutrients required for its cultivation. Nitrogen is the basic controlling factor for potato crop which improves vegetative growth and invariably increases yield, tuber per plant, tuber size as well as tuber numbers (Oliveira, 2000; Mustonen *et al*., 2010 and Yadav *et al*., 2017).The results of David and Cassidy (1990) cleared that crop amplified with the usage of up to 100–150 kg N ha^{-1}and continued constant thereafter; % DM of tubers was significantly lessened by quantities of nitrogen > 150 kg ha^{-1}. Potato is a sensitive crop to request managing of nitrogen and quantities less or more than its necessities or early and late application of nitrogen will disturb quantitative and qualitative of potato productivity (Rezaei and Soltani, 1996).

Sulphur is one of sixteen critical nutrient elements and fourth main nutrient after NPK, obligatory by plants for appropriate development and yield as it is recognized to take part in several

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reactions in all living cells (Sud and Sharma, 2002). Sulphur lacking plants had deprived use of nitrogen, phosphorus and potash and a major decrease of catalase activities at all age (Nasreen *et al*., 2003). Intensive cropping and usage of high-grade fertilizers have produced the reduction of sulphur in soils. Decline in tuber dry matter yield and concentrations of dry matter, starch and vital amino acids mainly cystine and leucine were detected with sulphur shortage (Petitte and Ormrod, 1988 and Eppendorfer and Eggum, 1994 a). Sulphur has a straight influence on soil properties as it may decrease soil pH which expands the obtainability of microelements such as Fe, Zn, Mn and Cu in addition to crop yield and its associated characteristics (Tantawy *et al*., 2009).

Potatoes are permanently cooked before consumption conventionally by frying and further cooking processes (Pedreschi *et al*., 2006). Deep fat frying is widely used in food processing both industrially and at home and fried potato products are one of its major appliances (Pedreschi *et al*., 2007). An accidental detection of acrylamide, a possible carcinogen in fried and baked foods by Swedish scientists and followed by the statement of National Food Administration in Sweden (SNFA) during April 2002, that acrylamide is located in numerous kinds of food, generated alarm among the food scientist and consumers. In general, deep fat fried potato products, roasted coffee beans and bakery products are the greatest significant foundations of acrylamide (EFSA 2015). Acrylamide creation in foods is affected by numerous factors, including processing temperature, time, content and species of reducing sugars and amino acids, pH, moisture content and frying oils, denoting that acrylamide in foods can be reduced by altering processing technology (Ciesarova *et al*., 2006).

The chief components that are dependable for acrylamide formation in foods are carbohydrates particularly reducing sugars and asparagine*,* one of the non-essential amino acids. Papers to date have obviously exhibited that asparagine is largely responsible for acrylamide formation in heated foods after condensation with reducing sugars or a carbonyl source (Gokmen and Palakzaglu, 2008). Free asparagine content in potato tubers rises with increasing nitrogen fertilization (Dewilde *et al*., 2006) since free asparagine is a nitrogen reservoir (Eppendorfer and Bille, 1996). An extra in nitrogen intake by fertilization leads to the biosynthesis of additional free asparagine, therefore lowering the reducing sugar content since they are used via the tuber for the biosynthesis of amino acids (Kolbe, 1990).

Quite a lot of findings have considered decreasing the formation of acrylamide by reducing acrylamide precursors, asparagine and reducing sugars, by soaking or blanching of potato slices in different solutions (Grob *et al*., 2003 and Jung *et al*., 2003). Soaking or blanching of potato slices in acid solutions was efficient, with the maximum reduction in acrylamide (90%) happening in acetic acid solutions for 60 min. at 20 °C (Kita *et al*., 2004). Conversely, a sour taste was detected when either citric acid or acetic acid was used. A large number of natural phenolic compounds have been stated to possess high antioxidant belongings. Most principal commercially obtainable natural antioxidants are tocopherols, ascorbic acid and Rosemary and Sage extracts (Löliger, 1991, Valenzuela *et al*., 2000 and El-Shawaf *et al*., 2014).

Hence, the aim of the present study is to maximize both potato crop productivity and quality through the use of optimum combination between nitrogen and sulphur fertilizers. Moreover, the study is concerned with the production of high quality processed potatoes by reducing the acrylamide contents in fried potato chips by using some pre-treatments as soaking potato slices in salt, acetic acid and rosemary before frying for different periods.

Materials and methods

The present examination was carried out for the two summer seasons of 2016 and 2017 at the experimental farm of Faculty of Agriculture (Saba Basha), Alexandria University at Abees region, Alexandria governorate, Egypt. Planting tuber seeds toke place on the middle of January in both growing seasons; using Hermes potato cultivar. Tuber seeds were planted under drip irrigation system in rows, 70 cm in wide, 10 m long and at spacing of 25 cm within rows.

Fertilization treatments

The trials were carried out to assessment the effects of two factors. The first factor was the sulphur treatments which were applied during soil preparation at four rates; i.e., zero, 100, 200 and 300 Kg S/fed. The second factor was the nitrogen fertilization treatments which were applied at two rates; i.e., 100 and 200 Kg N/fed. One fourth of nitrogen units were added in the form ammonium sulphate (20.5 %) during preparation soil. The remaining nitrogen units were added to three doses in the form of ammonium nitrate (33.5 %) throughout the dripping system. Each experimental unit was consisted of four rows with plot area of 28 m^2. The two central rows of each unit were used for analytical samples.

Agricultural practices

The following fertilizers were added to the soil at preparation; 75 Kg P_2O_5/fed.in the form of mono calcium phosphate (15.5 % P_2O_5), plus 20 m^3 organic manure /fed. Potassium fertilizer was added at the rate of 96 Kg K_2O / fed. in the form of potassium sulphate (48% K_2O) where, the first dose (100 Kg potassium sulphate / Fed.) was added during preparing the soil; while the remainder doses were applied throughout the drip irrigation system in two equal doses. A mixture of iron, manganese and zinc was sprayed to the growing plants after 55 and 70 days after planting. All other agricultural practices used for potato production were followed as common in the region throughout the both seasons of the study. Harvest was done 110 days after planting potato seeds. The physical and chemical properties of the soil were measured using laboratory tests suggested by the U.S. Salinity Laboratory Staff (1954) and are presented in Table (1).

Table 1: Physical properties and chemical analyses of the experimental soil

	Mechanical analysis			Texture	pH	EC. dS/m	$CaCo_3$ %	O.M.%	
Year	Sand %	Silt %	Clay %						
2016	39.12	10.00	50.88	clay	8.11	1.15	31.57	2.04	
2017	38.40	11.10	50.50	clay	8.01	1.09	31.60	1.85	
				Chemical analysis					
	Cations (meq/L)						Anions (meq/L)		
Year	N^+	P^+	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^-	HCO_3^-	CL^-	SO_4^{--}
2016	27.50	19.00	1.36	1.39	2.07	0.26	zero	2.70	11.96	1.52
2017	27.67	20.01	1.31	1.33	2.00	0.27	zero	2.53	11.99	1.43

Measurements

Vegetative growth:

Ten whole plant samples per experimental unit were randomly used, 90 days after planting, for the determination of the vegetative growth (plant height [cm] and number of main branches). Stem diameter was measured using a caliper on the fourth internodes from the base. Fresh foliage weight was calculated using three plants randomly collected from each experimental unit.

Yield parameters:

Tuber yield (ton/Fed.) was calculated for plot area then attributed to the feddan (Fed.), where Fed. = 4200 m^2. Number of tubers per plant was counted as the average number of tubers per plot area. Average tuber weight (g) was calculated by dividing tuber yield per plot by its tuber's number. Percentage of marketable tubers' number per plant (%) was calculated per plot; where, all tubers characterized by its diameter 2 cm or more free from injuries, wounds, cracks or cuts, decays, insect infestations, secondary growth tubers are considered acceptable for marketing.Percentage of marketable tuber weight (%) was calculated per plot; where, all tubers characterized by its weight 10 g or more are considered acceptable for marketing.

Tuber quality:

Random samples of 10 tubers per treatment were randomly used to determine tuber dry matter percentage which was carried out by weighing a certain weight of fresh tubers and then dried. The dry matter was found to be the ratio of the weight of sample after frying and its weight before frying multiplied by 100. A known mass (5 g) of fresh tuber was taken to determine reducing sugars percentages (glucose and fructose) using sulphuric acid and phenol (5%); then they were colourimetrically determined, according to the method of Dubois *et al*. (1956). Crude fibers (%), protein (%), fat (%) and ash (%) were analyzed according to A.O.A.C. (2007). Amino acid analyses (mg/100mg) (Aspartic, alanine, glutamic, glycine, isoleucine, leucine, phenylalanine, arginine, cysteine, Lysine, Threonine and proline) were done according to A.O.A.C. (2012).

Evaluation of acrylamide in potato chips processed

Chemicals:

All reagents were of analytical grade. Acrylamide (99.9%) was purchased from Sigma Chemical (St. Louis, Mo., U.S.A.). Acetic acid and rosemary were purchased from local market

Methods:

Potato tubers of season 2017 were washed under running water, hand-peeled for the outer skin and cut to be 1.5 ± 0.5 mm thick using a turning blade.

Soaking treatments:

Potato slices for every fertilization treatment were used in 7 soaking treatments:

- First treatment fried without soaking immediately after cutting in mixed oil at 180 c for 3 min
- Second and third treatments were soaking in 1 L of water containing salt (1gm) and acetic acid (10%) for 30 and 60 min., respectively.
- Fourth and fifth treatments were soaking in1 L of water containing salt (1gm) and rosemary powder (0.5 gm) for 30 and 60 min., respectively.
- Sixth and seventh treatments were soaking in 1 L of water containing salt (1gm), acetic acid (10%) and rosemary powder (0.5 gm) for 30 and 60 min., respectively.

Frying experiment:

The frying time was constant (3 min.). Twenty slices per sampling time were deep-fried in hot oil contained in 3 Liter capacity electrical fryer (Rival, Model CZF575, China) at a temperature (180±1°C).

Acrylamide analysis:

Acrylamide was analyzed for every fertilizer and soaking treatments (56 samples) by using HPLC method according to Khoshnam *et al*. (2010).

Sensory evaluation:

Sensory evaluation for fried potato chips were done for all treatments in separated eight days by a panel of 20 judges from food technology research institute to evaluate color, taste, flavor ,texture and general acceptability , they use score from one to ten in which one indicating very poor and 10 indicates excellent. The mean score for each item was calculated and recorded.

Experimental design and statistical analysis

The used experimental layout was arranged as factorial experiment designing in a randomized complete blocks design (R.C.B.D) with three replicates. Collected data of the experiments were statistically analyzed, using the analysis of variance method. Comparisons among the means of different treatments were done, using least significant differences (L.S.D) test procedure at $p = 0.05$ level of probability, as illustrated by Snedecor and Cochran (1980). Computation was done using Co-Stat software program (2004).

Results and Discussion

Effect of sulphur and nitrogen fertilization levels and their interaction on the vegetative growth of potato plants:

The results of Table (2) clearly showed that increasing sulphur fertilization from zero up to 300 Kg S / Fed. had positive effects on most of the vegetative characters except for No. of main branches / plant during the two seasons of the study. Adding 300 Kg / Fed. sulphur during soil preparation significantly possessed the highest mean values for plant height trait during the two seasons. Same trend of results were also detected respecting foliage fresh weight during the season of 2016. Adding 200 or 300 Kg/Fed. sulphur to the soil significantly gave higher mean values for stem diameter trait compared to without adding sulphur. In general, the results showed that the addition of sulphur to the soil gave better results for growth characters compared to non-addition, and can be returned to these results that the addition of sulphur works to reduce the number of soil acidity (pH), which facilitates the absorption of elements from the soil by plants, especially the nitrogen. The importance of elemental S application was indicated by several researchers (Bayoumi *et al*., 1997; El-Fayoumy and El- Gamal, 1998; Saleh and Abushal, 1998 and Saleh, 2001). The authors explained that sulphur fertilizer improved the availability of some nutrients in different types of soil and their uptake by plants. Awad *et al*. (2002) revealed that plant height (cm) and foliage dry weight (%) traits were significantly increased by increasing sulphur levels from 250 up to 750 kg / Fed., but not significant with number of main stems / plant and foliage fresh weight / plant traits in both seasons.

Table 2: Mean values of potato vegetative growth characters as affected by sulphur and nitrogen levels and their interactions during the seasons of 2016 and 2017.

Fertilization treatments	Season 2016				Season 2017			
	Plant height (cm)	No. of main branches /plant	Stem diameter (cm)	Foliage fresh weight (g)	Plant height (cm)	No. of main branches /plant	Stem diameter (cm)	Foliage fresh weight (g)
				Sulfur effect				
Zero Kg Sulfur/Fed.	48.01 c	4.40 a	1.51 b	404.00 d	45.51 c	4.12 a	1.46 b	398.33 c
100 Kg Sulfur /Fed.	51.76 b	3.65 a	1.52 ab	449.17 c	49.16 b	4.13 a	1.50 ab	410.00 bc
200 Kg Sulfur/Fed.	52.43 b	4.30 a	1.53 ab	482.83 b	48.70 b	4.32 a	1.52 a	426.17 ab
300 Kg Sulfur/Fed.	58.20 a	3.85 a	1.56 a	507.00 a	53.57 a	4.48 a	1.53 a	442.67 a
				Nitrogen effect				
100 Kg Nitrogen /Fed.	46.83 b	3.69 a	1.50 b	427.50 b	44.14 b	4.06 b	1.47 b	402.33 b
200 Kg Nitrogen/Fed.	58.37 a	4.41 a	1.56 a	494.00 a	54.33 a	4.47 a	1.54 a	436.25 a
				Nitrogen X Sulfur Interaction				
1) Zero S/Fed. X 100 Kg N/Fed.	41.72 d	4.26 a	1.48 d	361.67 e	40.10 d	3.97 b	1.39 c	386.76 d
2) Zero S/Fed. X 200 Kg N/Fed.	54.30 b	4.53 a	1.54 bc	446.33 cd	50.91 b	4.27 ab	1.53 ab	410.00 cd
3) 100 S/Fed. X 100 Kg N/Fed.	47.87 c	3.50 a	1.53 bcd	420.00 d	44.47 c	4.03 b	1.49 b	390.00 d
4) 100 S/Fed. X 200Kg N/Fed.	55.65 b	3.80 a	1.51 bcd	478.33 bc	53.86 b	4.23 ab	1.51 ab	430.00 abc
5) 200 S/Fed. X 100Kg N/Fed.	48.57 c	3.90 a	1.50 cd	455.67 c	45.40 c	3.93 b	1.49 b	408.33 cd
6) 200 S/Fed. X 200 Kg N/Fed.	56.30 b	4.70 a	1.56 b	510.00 ab	51.99 b	4.70 a	1.55 ab	444.00 ab
7) 300 S/Fed. X 100 Kg N/Fed.	49.18 c	3.10 a	1.50 cd	472.67 c	46.58 c	4.30 ab	1.48 b	424.33 bc
8) 300 S/Fed. X 200 Kg N/Fed.	67.22 a	4.60 a	1.62 a	541.33 a	60.57 a	4.76 a	1.57 a	461.00 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at p= 0.05 level of probability.

Fertilization potato plants with 200 kg N / Fed. had significant positively effects on most of the studied vegetative characters compared to the fertilization with 100 Kg N / Fed. during the two seasons, except for number of main branches / plant during the first season only (Table, 2). The significant improvement for the studied vegetative characters resulting from increasing nitrogen level from 100 up to 200 kg / Fed may be due to the fact that higher nitrogen concentration stimulated the assimilation of carbohydrates and protein, which in turn stimulated cell divisions and formation of more tissues that resulted in enhanced vegetative growth of potato plants. Same trend of results were also detected by (Banjare, *et al*. 2014). Increasing nitrogen fertilizer rates up to 230 kg N/Fed. Heightened vegetative progress as expressed by plant length, leaf number and area, plant fresh and dry weights, and leaf chlorophyll content (Ahmed, *et al*. 2009). Sriom *et al*. (2017) explaind that nitrogen influences the rate and extent of protein synthesis. Therefore, it increases the plant height and number of leaves per plant. This finding was close consistency with the results of Bekhit *et al*. (2005) and Kumar *et al*. (2007a).

The data of the interaction between sulphur level and nitrogen level are presented in Table (2). There were highly significant differences among the tested fertilization treatments regarding the vegetative traits all over the two seasons of this experiment except for number of main branches per plant during the first season. The highest mean values regarding most studied vegetative characters were given when potato plants were fertilized with 300 Kg S / Fed. + 200 Kg N / fed., as shown in Table (2).

The data of Singh *et al*. (2016) revealed that adding 180 kg N + 50 kg S ha^{-1} significantly gave maximum number of branches and higher plant height. The authors explored that these results might be due to the fact that fertilization application encouraged more number of independent stems and more uptake of N during growth period resulting in increase in cell size, elongation and enhancement of cell division which ultimately increase the plant growth. The results are in consonance with those of Zamil *et al.* (2010); who reported that the highest number of stems per hill obtained when the highest rate of nitrogen (254 kg ha^{-1}) was applied.

Effect of sulphur and nitrogen fertilization levels and their interaction on the productivity of potato plants and tubers' dry matter percentage:

The results of Table (3) showed that there was no significant effect of the four tested sulfur levels on the effect of the number of tubers / plant during the two seasons of this experiment. The data of the two seasons appeared that addition of 300 kg sulphur for the agricultural soil had a significant effect on increasing the average tuber weight compared to the treatment of zero sulfur. However, there were no significant differences among the three treatments (100, 200, 300 kg sulfur/Fed.) in the effect on this character. The highest yield per feddan was obtained by adding 300 kg sulphur / Fed. while the non-addition of sulphur gave the lowest value for feddan productivity without significant effects with the treatment 100 kg sulphur / Fed. There was no significant difference between the treatments 200, 100 kg of sulfur in the effect on the potato productivity. The data of the first season showed that the treatment 300 kg sulphur per Fed. gave the highest value for the percentage of marketable tubers per plant without significant differences between the two treatments 100 and 100 kg sulfur per feddan. The data of the second season showed that adding 300 or 200 kg sulfur / Fed. significantly gave highest values for the marketable tubers / plant (%). In terms of marketable yield / plant (%) trait, the results recorded during the two seasons showed that adding 300 kg sulphur to the soil significantly gave the best results. The results of the first season showed that the addition of 100 or 200 or 300 kg sulphur / Fed. had a significant positive effect on the tubers' dry matter percentage compared to the treatment of zero sulfur (Table, 3). From another perspective, the results of the second season showed that the two treatments zero and 200 kg sulphur / Fed. Significantly gave the best results for the dry matter percentages. The previous results showed that sulphur application had a positive effect on potato tuber yield and improved the percentages of both marketable tubers' number and marketable tubers' yield. Positive impact of sulphur fertilization on potato yields has been reported by numerous authors, e.g. El-Fayoumy and El-Gamal (1998) and Carew *et al*. (2009). The results of Awad *et al*. (2002) emphasized that total potato tubers yield / Fed. , numbers of tuber / plant , tuber average weight and tuber dry matter content significantly increased by increasing sulphur levels from 250 up to 750 kg / Fed. in both growing seasons. Sulphur applications have been found to increase potato productivity and improve tubers' quality characteristics (Klikocka *et al*., 2005 and Klikocka 2010). Eppendorfer and Eggum (1994a) and Kumar *et al*. (2007b) reported that the tuber dry matter percentage was positively affected with the application of sulphur compared with non-addition treatment. Sulphur application increased dry matter content in tuber up to 45 kg ha^{-1}. Thereafter, further increase in sulphur did not showed any notable effect (Sharma *et al*., 2011). The findings of Singh *et al*. (2018) suggests that application of sulphur had significantly improved potato tuber yield per plant, dry matter content, starch content, economic yield and net income to more than double. Thus, application of sulphur in different phase of plant growth can be used to improve quality and economic yield in potato.

Regarding to nitrogen levels on potato yield and its component characters; the recorded data showed that there was no significant effect of the two tested nitrogen levels (100 and 200 kg N / fed.) in the effect on the number of tubers / plant during the first season (Table, 3). In the second season, the results showed that the treatment 200 kg N / Fed significantly possessed high value for number of

Table 3: Mean values of potato yield, yield component characters and tubers' dry matter as affected by sulphur and nitrogen levels and their interactions during the seasons of 2016 and 2017.

Fertilization treatments	Season 2016						Season 2017					
	No. of tubers/ plant	Average tuber weight (g)	Yield / feddan (ton)	No. of marketable tubes / plant (%)	Marketable yield / plant (%)	Tubers' dry matter (%)	No. of tubers/ plant	Average tuber weight (g)	Yield / feddan (ton)	No. of marketable tubes / plant (%)	Marketable yield / plant (%)	Tubers' dry matter (%)
Sulfur effect												
Zero Kg Sulfur/Fed.	5.85 a	71.60 b	9.55 c	85.15 b	83.87 c	22.11 b	6.36 a	59.14 b	8.60 c	79.53 c	79.28 d	25.49 a
100 Kg Sulfur /Fed.	5.72 a	75.97 ab	9.81 bc	87.49 ab	85.73 b	23.95 a	6.34 a	61.35 ab	8.94 bc	82.93 b	81.43 c	23.53 c
200 Kg Sulfur/Fed.	5.75 a	78.58 ab	10.19 b	88.17 ab	86.56 b	24.23 a	6.52 a	62.26 ab	9.30 b	86.06 a	82.71 b	25.26 ab
300 Kg Sulfur/Fed.	6.07 a	83.64 a	11.50 a	89.34 a	87.53 a	24.98 a	6.65 a	64.34 a	9.81 a	87.36 a	84.19 a	24.93 b
Nitrogen effect												
100 Kg Nitrogen /Fed.	5.77 a	66.97 b	8.74 b	79.50 b	76.11 b	24.33 a	6.14 b	56.12 b	7.87 b	77.31 b	76.01 b	23.90 b
200 Kg Nitrogen/Fed.	5.92 a	87.93 a	11.79 a	95.58 a	95.73 a	23.35 b	6.79 a	67.42 a	10.46 a	90.63 a	87.80 a	25.71 a
Nitrogen X Sulfur Interaction												
1) Zero S/Fed. X 100 Kg N/Fed.	5.83 a	62.80 c	8.29 e	78.13 c	73.70 e	22.74 cd	5.93 c	54.96 d	7.39 f	72.49 d	72.50 f	24.64 de
2) Zero S/Fed. X 200 Kg N/Fed.	5.87 a	80.41 ab	10.80 c	92.16 b	94.03 b	21.49 d	6.79 a	63.33 bc	9.81 c	86.58 b	86.07 c	26.34 b
3) 100 S/Fed. X 100 Kg N/Fed.	5.87 a	63.37 c	8.41 e	79.24 c	75.70 d	24.52 abc	6.01 c	55.13 d	7.58 ef	75.36 d	76.06 e	22.84 f
4) 100 S/Fed. X 200Kg N/Fed.	5.57 a	88.56 ab	11.21 bc	95.74 ab	95.75 a	23.39 bc	6.67 ab	67.56 ab	10.29 bc	90.50 ab	86.80 bc	24.23 e
5) 200 S/Fed. X 100Kg N/Fed.	5.94 a	64.15 c	8.61 e	79.03 c	76.93 cd	24.58 ab	6.23 bc	57.10 cd	8.11 de	79.72 c	77.41 de	25.38 c
6) 200 S/Fed. X 200 Kg N/Fed.	5.55 a	93.01 a	11.78 b	97.30 a	95.19 a	24.06 abc	6.80 a	67.43 ab	10.48 b	92.39 a	88.00 b	25.15 cd
7) 300 S/Fed. X 100 Kg N/Fed.	5.45 a	77.53 bc	9.64 d	81.58 c	78.09 c	25.47 a	6.40 abc	57.31 cd	8.38 d	81.67 c	78.06 d	22.74 f
8) 300 S/Fed. X 200 Kg N/Fed.	6.69 a	89.74 ab	13.36 a	97.11 a	96.96 a	24.48 abc	6.89 a	71.37 a	11.24 a	93.06 a	90.32 a	27.11 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at *p*= 0.05 level of probability tubers / plant. For the characteristics of the average tuber weight, tuber yield / Fed., No. of marketable tubers / plant and marketable yield / plant, the data showed that fertilization potato plants at the rate of 200 kg N / Fed significantly gave higher values compared to fertilization potato plants at the rate of 100 kg N / Fed during the two seasons (Table, 3). Increasing nitrogen fertilizer level from 100 kg N / Fed up to 200 kg N / Fed significantly reduced dry matter content of tubers.

Banjare *et al*. (2014) illustrated that fresh weight of tuber per plant was significantly increased by raising nitrogen fertilizer level from zero up to 375 kg N/ha. The authors located that the maximum dry weight of tuber per plant (21.08 g) was noted on application of 375 kg N/ha. However, all the levels of nitrogen except 75 kg N/ha were observed to be significantly superior over 0 kg N/ha, but were having at par effect on dry weight of tuber amongst themselves. The increase in dry matter percentage with nitrogen application might be due to the fact that higher doses of nitrogen might have helped in the production of photosynthesis, resulting in the accumulation of dry matter to be higher in the storage part i.e. tuber (Jha, *et al*., 2008). These results have been found to be in conformity with the findings of Sinha (2007) and Etemad and Sarajuoghi (2012). Banjare *et al*. (2014) observed that there was positively effect on tuber number in response to nitrogen fertilization. The authors explained that this positively effect could be attributed to an increase in stolon number through its effect on gibberellin biosynthesis in the potato plant. Similar findings were also reported by Yenagi *et al*. (2005) for number of tubers trait. Banjare *et al*. (2014) detected that the highest total tuber yield (24.13 kg/plot) was recorded in 225 kg N/ha. However, no significant difference was observed between the treatments 225 kg N/ha and other treatments viz., 150 kg N/ha, 300 kg N/ha and 375 kg N/ha for this attribute. Regassa *et al.* (2016) appeared that tuber yield was significantly affected by N levels. In this respect, Reiter *et al*. (2012) observed that substantial inorganic N fertilizer sources are necessary for optimal production. Banjare *et al*. (2014) observed that the highest unmarketable tuber yield was recorded with the lowest nitrogen level 0 kg N/ha, which was at par with 75 kg N/ha. Moreover, with increasing nitrogen application, number of stolon, number of tuber and consequently yield were increased (Zabihi, *et al*. 2010). Maiti *et al*. (2004) and Marguerite *et al*. (2006) revealed that tuber yield per unit area increased with increasing nitrogen fertilizer up to a suitable level only. Kandi *et al*. (2011) reported a reduced percent dry matter of potato tubers as nitrogen rates increased. Similarly, Assefa (2005) indicated that increasing rate of nitrogen application significantly decreased dry matter content of potato tuber. Other finding reported by Cucci and Lacolla (2007) that dry matter percentage increased shifting from the control to the application of 200 kg N ha^{-1} and decreased at the highest N level. On the contrary, Zelalem *et al.* (2009) indicated that nitrogen fertilization significantly reduced tuber dry matter content without affecting stem number, unmarketable tuber yield and number. The authors explained that this decreasing happened in tuber dry matter content may be associated with the influence of N on gibberellins biosynthesis and other phytohormonal activities which have direct influence on plant growth and dry matter accumulation. In this respect, Abdella *et al*. (1995) illustrated that high levels of endogenous GA delay or inhibit tuberization, and impede the accumulation of starch and protein (Vreugdenhil and Sergeeva, 1999).

The data of the interaction between sulphur levels and nitrogen levels are presented in Table (3). The data recorded during the first season showed that the interaction between sulfur levels and nitrogen levels was significant for most studied traits except for the number of tubers per plant (Table3). For the average tuber weight, the fertilization treatments number 2, 4, 6 and 8 significantly achieved the highest mean values without significant differences between them compared with the other tested fertilization treatments. The fertilization treatment No. 8 (300 kg S / Fed. + 200 kg N / Fed.) significantly gave the highest tuber yield per feddan followed by two fertilization treatments number 4 and 6 (without significant differences between them). Each of the following characters: No. of marketable tubers / plant (%) and marketable yield / plant (%) gave the highest mean values with the fertilization treatments number 4, 6 and 8; as shown in Table (3). With respect to tubers' dry matter percentage, it seemed from the data in Table (3) that the highest mean value was given with the fertilization treatments No. 7 without significant differences with the fertilization treatments No. 3, 5, 6 and 8.

For the results of the second season, the data in Table (3) showed that the fertilization treatment No. 8 gave the highest mean value for No. of tubers per plant trait without significant differences with the fertilization treatments No. 2, 4, 6 and 7. The data of the mean values for average tuber weight character showed that the fertilization treatments No. 4, 6 and 8significantly possessed the highest mean values. As shown in Table (3), the tabulated data cleared that the fertilization treatment No. 8 (300 kg S / Fed. + 200 kg N / Fed.) significantly gave the highest mean value for tuber yield / Fed. trait. For the two traits No. of marketable tubers / plant (%) and marketable yield / plant (%), the data showed that the fertilization treatments No. 4, 6 and 8 significantly gave the best results. The data of tubers' dry matter percentage showed that the fertilization treatments No. 7 gave the highest percentage without significant differences with the fertilization treatments No. 3, 5, 6 and 8 (Table, 3). Sud and Sharma (2002) reported that increase in potato yield with increasing sulphur rates may be assigned to its role in better partitioning of the photosynthates in the shoot and tubers. Sharma *et al*. (2011) and Lei *et al*. (2012) reported that nitrogen and sulphur applications can significantly affect the dry matter accumulation in tubers with their genetic material under their conditions.

Effect of sulphur and nitrogen fertilization levels and their interaction on potato tubers quality characteristics:

The data shown in Table (4) appeared that, the applied sulphur fertilization treatments had a significant effect on most of the studied quality characteristics. The highest glucose content was produced when 300 kg of sulphur / Fed was added to the soil without significant differences with the treatments zero and 100 kg sulphur / Fed. The highest significant content of fructose resulted when adding300 kg sulphur / Fed. The same finding was also found for total sugars content; where the highest significant content was given with the treatments 300 kg sulphur / fed. The three sulphur fertilization treatments (100, 200 and 300 kg sulphur / Fed.) significantly excelled the non-addition treatment (zero sulphur) for potato tubers protein content. Adding 100, 200 or 300 kg sulphur / Fed. significantly exceeded fat content compared with the non-addition treatment. Adding 200 kg sulphur / Fed. to the soil significantly gave the highest content for tubers crude fibers. Ash content found to be not affected with the tested sulphur fertilization treatments. The obtained results of Sharma *et al*. (2011) illustrated that each incremental dose of sulphur enhances the total sugars content in potato tuber up to 45 kg ha^{-1}. Further increase in sulphur dose recorded slight reduction in sugars content. There was no significant difference in sugars content of tuber at 15 and 30 kg ha^{-1}sulphur as well as 45 and 60 kg ha^{-1}.

Table 4: Mean values of potato quality characteristics as affected by sulphur and nitrogen levels and their interactions during the season of 2017.

Fertilization treatments	Glucose (%)	Fructose (%)	Total reducing sugars (%)	Protein (%)	Fat (%)	Crude fibers (%)	Ash (%)
				Sulfur effect			
Zero Kg Sulfur/Fed.	0.70 ab	0.25 b	0.95 b	12.40 b	2.52 b	4.50 c	5.28 a
100 Kg Sulfur /Fed.	0.70 ab	0.23 b	0.93 b	13.07 a	2.68 a	4.63 b	5.28 a
200 Kg Sulfur/Fed.	0.22 b	0.21 b	0.42 b	13.16 a	2.79 a	4.73 a	5.30 a
300 Kg Sulfur/Fed.	1.24 a	1.07 a	2.31 a	13.01 a	2.63 ab	4.57 bc	5.27 a
				Nitrogen effect			
100 Kg Nitrogen /Fed.	0.72 a	0.43 a	1.15 a	12.72 b	2.68 a	4.49 b	5.28 a
200 Kg Nitrogen/Fed.	0.72 a	0.44 a	1.16 a	13.10 a	2.63 a	4.73 a	5.28 a
				Nitrogen X Sulfur Interaction			
1) Zero S/Fed. X 100 Kg N/Fed.	0.93 abc	0.44 abc	1.37 abc	12.00 c	2.47 c	4.33 d	5.27 a
2) Zero S/Fed. X 200 Kg N/Fed.	0.47 bc	0.06 c	0.53 bc	12.80 b	2.57 bc	4.67 b	5.30 a
3) 100 S/Fed. X 100 Kg N/Fed.	0.39 bc	0.00 c	0.39 bc	13.10 ab	2.77 ab	4.60 bc	5.30 a
4) 100 S/Fed. X 200Kg N/Fed.	1.02 abc	0.46 abc	1.48 ab	13.03 b	2.60 bc	4.67 b	5.27 a
5) 200 S/Fed. X 100Kg N/Fed.	0.22 c	0.31abc	0.39 bc	12.86 b	2.83 a	4.54 bc	5.29 a
6) 200 S/Fed. X 200 Kg N/Fed.	0.21 c	0.10 bc	0.31 c	13.46 a	2.74 ab	4.92 a	5.30 a
7) 300 S/Fed. X 100 Kg N/Fed.	1.32 a	0.99 ab	2.31 a	12.91 b	2.63 abc	4.47 cd	5.27 a
8) 300 S/Fed. X 200 Kg N/Fed.	1.16 ab	1.15 a	2.31 a	13.10 ab	2.63 abc	4.67 b	5.27 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at p= 0.05 level of probability.

The data of Table (4) showed that tubers contents of glucose, fructose, total sugars, fat and ash did not significantly affect with the tested nitrogen fertilization treatments. On the other hand, each of protein and crude fibers significantly affected with the tested nitrogen treatments; where adding 200 kg N / Fed. gave the highest contents in this respect. In preliminary studies, Kara (2002) and Öztürk *et al.* (2010) reported the positive effects of nitrogen fertilization on protein content of potato tubers; where, the authors found that the protein contents of tubers significantly increased with increasing nitrogen dose.

The interaction between sulphur treatments and nitrogen treatments appeared to be significant for the studied tubers quality characteristics except for ash content (Table, 4). The data of glucose content showed that the fertilization treatment No. 7 gave the highest glucose content without significant differences with the treatments 1, 4 and 8. As for fructose content, the fertilization treatment No. 8 gave the highest level without significant differences with the fertilization treatments No. 1, 4, 5 and 7. The fertilization treatments No. 7 and 8 possessed the highest content for total sugars without significant effects with the fertilization treatments 1and 4. The highest tubers protein content was given with the fertilization treatment No. 6 without significant differences with the fertilization treatments No. 3 and 8. The fertilization treatment No. 5 gave the highest tubers fat content with no significant effects with the treatments No. 3, 6, 7 and 8. The data showed that the fertilization treatment No. 6 significantly gave the highest content for tubers crude fibers. The results of Singh *et al*. (2016) detected that reducing sugars percentage was found maximum and significantly higher with the treatment of 180 kg N + 50 kg S ha^{-1} as compared to all other tested treatments.

Effect of fertilization treatments and soaking treatments on sensory evaluations of processed potatoes:

1- Effect of fertilization treatments:

Table (5) showed that the high score of color was found with the treatment (zero S+200 kg N/Fed.) followed by the treatment 100 kg S+200 kg N/Fed., While for taste ,texture and odor they scored high values with the treatment 200 kg S+100 kg N/Fed.

Table 5: Effect of fertilization treatments on sensory evaluations of processed potatoes

Fertilization treatments	Sensory evaluation			
	Color	Taste	Texture	Odor
1) Zero S/Fed. X 100 Kg N/Fed.	7.47 cd	7.23 bc	7.23 b	7.5 a
2) Zero S/Fed. X 200 Kg N/Fed.	8.61 a	7.43 b	7.27 b	6.78 b
3) 100 S/Fed. X 100 Kg N/Fed.	7.34 d	6.63 ef	6.55 c	6.43 c
4) 100 S/Fed. X 200Kg N/Fed.	7.59 c	7.05 cd	7.33 b	6.93b
5) 200 S/Fed. X 100Kg N/Fed.	8.34 b	7.91 a	7.7 a	7.31 a
6) 200 S/Fed. X 200 Kg N/Fed.	7.46 cd	6.90 de	7.16 b	6.89 b
7) 300 S/Fed. X 100 Kg N/Fed.	6.85 e	6.93 d	6.71 c	6.43 c
8) 300 S/Fed. X 200 Kg N/Fed.	6.83 e	6.61 f	6.27 d	6.01 d

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at p= 0.05 level of probability.

2- Effect of soaking treatments:

As found in Table (6), soaking in acetic acid for 30 min had high score in color and texture, while soaking in salt + rosemary or salt + rosemary + acetic acid for 60 min had the highest score in taste and odor. Kita *et al*. (2004) examined the effect of soaking in solutions with different pH values and found a sour taste when either citric acid or acetic acid was used. Ismail *et al*. (2013) found that the acceptability of fried potatoes was not affected by the addition of fresh leaves as rosemary, bamboo, guava and olive leaves, which ensures good taste, texture, appearance, color, odor and generally suitability of fried potato.

Table 6: Effect of soaking treatments on sensory evaluations of processed potatoes

Soaking treatments	Sensory evaluation			
	Color	Taste	Texture	Odore
Without soaking	7.35 bc	6.99 bc	7.16 b	6.43 c
30 min salt+acetic acid	8.21 a	7.02 b	7.51 a	6.78 b
30 min salt+ rosemary	7.25 c	6.71 c	6.67 c	6.52 c
30 min salt+acetic acid + rosemary	7.54 b	6.86 bc	7.35 ab	7.06 a
60 min salt+ acetic acid	7.51 b	7.08 b	7.10 b	6.42 c
60 min salt+ rosemary	7.53 b	7.49 a	6.15 d	7.19 a
60 min salt+acetic acid + rosemary	7.55 b	7.43 a	7.25 b	7.09 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at p= 0.05 level of probability.

Effect of fertilization treatments on amino acid contents:

From Table (7), it was found that sulphur fertilizer had significant effect on amino acid contents in potato, by increasing level of sulphur fertilizer ,levels of amino acids as; Aspartic and alanine were significantly increased, while increasing sulphur caused a significant decrease in Glutamic, Glycine, Leucine, Phenylalanine, Lysine and cysteine. On the other hand as showed in Table (7), it was found that high level of nitrogen fertilizer (200 kg/Fed.) caused significant increase in most tested amino acids specially Aspartic, while it didn't effect on isoleucine, arginine and cysteine.

The increase levels in both sulphur and nitrogen fertilizations caused significant increase in Aspartic, Glutamic, Leucine and Proline, but it didn't have any effect on the other tested amino acids.

(De Wilde *et al*. 2006) reported that free asparagine content in potato tubers increases with increasing nitrogen fertilization since free asparagine is a nitrogen reservoir (Eppendorfer *et al*. 1996). An excess in nitrogen intake through fertilization leads to the biosynthesis of more free asparagine, thus decreasing the reducing sugars content since they are used by the tuber for the biosynthesis of amino acids (Kolbe, 1990). However, there are other factors that must be considered regarding potato farming, and other conditions, such as type of soil, will influence nutrient uptake and metabolism by the plant. The first procedure explains the direct formation of acrylamide from amino acids such as alanine, asparagine and glutamine and from methionine (Youssef *et al*., 2004). Lerner *et al*. (2006) also found a significant increase in amounts of Asparagine in wheat grains with higher nitrogen rates, which were attributed to an improved utilization. When non-addition of nitrogen fertilizer (0 kg N/ha) was compared with applying the highest level (220 kg N/ha), the AA in breads increased four-fold from 10.6 to 55.6 mg/kg.

Asparagine rates in fresh potatoes are typically between 2 and 4 g/kg. Concentrations of reducing sugars range between 0.1 and 3g/kg after harvesting and could reach 20g/kg after presently used storage at low temperature (Amrein *et al*., 2003).

Sulphur shortage caused principally strong decreases in concentrations of essential amino acids ascystine, methionine, lysine and leucine, respectively. Glutamic acid (glutamine) content was increased by sulphur deficiency, as reported by (Eppendorfer and Eggum, 1994a).

Effect of fertilization treatments and soaking treatments and their interactions on acrylamide contents in processed potatoes:

1- Effect of nitrogen treatments:

From figure (1) it was noticed that levels of acrylamide were significantly increased by increasing nitrogen fertilizer treatments from 100 up to 200 kg N/Fed. It increased from 951.554 to 1487.596 ug/100g (by 56.33%).

Table 7: Effect of fertilization treatments on amino acid contents of processed potatoes

Fertilization treatments	Aspartic (mg/100 gm)	Threonine (mg/100 gm)	Glutamic (mg/100 gm)	Glycine (mg/100 gm)	Alanine (mg/100 gm)	Isoleucine (mg/100 gm)	Leucine (mg/100 gm)	Lysine (mg/100 gm)	Cysteine (mg/100 gm)	Arginine (mg/100 gm)	Phenylalanine (mg/100gm)	Proline (mg/100 gm)
Sulfur effect												
Sulfur 0 Kg	1.418 d	0.353 a	1.842 a	0.360 c	0.395 d	0.412 a	0.520 c	0.603 a	0.185 ab	0.380 a	0.432 b	0.543 b
Sulfur 100 Kg	1.783 c	0.360 a	1.615 b	0.375 bc	0.445 c	0.393 a	0.630 ab	0.575 b	0.167 b	0.372 a	0.447 ab	0.627 a
Sulfur 200 Kg	1.911 b	0.377 a	1.542 b	0.415 a	0.500 b	0.397 a	0.678 a	0.583 ab	0.202 a	0.375 a	0.468 a	0.628 a
Sulfur 300 Kg	2.118 a	0.372 a	1.285 c	0.388 b	0.525 a	0.372 a	0.603 c	0.558 b	0.177 ab	0.382 a	0.452 ab	0.602 a
Nitrogen effect												
Nitrogen 100 Kg	1.629 b	0.344 b	1.460 b	0.369 b	0.438 b	0.392 a	0.588 b	0.559 b	0.184 a	0.359 a	0.428 b	0.581 b
Nitrogen 200 Kg	1.987 a	0.387 a	1.682 a	0.400 a	0.494 a	0.395 a	0.628 a	0.601 a	0.181 a	0.359 a	0.471 a	0.619 a
Nitrogen X Sulfur Interaction												
S 0 X N 100 Kg	1.250 f	0.350 a	1.827 a	0.353 a	0.400 a	0.440 a	0.510 c	0.583 a	0.170 a	0.367 a	0.417 a	0.557 de
S 0 X N 200 Kg	1.587 e	0.357 a	1.857 a	0.367 a	0.390 a	0.383 abc	0.530 c	0.623 a	0.200 a	0.393 a	0.447 a	0.530 e
S 100 X N 100 Kg	1.69 de	0.350 a	1.613 b	0.373 a	0.420 a	0.407 abc	0.613 b	0.580 a	0.180 a	0.377 a	0.450 a	0.570 cde
S 100 X N 200Kg	1.877 c	0.370 a	1.617 b	0.377 a	0.470 a	0.380 bc	0.647 b	0.570 a	0.153 a	0.367 a	0.443 a	0.683 a
S 200 X N 100Kg	1.713 d	0.337 a	1.223 d	0.387 a	0.457 a	0.370 bc	0.627 b	0.537 a	0.230 a	0.343 a	0.430 a	0.613 bcd
S 200 X N 200 Kg	2.110 b	0.417 a	1.860 a	0.443 a	0.543 a	0.423 ab	0.730 a	0.630 a	0.173 a	0.407 a	0.507 a	0.643 ab
S 300 X N 100 Kg	1.863 c	0.340 a	1.177 d	0.363 a	0.477 a	0.350 c	0.603 b	0.537 a	0.157 a	0.350 a	0.417 a	0.583 cde
S 300 X N 200 Kg	2.373 a	0.403 a	1.393 c	0.413 a	0.573 a	0.393 abc	0.603 b	0.580 a	0.197 a	0.413 a	0.487 a	0.620 bc

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using least significant differences test procedure (L.S.D) at p= 0.05 level of probability.

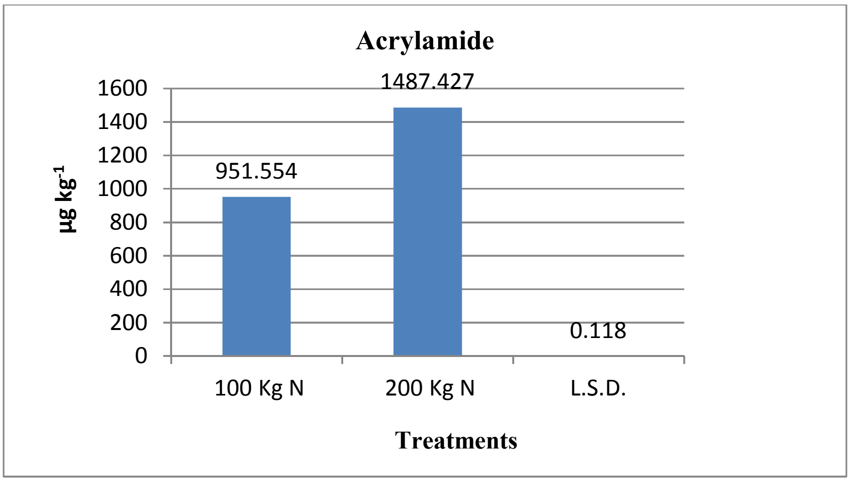

Fig. 1: Effect of nitrogen treatments on acrylamide contents in processed potatoes

2- Effect of sulphur treatments:

Figure (2) showed that level of acrylamide was high in zero kg S treatment but it was lower than the high treatment (300 kg S/Fed.). Also it was noticed that by increasing sulphur treatments from 100 kg up to 300 kg S/Fed., the level of acrylamide significantly increased from 319.078 to 1978.596 ug/100g (by 520%).

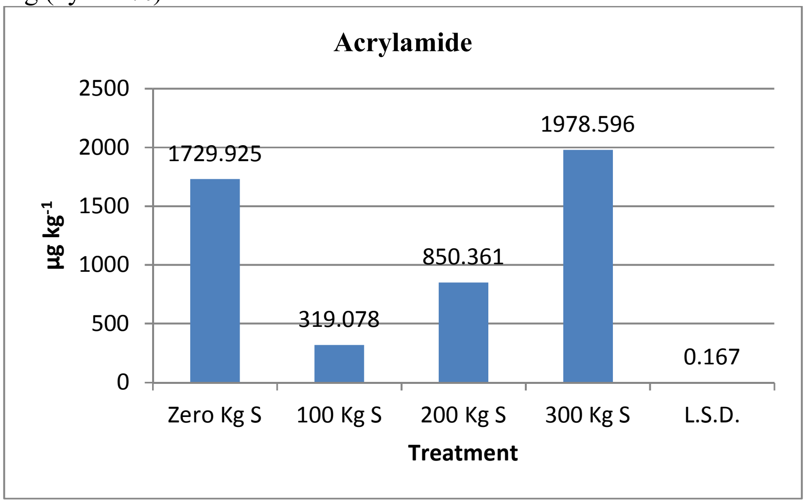

Fig. 2: Effect of sulphur treatments on acrylamide contents in processed potatoes

3- Effect of interaction between sulphur and nitrogen fertilization treatments:

From figure (3) it was found that high acrylamide level was found with 200 kg N and zero S/Fed. Also it was noticed that by increasing sulphur fertilizer with low nitrogen treatment, levels of acrylamide were significantly increased, but it still lower than high nitrogen treatment and zero sulphur, while present of sulphur in low level with high nitrogen level significantly decreased level of acrylamide than high nitrogen treatment alone .Although acrylamide levels was increased by increasing suphur but it still lower than high nitrogen treatment alone.

It was reported that fertilization strategies influence the composition of potato tubers. Kumar *et al*. (2004) suggested that, nitrogen seems to be indirectly related through its effects on dry matter and relative maturity of harvested tubers. Plants with suitable nitrogen fertilization produce tubers with lower reducing sugars concentration at harvest and accumulate less reducing sugars during storage. De Wilde *et al*. (2006) also found that, free asparagine content in potato tubers increases with increasing nitrogen fertilization. Eppendorf (1996) and Kolbe (1990) explained that because free asparagine is a nitrogen reservoir, an excess in nitrogen intake by fertilization leads to the biosynthesis of more free-asparagine.

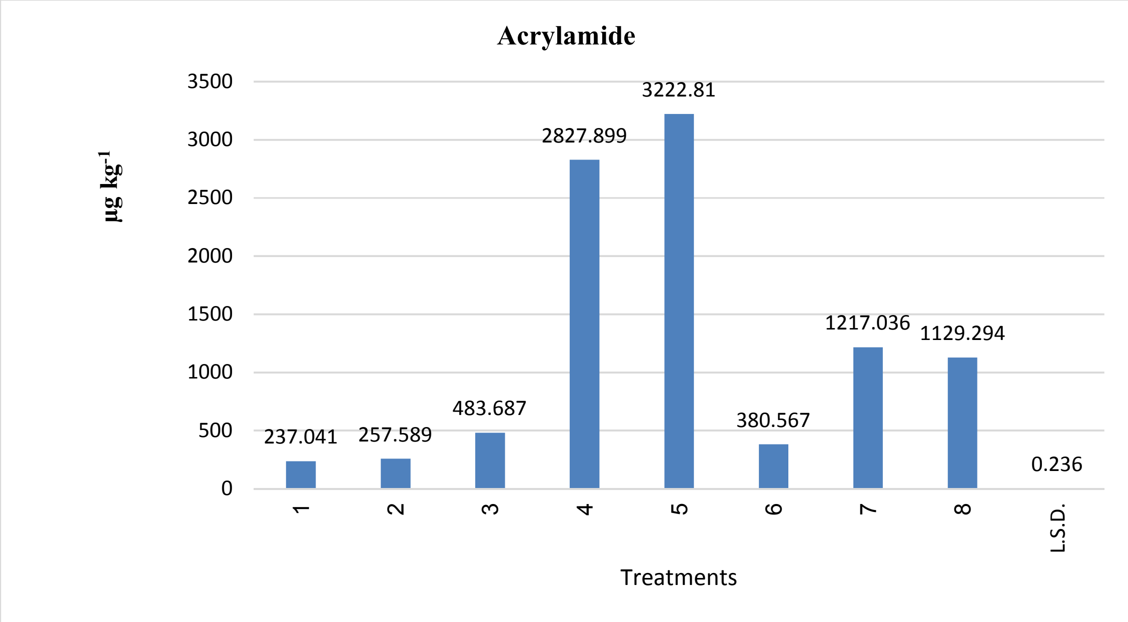

Fig. 3: Effect of interaction between sulphur and nitrogen fertilization treatments on acrylamide contents in processed potatoes

1	100Kg N + zero kg S	**5**	200Kg N + zero Kg S
2	100Kg N + 100 Kg S	**6**	200Kg N + 100 Kg S
3	100Kg N + 200 Kg S	**7**	200Kg N + 200 Kg S
4	100Kg N + 300 Kg S	**8**	200 Kg N + 300 Kg S

The result of this study agreed with the result of De Wilde *et al*. (2006) who verified that Nitrogen fertilization positively motivated acrylamide formation in potato products. Excess nitrogen in soil and deficiencies in potassium, sulphur, phosphorus or magnesium can cause asparagine levels to rise in wheat and potato and increase acrylamide risk (Halford, 2007). The author also suggested that increasing sulfur levels in the soil and declining nitrogen availability in crops can decrease levels of asparagine which an acrylamide precursor.

4- Effect of soaking treatments

As shown in figure (4) it was found that soaking time had an effect on acrylamide levels, where soaking for 1 hour caused significant decrease in acrylamide level than soaking for 1/2 h or without soaking which had the highest level of acrylamide (4200.703 µg/100gm).The lowest level of acrylamide was found with soaking in aceti acid and rosemary for 1 hour (44.083 µg/100gm). Pedreschi *et al.* (2004) established that the reduction in glucose sugar level for 40 min. and 90 min. soaking was found to be 25% and 32%; respectively as related to the control treatment (without soaking). The authors suggested that reducing sugars in fried potatoes can be dropped by soaking in water before frying.

Also, it was revealed that lowering the pH by supplementation of organic acids in the food system to reduce acrylamide creation may assign protonating of-amino group of asparagine, which consequently cannot engage in nucleophilic addition reactions with carbonyl sources (Jung *et al.*, 2003). Potato slices immersed in citric acid solution (1-2%) for 1 hour resulted in a significant decrease (>70%) in acrylamide after frying at190°C for 6.5min.). Kita *et al*. (2004) assessed the effect of soaking in solutions with different pH values on the formation of acrylamide in slice potato chips. The authors detected that soaking potato slices in acid solutions was efficient, with the greatest reduction in acrylamide (90%) occurring in acetic acid solutions for 60 min. at 20 °C. Becalski *et al.* (2002) also found that acrylamide might be reduced when adding rosemary herb to the oil used for frying potato slices. Rosemary is known for its antioxidant content, but this effect might also be a result of many other factors. The results of El-Shawaf *et al*. (2014) indicated that natural antioxidants could reduce the acrylamide content generated in fried potato chips meantime keeping accepted product by well-chosen of concentrations degrees in order not to have inadmissible product.

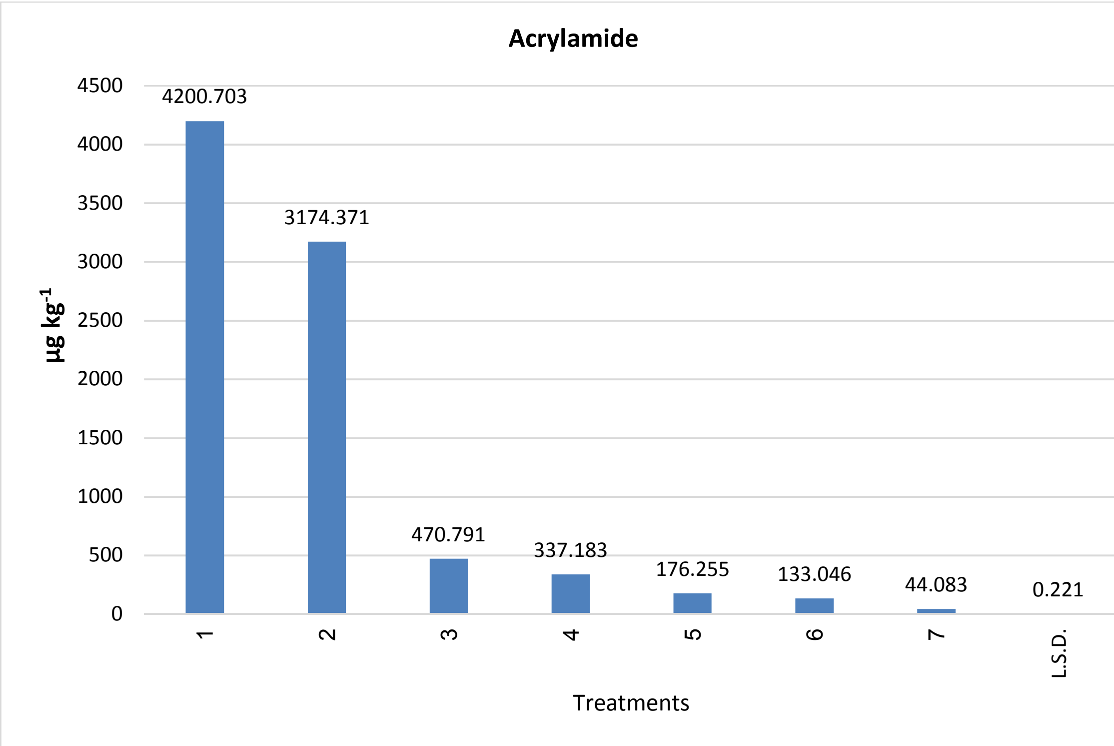

Fig.4: Effect of soaking treatments on acrylamide contents in processed potato

1	Without soaking	**4**	30min salt + acetic acid + rose mary
2	30min salt + acetic acid	**5**	60min salt + acetic acid
3	30min salt + rose mary	**6**	60min salt + rose mary
7	60 min salt + acetic acid + rose mary		

5-Effect of interaction between fertilization treatments and soaking treatments on acrylamide levels:

Figure (5) clears that high nitrogen fertilization treatment (200 kg N/Fed.) caused increase in acrylamide level with all soaking treatments than low nitrogen fertilization treatment (100 kg N/Fed.). It was also noticed that by increasing soaking time level of acrylamide decreasing in both nitrogen fertilization treatments. The highest level of acrylamide found without soaking and the lowest level noticed with soaking for 60min in salt+ acetic acid and rosemary.

Figure (5)shows that, with zero sulphur fertilization treatment it was found that long time of soaking caused decrease in acrylamide level ,while increase sulphur fertilization from 100 kg to 300 kg S/Fed. caused increase in acrylamide level from 559.535µg/100gm to 7982.880 µg/100gm .The highest level of acrylamide showed with 300 kg S/Fed. without soaking while the lowest level found with 300kg S/Fed and soaking for 60min in salt + acetic acid + rosemary. Generally; it was found that by increasing soaking time with all fertilization treatments, level of acrylamide was decrease, respectively. The best treatment for decreasing the acrylamide formation to its minimum level (zero acrylamide) appeared to fertilize growing potato plants with 100 kg S/Fed. +100 kg N/Fed. Followed by soaking the potato slices before frying in a solution composed of salt + acetic acid + rosemary for 60 min. (Fig. 5).

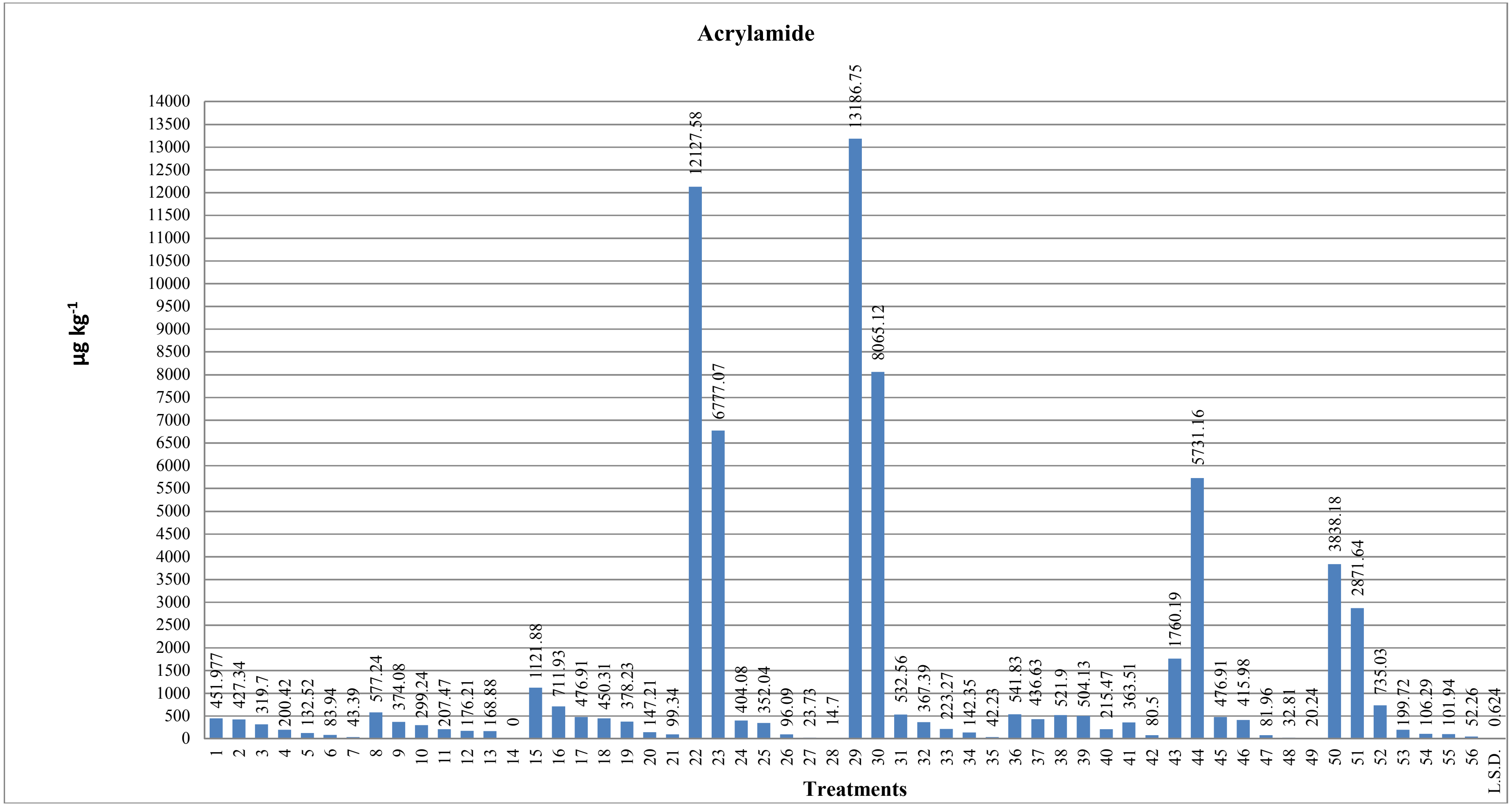

Fig. 5: Effect of interaction between fertilization treatments and soaking treatments on acrylamide contents in processed potato

1	100 Kg N + Zero Kg S + Without soaking
2	100 Kg N + Zero Kg S + 1/2 h acetic acid
3	100 Kg N + Zero Kg S + 1/2 h rose mary
4	100 Kg N + Zero Kg S + 1/2 h acetic acid + rose mary
5	100 Kg N + Zero Kg S + 1 h acetic acid
6	100 Kg N + Zero Kg S + 1 h rose mary
7	100 Kg N + Zero Kg S + 1 h acetic acid + rose mary
8	Without soaking 100 Kg N + 100 Kg S +
9	100 Kg N + 100 Kg S + 1/2 h acetic acid
10	100 Kg N +100 Kg S + 1/2 h rose mary
11	100 Kg N +100 Kg S + 1/2 h acetic acid + rose mary
12	100 Kg N +100 Kg S + 1 h acetic acid
13	100 Kg N +100 Kg S + 1 h rose mary
14	100 Kg N +100 Kg S + 1 h acetic acid + rose mary
15	Without soaking 100 Kg N + 200 Kg S +
16	100 Kg N + 200 Kg S + 1/2 h acetic acid
17	100 Kg N + 200 Kg S + 1/2 h rose mary
18	100 Kg N + 200 Kg S + 1/2 h acetic acid + rose mary
19	100 Kg N + 200 Kg S + 1 h acetic acid
20	100 Kg N + 200 Kg S + 1 h rose mary
21	100 Kg N + 200 Kg S + 1 h acetic acid + rose mary
22	Without soaking 100 Kg N + 300 Kg S +
23	100 Kg N + 300 Kg S + 1/2 h acetic acid
24	100 Kg N + 300 Kg S + 1/2 h rose mary
25	100 Kg N + 300 Kg S + 1/2 h acetic acid + rose mary
26	100 Kg N + 300 Kg S + 1 h acetic acid
27	100 Kg N + 300 Kg S + 1 h rose mary
28	100 Kg N + 300 Kg S + 1 h acetic acid + rose mary
29	200 Kg N + Zero Kg S + Without soaking
30	200 Kg N + Zero Kg S + 1/2 h acetic acid
31	200 Kg N + Zero Kg S + 1/2 h rose mary
32	200 Kg N + Zero Kg S + 1/2 h acetic acid + rose mary
33	200 Kg N + Zero Kg S + 1 h acetic acid
34	200 Kg N + Zero Kg S + 1 h rose mary
35	200 Kg N + Zero Kg S + 1 h acetic acid + rose mary
36	Without soaking 200 Kg N + 100 Kg S +
37	200 Kg N + 100 Kg S + 1/2 h acetic acid
38	200 Kg N +100 Kg S + 1/2 h rose mary
39	200 Kg N +100 Kg S + 1/2 h acetic acid + rose mary
40	200 Kg N +100 Kg S + 1 h acetic acid
41	200 Kg N +100 Kg S + 1 h rose mary
42	200 Kg N +100 Kg S + 1 h acetic acid + rose mary
43	Without soaking 200 Kg N + 200 Kg S +
44	200 Kg N + 200 Kg S + 1/2 h acetic acid
45	200 Kg N + 200 Kg S + 1/2 h rose mary
46	200 Kg N + 200 Kg S + 1/2 h acetic acid + rose mary
47	200 Kg N + 200 Kg S + 1 h acetic acid
48	200 Kg N + 200 Kg S + 1 h rose mary
49	200 Kg N + 200 Kg S + 1 h acetic acid + rose mary
50	Without soaking 200 Kg N + 300 Kg S +
51	200 Kg N + 300 Kg S + 1/2 h acetic acid
52	200 Kg N + 300 Kg S + 1/2 h rose mary
53	200 Kg N + 300 Kg S + 1/2 h acetic acid + rose mary
54	200 Kg N + 300 Kg S + 1 h acetic acid
55	200 Kg N + 300 Kg S + 1 h rose mary
56	200 Kg N + 300 Kg S + 1 h acetic acid + rose mary

Conclusion

Different sulphur and nitrogen levels and their interaction have sound and promising impact on potato plants growth, yield and tubers' quality. Therefore, it is indicative that potato yield and its component characters can be improved with application of the adequate amounts of sulphur and nitrogen fertilizers. Each of fertilization treatments (sulfur and nitrogen fertilizers) and following some pre-treatments (soaking potato slices in acetic acid and / or rosemary) before frying have clear effects on the quality of potato chips processed especially on its acrylamide content. The acrylamide content can be reduced by soaking potato slices in a solution of salt + rosemary powder + acetic acid for 60 min. before frying. Potato productivity could be maximized by fertilizing the growing potato plants with 300 kg sulfur/Fed. + 200 kg nitrogen /Fed. At the same time, acrylamide percentage formed in the fries could be reduced to very low rates through soaking potato chips before frying for 60 min. in a solution composed of salt + acetic acid + rosemary.

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