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Influence of Organic Fertilizers and Urea-Formaldehyde on Potato Crop and Evaluation of Pre-Frying Treatments on Acrylamide Levels in Potato Chips

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ABSTRACT: This research aimed to assess the influence of organic fertilizers and urea-formaldehyde, a slow-release fertilizer, on potato crop, along with the impact of pre-frying treatments on acrylamide levels in potato chips. Two field experiments were carried out during the two summer seasons of 2022/2023 and 2023/2024 in ShoubraKheet town, situated in Beheira Governorate, Egypt. The experiment was carried out in a split-plot design with three replicates. Three sources of organic fertilizers were randomly arranged in the main plots; whereas, four nitrogen fertilization treatments were randomly distributed in the sub plots. Most of the vegetative traits, yield trait and its component characters, and potato quality characteristics studied were significantly affected by the additions of organic fertilizers, varying nitrogen fertilization rates, and their interaction. Involving 10 m³ of farmyard manure plus 10 m³ of vermicompost together with 180 units of nitrogen per feddan, delivered in form of urea-formaldehyde resulted in the highest total tuber yield across both seasons. The findings indicated that 20 % of the nitrogen added per feddan could be saved without adverse effects on total potato yield. This was achieved through adding a mixture of both farmyard manure and vermicompost each at a rate of 10 m³, along with adding of 144 units of nitrogen per feddan in the form of urea formaldehyde. Additionally, soaking potato slices prior to frying for 30 minutes in an aqueous solution containing 5 g/l of salt and 10 g/l of lysine followed by frying in oil containing 1 gram of olive leaves significantly decreased acrylamide contents in potato chips compared to other pre-frying treatments evaluated.

Keywords: ***:*** *potato, tuber yield, Organic fertilizer, urea-formaldehyde, slow-release fertilizer, soaking treatments, acrylamide.*

INTRODUCTION

Potato (*Solanum tuberosum*, L.) is a member of the Solanaceae family and is considered one of the most important crops worldwide. Potato is widely consumed by millions of people across diverse cultures and serves as a staple food in many developing countries. According to FAO, global potato production reached 383,082,607.38 tons grown on an area of 16,799,108 hectares (**FAO, 2023**). The total potato production in Egypt amounts to 6,869,330.96 tons from an area of 235,625 hectares, with an average yield of 29.15 tons ha^{-1}. Egypt is the tenth largest producer of potatoes and ranks first in Africa in terms of potato production (**FAO, 2023**).

Nitrogen is frequently the primary limiting nutrient in most plants. So, cropping systems focus on effective nitrogen management to optimize yields. Furthermore, nitrogen is typically found in higher amounts than any other mineral nutrient in most plants. Nitrogen is the most widely used nutrient in potato production compared to other nutrients. Potato crops require a relatively high amount of nitrogen because it is an essential nutrient for growth (**Muleta and Aga, 2019**). Proper nitrogen fertilization is critical for achieving high potato production and improving tuber quality. Nitrogen significantly affects growth parameters, resulting in positive growth. In potatoes, the balance between vegetative growth and reproductive processes largely depends on adequate nitrogen supply. Potato tuber quality and yield are affected by nitrogen fertilization. In general, nitrogen deficiency results in low sugars and dry matter contents, while excess nitrogen levels enhance vegetative growth and retard tuber development. Effective nitrogen management is essential for building leaf areas that can absorb sunlight for photosynthesis, thus maximizing potato yield. In addition, proper spacing and nutrient management are important to ensure high-quality tubers (**Abewoy, 2024**).

Nowadays, there is a gradual and noticeable decline in the content of organic matter in Egyptian soils, which has an adverse impact on crop productivity and quality. This coincides with a significant increase in the prices of inorganic fertilizers. Nevertheless, farmers can access to more affordable organic fertilizers, such as farmyard manure and vermicompost which are available at significantly lower costs compared to their inorganic fertilizers. The shortage of mineral fertilizers has led to the trend towards implementing nutrient and energy cycling while improving the soil's water and nutrient holding capacity. Low-cost organic fertilizers are crucial for preserving and enhancing soil health (**Choudhary** *et al***., 2022**). As illustrated by **Zhang** *et al***. (2020)**, these organic fertilizers have a useful role in modifiable soil pH and improving plant growth, since they facilitate the absorption of macro and micronutrients. Vermicomposting is a bio-oxidation process that involves earthworms, microbes and other biodegradable communities to accelerate the decomposition of organic waste (**Patwa** *et al***., 2020**). The final product, vermicompost, has numerous beneficial effects on soil, including improving its physical, chemical and biological properties, and can successfully enhance sustainable agriculture (**Das** *et al***., 2019**).

Slow-release nitrogen (SRN) can be measured and is defined as the portion of nitrogen in a fertilizer that is gradually released into the soil. Soil properties such as pH, moisture, and temperature are the three main determinants of SRN. By incorporating urea into chemical reactions, SRN fertilizers create bound urea products that decompose slowly and release nitrogen from the soil (**Hojjatie, 2021**). The use of CRFs increased crop yield, the level of NO_3^{-}‾N in the petioles and total nitrogen content in the plant. Controlled-release fertilizers were also shown to reduce nitrogen losses, which improves nitrogen use efficiency and reduces environmental damage, as explained by **Li** *et al.* **(2023)**. Adopting this method in agriculture improved crop yield and quality, surpassing other soluble nitrogen fertilizers. Reducing the nitrogen losses caused by nitrogen fertilizers is essential. Slow-release nitrogen fertilizers (SRNF), which release small amounts of nitrogen at the time of crop need, provide a promising solution to this challenge and improve nitrogen efficiency by reducing losses (**Bahar** *et al***., 2019**). Many environmental problems, such as groundwater pollution, air pollution, and soil degradation, are largely due to the loss of nutrients in fertilizers, which account for 30% to 50% of total food production (**Guan** *et al***., 2023** and **Marchuk** *et al***., 2023**). To address these challenges, slow-release fertilizers have been used, focusing on several points: improving fertilizer use efficiency, reducing application rates, ensuring timely delivery of nutrients to plants during different growth stages, and mitigating environmental problems (**Banik** *et al***., 2023**). Urea-formaldehyde is one of the most commonly used organic nitrogen compounds in slow-release fertilizers (**Liu** *et al***., 2020**). **Guo** *et al.* **(2023)** emphasized that urea-formaldehyde fertilizer is an environmentally sustainable fertilizer. Such fertilizers are characterized by superior physical attributes, fast nutrient release, and play a role in improving soil structure while enhancing root permeability and penetration power of roots. Additionally, **Yamamoto** *et al.* **(2016)** demonstrated that these fertilizers are capable of achieving nitrogen release efficiencies exceeding 50%, both in rapid and long-term usages.

In 2022, Swedish food scientists identified the acrylamide (C3H5NO) in fried and baked foods. These scientists considered it a probable carcinogen. Consequently, Swedish National Food Administration (SNFA) informed the presence of acrylamide in a wide range of food products, raising worries among both food scientists and consumers alike. The following items are considered the most common sources of acrylamide: French fries, roasted coffee beans, and baked goods, which are considered the most important sources of its presence (**EFSA, 2015**). Acrylamide is believed to be formed in foods through the reaction of asparagine, an amino acid, with carbonyl-containing compounds, such as reducing sugars, under conditions of high temperature and low humidity. This process involves the formation of a Schiff base, followed by decarboxylation and removal of the imine. This mechanism has been validated through isotopic substitution studies (**Nguyen** *et al***., 2022**).

This research aims to improve potato yield and quality by identifying the optimal combination of organic fertilizer sources and urea-formaldehyde levels, with a focus on environmentally friendly fertilizer options. The research also aims to upgrade the quality of processed potatoes by lessening acrylamide content in fried potato chips. This is achieved through pre-frying treatments, including soaking potato chips in aqueous solutions containing salt, lysine acid, or both, and frying them in oil containing olive leaves.

MATERIALS AND METHODS

Experimental site

A two-year field experiment was carried out consecutively for two summer seasons of 2022/2023 and 2023/2024 on a farmer's field situated in Shoubra khet town, Beheira governorate, Egypt. The soil texture was classified as clay loam, with an organic matter of 2.39 %, a pH of 8.1 and EC of 0.332 ds/m. The available nutrient concentrations (N, P and K) = 9.6, 15.6 and 300 mg / kg, respectively.

Experimental design and treatments

Certified Diamant potato seeds were planted on December 17th in both growing seasons. Tuber seeds were planted in rows, 75 cm apart, 9 m long and at spacing of 25 cm within rows. Each experimental unit consisted of four rows covering an area of 27 m^2, giving a total of 72 planting hills per plot, and 22,400 plants per feddan (where one feddan [fed.] equals 4,200 m^2). The potato crop was harvested 130 days after planting.

The experiment was designed as a split plot with three replicates to evaluate the effects of organic fertilizer sources, urea formaldehyde, and their interactions on potato plant growth, tuber yield, and the acrylamide content of processed potatoes. Organic fertilizer treatments were allocated to the main plots; whereas, nitrogen fertilizer treatments were assigned to the subplots. The experimental treatments comprised three organic fertilizers sources: (1) farm yard manure (FYM) at 20 m^3 $fed.^{-1}$, which applied by the potato farmers (2) vermicompost (VC) at 20 m^3 $fed.^{-1}$, and (3) a combination of FYM (10 m^3 $fed.^{-1}$) and VC (10 m^3 $fed.^{-1}$). Additionally, four nitrogen fertilization treatments were applied: the recommended nitrogen dose (RND) at 180 Kg N unit $fed.^{-1}$) in the form of Ammonium sulfate (20.5% N) and three levels of nitrogen in the form of urea formaldehyde as a slow-release nitrogen fertilizer (40 % N): UF1 (180 Kg N unit $fed.^{-1}$), UF2 (144 Kg N unit $fed.^{-1}$), and UF3 (108 Kg N unit $fed.^{-1}$). The urea formaldehyde fertilizer was produced by the General Authority for Agricultural Balance Fund (GAABF) at the Agricultural Research Center (ARC), Egypt under the trade name (Enciabein 40% N). It was applied during soil preparation as a slow-release nitrogen source. The recommended nitrogen dose was supplied in four split applications as ammonium sulfate (20.5% N). One-quarter of the nitrogen units were added during soil preparation, while the remaining quantity was added in three subsequent applications: at planting, and 40 and 70 days after planting.

Data collection

Measurements

Vegetative growth traits were assessed using ten randomly selected whole plant samples from each experimental unit, 90 days after planting. The measurements included plant height (cm), number of main branches, and fresh foliage weight (g).

Yield parameters were determined as follows: total tuber yield (ton / feddan) was calculated based on the plot area and subsequently attributed to the feddan. Number of tubers per plant was determined by averaging the total tuber count recorded within each plot area. Average tuber weight (g) was derived by dividing the total tuber yield of the plot by the corresponding number of tubers.

Tuber quality characteristics were recorded during the second study season. The traits were evaluated using random samples of 10 tubers per treatment. The percentage of tuber dry matter was determined by weighing a specific amount of fresh tubers, drying them, and then calculating the ratio of the sample's weight after drying to their initial fresh weight b, multiplied by 100. To evaluate the reducing sugars percentage (glucose and fructose), a 5-gram sample of fresh tuber was analyzed using the methodology outlined by (**Malik and Singh, 1980**). Additionally, aspartic acid content (mg/100 mg) was performed based on the procedures provided by **AOAC (2012)**.

Evaluation of acrylamide in potato chips processed

Potato crops subjected to three different fertilizer treatments, characterized by tubers with elevated levels of reducing sugars and aspartic acid, were picked to determine the acrylamide content in fried chips. During the 2023/2024 growing season, tubers from these treatments were combined, washed under running water, hand- peeled to remove the outer skin, and sliced to a uniform thickness of 1.5 ± 0.5 mm using a turning blade.

Pre-frying treatments:

Four different treatments were applied to potato slices prior to frying:

- The first treatment (T1) involved soaking the slices in 1 liter of water containing 5 grams of salt for 30 minutes.
- The second treatment (T2) involved soaking the slices in 1 liter of water containing 5 grams of salt for 30 minutes, afterward; the slices were fried in oil infused with 1 gram of olive leaves.
- The third treatment (T3) involved soaking the slices in 1 liter of water containing 5 grams of salt and 10 grams of lysine acid for 30 minutes.
- The fourth treatment (T4) involved soaking the slices in 1 liter of water containing 5 grams of salt and 10 grams of lysine acid for 30 minutes, afterward, the slices were fried in oil infused with 1 gram of olive leaves.

Acrylamide analysis was conducted to determine the acrylamide content in potato chips (mg/ kg) using the HPLC method as outlined by **Khoshnam** *et al*. **(2010)**.

Statistical data analysis

Data were subjected to the proper methods of statistical analysis of variance (ANOVA) appropriate to the split-plot system in Microsoft Excel. Critical difference ($CD_{0.05}$) was calculated using Least Significant Differences test (L.S.D.) procedure at $p \leq 0.05$ level of probability to compare treatment means. **CoState** Software (version 6.400, **2004)** was used for performing the mentioned statistical analysis.

RESULTS AND DISCUSSION

Vegetative growth characters of potato

Over a two-year study, the findings regarding the studied vegetative growth traits of potato plants, specifically plant height (cm), number of main branches/plant and fresh foliage weight (g), revealed significant effects from the application of different organic fertilizer sources at a 0.05 significance level of probability (Table, 1). Notably, the application of a combined mixture consisting of 10 m^3 of farm yard manure and 10 m^3 of vermicompost had a substantially greater impact on enhancing the vegetative growth of potato plants compared to the use of either farm yard manure or vermicompost alone. Regarding the influence of nitrogen fertilizer rates, the various levels tested generally showed significant effects on most of the vegetative traits studied, with the exception of fresh foliage weight trait during the second season of the experiment. The findings indicated that the highest performance was achieved with the application of 180 kg N / feddan as urea formaldehyde, followed closely by the treatment using 180 kg N / feddan as soluble nitrogen fertilizers. The combinations between organic manure sources and nitrogen fertilization treatments showed that applying 10 m^3 farm yard manure + 10 m^3 vermicompost combined with 180 kg soluble N / feddan or 180 kg N / feddan as urea formaldehyde resulted in the highest mean values for vegetative treats across both seasons of the study (Table, 1).

The findings from the two study seasons of this experiment indicate that the vegetative traits, such as plant height (cm), number of main branches, and fresh foliage weight (g), which are essential for achieving high potato yields, can be effectively stimulated by applying a specific fertilization approach. This involves applying a mixture of organic fertilizers comprising 10 m^3 of farm yard manure + 10 m^3 of vermicompost, supplemented with 180 units of N per feddan in the form of urea-formaldehyde fertilizer, applied once during soil preparation for planting. The results of **Ahmed** *et al*. **(2015)** showed that adding farm yard manure up to 20 m^3 $fed.^{-1}$ positively enhanced the vegetative traits of the growing potato plants. The results of **Hensh** *et al*. **(2020)** and **Malla** *et al*. **(2021)** revealed that plant height of potato plants has been influenced by the different treatments of vermicompost. Vermicompost enhances vegetative growth as well as the chemical composition of potato leaves because it contains essential nutrients, hormones related to plant growth, and beneficial microbes **El-Metwaly** *et al*. **(2024)**. **Rehman** *et al*. **(2023)** indicated that the use of vermicompost improves the absorption of nutrients, which enhances soil health and crop productivity, so vermicompost is an effective stimulant for plant growth. **Saif El-Deen** *et al*. **(2015)** illustrated that application of slow release nitrogen fertilizers rates gave rise to significant increases in the vegetative growth characters of sweet potato.

Table (1). Averages of the studied vegetative growth characters of potato as affected by organic manure additions, nitrogen fertilization rates and their combinations during the two study seasons.

Treatments	2022/2023			2023/2024		
	Plant height (cm)	No. of main branches / plant	fresh foliage weight (g)	Plant height (cm)	No. of main branches / plant	fresh foliage weight (g)
Main effect of organic manure additions (A)						
20 m³ FYM	51.18	11.45	277.70	54.89	11.66	249.06
20 m³ VC	51.68	11.94	285.30	56.50	11.86	249.17
10 m³ FYM + 10 m³ VC	52.63	12.27	306.40	58.45	12.12	258.22
SEm (±)	3.90	1.49	40.52	7.99	1.37	33.20
L.S.D. (5%)	0.85	0.67	3.90	1.70	0.24	4.57
Main effect of nitrogen fertilizer rates (B)						
180 kg N fed.$^{-1}$ as soluble N	52.87	12.29	303.90	58.99	12.23	255.01
180 kg N fed.$^{-1}$ as urea formaldehyde (UF1)	53.03	12.38	306.99	60.7	12.37	255.85
144 kg N fed.$^{-1}$ as urea formaldehyde (UF2)	51.13	11.66	283.1	55.43	11.69	250.04
108 kg N fed.$^{-1}$ as urea formaldehyde (UF3)	50.27	11.22	265.2	51.33	11.22	247.7
SEm (±)	3.39	1.34	32.84	4.23	1.05	32.00
L.S.D. (5%)	1.93	0.64	12.30	1.46	0.23	NS
Fertilization treatments (A + B)						
20 m³ FYM + Soluble N (FT1)	52.10	11.80	288.40	57.37	12.07	251.80
20 m³ FYM + UF1 (FT2)	52.10	11.87	288.40	58.00	12.13	252.56
20 m³ FYM + UF2 (FT3)	50.37	11.60	272.97	53.87	11.47	247.22
20 m³ FYM + UF3 (FT4)	50.13	10.53	260.43	50.33	10.97	244.67
20 m³ VC + Soluble N (FT5)	52.50	12.27	296.60	58.00	12.20	251.89
20 m³ VC + UF1 (FT6)	52.90	12.33	292.70	61.40	12.30	252.67
20 m³ VC+ UF2 (FT7)	50.97	11.63	287.97	55.27	11.67	246.78
20 m³ VC + UF3 (FT8)	50.33	11.53	263.70	51.33	11.43	245.33
10 m³ FYM + 10 m³ VC + Soluble N (FT9)	54.00	12.80	326.70	61.60	12.43	261.33
10 m³ FYM + 10 m³ VC + UF1 (FT10)	54.10	12.93	339.10	62.70	12.67	262.33
10 m³ FYM + 10 m³ VC + UF2 (FT11)	52.07	11.73	288.40	57.17	11.93	256.11
10 m³ FYM + 10 m³ VC + UF3 (FT12)	50.33	11.60	271.00	52.33	11.43	253.11
SEm (±)	3.19	1.11	19.49	2.79	1.10	34.98
L.S.D. (5%)	3.34	1.12	21.32	2.53	0.39	NS

Potato tuber yield and its component characters

The findings presented in Table (2) demonstrated that tuber yield (tons fed.$^{-1}$), the number of tubers per plant, and average tuber weight (g) were significantly influenced ($p \leq 0.05$) by the studied independent variables, organic manure applications and nitrogen fertilization treatments, across both growing years. An exception was observed in the second season, where the average tuber weight (g) was not significantly influenced by organic manure additions. Overall, the primary effect of organic manure on potato yield and its associated traits revealed that the combination of farmyard manure and vermicompost, each applied at a rate of 10 m³ per feddan, produced the highest mean values for these studied traits.

The nitrogen fertilization treatments had a significant effect ($p \leq 0.05$) on all the evaluated traits, including total tuber yield (ton / feddan), number of tubers per plant, and average tuber weight (g), during both study years of the experiment (Table, 2). Notably, treatments involving 180 kg N per feddan in the form of soluble nitrogen fertilizers and 180 kg N per feddan as urea formaldehyde (UF1) exhibited the highest mean values for total tuber yield, number of tubers per plant, and average tuber weight traits during the first study season (Table, 2). A similar trend of results was generally observed during the second year, where these two nitrogen fertilization treatments achieved the highest mean values for the total tuber yield and average tuber weight characters. As for the number of tubers per plant trait, the UF1 treatment significantly outperformed the other examined nitrogen treatments, followed by the treatment with 180 kg N per feddan in soluble nitrogen form during the second year (Table, 2).

The combination between the two independent variables studied, organic manure applications and nitrogen fertilization treatments, statistically revealed significant effects ($p \leq 0.05$) on all examined characters during both years of the experiment, as shown in Table (2). Overall, it can be concluded that the application of a mixture of organic fertilizers containing 10 m³ of farmyard manure and 10 m³ of vermicompost, along with 180 units of nitrogen per feddan, supplied as urea formaldehyde, resulted in the highest values for both the number of tubers per plant during the two seasons and the average tuber weight (g) during the first season. Consequently, this approach yielded the highest overall total tuber production (tons per feddan).

The results of Table (2) also revealed that there were no significant differences were observed between the control fertilization treatment (FT1) and the fertilization treatment utilizing only 80% of the recommended nitrogen dosage (144 kg N / feddan), applied in the form of urea formaldehyde combined with a mixture of farm yard manure and vermicompost at the rate of 10 m^3/feddan for each component with regard to the total potato tuber yield trait during the two study years. Hence, it is preferable to fertilize potato plants with urea formaldehyde for several reasons, including that it is considered an environmentally friendly fertilizer. Secondly, it is added once during soil preparation prior to planting, unlike traditional nitrogen fertilizers that are added in several batches. This characteristic reduces the costs of cultivation. Additionally, it reduces the amount of nitrogen added per unit area by 20% without negative effects on potato yield compared to the control treatment, leading to minimize the costs of purchasing nitrogen fertilizers.

Organic fertilizer, when applied alone, demonstrated a higher yield compared to inorganic fertilizer but its yield remained lower than that achieved with a combination of organic and inorganic fertilizers. When applying organic and inorganic fertilizers together synergically increased potatoes yield (**Karangwa** *et al*.**, 2023**). **Ahmed** *et al*. **(2015)** and **Teshome and Amide (2022)** observed that adding farmyard manure as an organic fertilizer positively influenced potato vegetative growth characteristics, yield traits and tubers' quality, including specific gravity as well as starch, protein, and dry matter percentages. Their findings further highlighted the significance of farmyard manure in maintaining soil health. Moreover, application for organic fertilizer integrated with mineral fertilizer decreases the cost of production due to the continuous increase in the prices of mineral fertilization (**Ahmed** *et al*.**, 2015**).

The reason for the increased yield when measured is probably twofold. First, it has been shown that, in contrast conventional urea, nitrogen release from slow release urea fertilizer more closely matches the nitrogen uptake needs of potato plants under field conditions (**Cambouris** *et al*.**, 2014**). Second, slow release urea fertilizer has been found to reduce nitrogen losses from NO_3^- leaching, N_2O emission, and NH_3 volatilization (**LeMonte** *et al*.**, 2016; 2018; Gao** *et al*.**, 2017; Hopkins**, **2020 and Clément** *et al*.**, 2021**). This often leads to an increase in nitrogen-use efficiency (**Gao** *et al*.**, 2015 and Kitchen** *et al*.**, 2022**). A study by **Xue** *et al*. **(2024)** found that controlled-release fertilizers (CRFs) with low levels and frequencies of nitrogen were more effective than soluble urea in nitrogen management in potato cultivation. The results of **Saif El-Deen** *et al*. **(2015)** showed that sweet potato yield and its component characters were more enhanced with applied slow release nitrogen fertilizers rates to the growing plants comparing with the untreated plants.

Table (2). Averages of potato tuber yield and its component characters as affected by organic manure additions, nitrogen fertilization rates and their combinations during the two study seasons.

Treatments	2022/2023			2023/2024		
	Total tuber yield (ton fed.$^{-1}$)	No. of tubers / plant	Av. tuber weight (g)	Total tuber yield (ton fed.$^{-1}$)	No. of tubers / plant	Av. tuber weight (g)
Main effect of organic manure additions (A)						
20 m^3 FYM	14.10	6.84	146.65	14.50	6.70	140.68
20 m^3 VC	15.02	7.05	156.55	14.92	6.86	143.10
10 m^3 FYM + 10 m^3 VC	15.29	7.28	157.95	15.14	7.06	143.61
SEm (±)	2.32	0.83	21.04	1.51	0.82	17.03
L.S.D. (5%)	0.61	0.07	7.51	0.10	0.17	NS
Main effect of nitrogen fertilizer rates (B)						
180 kg N fed.$^{-1}$ as soluble N	15.78	7.38	159.64	15.41	6.91	146.47
180 kg N fed.$^{-1}$ as urea formaldehyde (UF1)	15.61	7.39	162.46	15.57	7.29	144.43
144 kg N fed.$^{-1}$ as urea formaldehyde (UF2)	14.54	6.89	152.74	14.58	6.76	139.99
108 kg N fed.$^{-1}$ as urea formaldehyde (UF3)	13.24	6.55	140.03	13.86	6.52	138.93
SEm (±)	1.44	0.52	15.85	1.52	0.65	15.84
L.S.D. (5%)	0.60	0.23	0.56	0.28	0.34	3.20
Fertilization treatments (A + B)						
20 m^3 FYM + Soluble N (FT1)	15.02	7.11	151.84	14.89	6.61	142.99
20 m^3 FYM + UF1 (FT2)	15.16	7.09	158.39	15.18	7.08	144.23
20 m^3 FYM + UF2 (FT3)	13.81	6.80	145.24	14.45	6.71	140.35
20 m^3 FYM + UF3 (FT4)	12.32	6.35	131.15	13.48	6.39	135.16
20 m^3 VC + Soluble N (FT5)	15.79	7.39	163.36	15.56	6.81	148.48
20 m^3 VC + UF1 (FT6)	15.91	7.37	164.70	15.69	7.27	145.78
20 m^3 VC+ UF2 (FT7)	14.89	6.83	156.53	14.52	6.78	139.53
20 m^3 VC + UF3 (FT8)	13.45	6.60	142.24	13.89	6.58	138.53
10 m^3 FYM + 10 m^3 VC + Soluble N (FT9)	16.03	7.65	163.73	15.76	7.33	147.94
10 m^3 FYM + 10 m^3 VC + UF1 (FT10)	16.26	7.71	164.91	15.83	7.52	143.29
10 m^3 FYM + 10 m^3 VC + UF2 (FT11)	14.93	7.05	156.45	14.76	6.79	140.09
10 m^3 FYM + 10 m^3 VC + UF3 (FT12)	13.95	6.70	146.70	14.21	6.59	143.10
SEm (±)	0.95	0.37	12.60	1.60	0.59	17.42
L.S.D. (5%)	0.98	0.39	11.37	0.47	0.58	5.53

Potato tuber quality characters

Data of Table (3) showed that tuber dry matter, reducing sugars percentages and aspartic acid content were significantly influenced by the main independent variables of organic manure additions and nitrogen fertilization treatments. A combination of farm yard manure and vermicompost (10 m^3 of each per feddan) significantly increased the mean values for both tuber dry matter and reducing sugars percentages, while vermicompost at the rate of 20 m^3 fed.-1 significantly increased the aspartic acid content in potato tubers. By using urea-formaldehyde at the rate of 180 kg N / feddan gave the highest mean values for tuber dry matter percentage without significant differences with the control treatment. A similar pattern of results was observed for reducing sugars and aspartic acid contents, where the addition of 180 Kg N / feddan to the growing potato plants significantly gave the highest average values for these two characteristics followed by the control nitrogen treatment (Table, 3).

As for the combination between the two studied variables (organic manure supplies and nitrogen fertilization treatments), the results of Table (3) showed that tuber dry matter and reducing sugars percentages were significantly affected by this interaction. The highest mean value for tuber dry matter percentage was possessed by the combination treatment of farm yard manure and vermicompost (10 m^3 of each) + 180 kg of N per feddan as urea-formaldehyde (FT10). The same treatment significantly gave the highest percentage of reducing sugars in potato tubers followed by treatment FT1 which involved 20 m^3 farm yard manure combined with 180 kg N / feddan as soluble nitrogen fertilizers (control treatment) and treatment FT6 comprising 20 m^3 of vermicompost with 180 kg N / feddan as urea-formaldehyde. The highest percentages of aspartic acid in potato tubers were achieved through the following fertilization treatments: 20 m^3 vermicompost + 180 kg N per feddan in form of urea formaldehyde (FT6), 20 m^3 farm yard manure + 180 kg N per feddan as soluble nitrogen fertilizers (FT1), 20 m^3 farm yard manure plus 180 kg N per feddan as urea-formaldehyde (FT2) and 20 m^3 vermicompost + 144 kg N per feddan as soluble nitrogen fertilizers (FT7), as shown in Table (3). Based on the previous findings on reducing sugars and aspartic acid levels in potato tubers, three fertilization treatments were selected for frying its potato tubers and estimating the acrylamide content in the resulting chips, as these three treatments contained high levels of both aspartic acid and reducing sugars. The three selected fertilization treatments included; 20 m^3 farm yard manure + 180 kg N of soluble N per feddan (FT1), 20 m^3 vermicompost + 180 kg N of UF per feddan (FT6) and 10 m^3 farm yard manure + 10 m^3 vermicompost + 180 kg N of UF per feddan (FT10).

The quality of tubers, in terms of dry matter percentages, was improved with increasing of farmyard manure levels. Conversely, increasing in inorganic nitrogen fertilizer levels led to reductions in the dry matter percentages **Ahmed** *et al*. **(2015)**. The effect of slow release nitrogen fertilizers rates seemed to be have positive effects regarding the reducing sugars percentages compared with the untreated plants (**Ezzat and Abd El-Hameed, 2010** on potato**, and Saif El-Deen** *et al*.**, 2015** on sweet potato).

Table (3). Averages of potato tuber quality characters as affected by organic manure additions, nitrogen fertilization rates and their combinations during the study season of 2023.

Treatments	2023/2024		
	Tuber dry matter (%)	**Reducing sugars (%)**	**Aspartic acid (%)**
Main effect of organic manure additions (A)			
20 m^3 FYM	20.67	0.47	1.03
20 m^3 VC	21.23	0.39	1.11
10 m^3 FYM + 10 m^3 VC	21.80	0.89	0.83
SEm (±)	2.59	1.48	0.33
L.S.D. (5%)	0.32	0.36	0.02
Main effect of nitrogen fertilizer rates (B)			
180 kg N $fed.^{-1}$ as soluble N	21.92	0.72	1.01
180 kg N $fed.^{-1}$ as urea formaldehyde (UF1)	22.22	1.33	1.19
144 kg N $fed.^{-1}$ as urea formaldehyde (UF2)	21.06	0.14	0.93
108 kg N $fed.^{-1}$ as urea formaldehyde (UF3)	19.74	0.15	0.83
SEm (±)	1.80	0.99	0.29
L.S.D. (5%)	0.53	0.23	0.02
Fertilization treatments (A + B)			
20 m^3 FYM + Soluble N (FT1)	21.5	1.44	1.24
20 m^3 FYM + UF1 (FT2)	21.49	0.18	1.21
20 m^3 FYM + UF2 (FT3)	20.72	0.12	0.91
20 m^3 FYM + UF3 (FT4)	18.96	0.14	0.79
20 m^3 VC + Soluble N (FT5)	22.01	0.51	1.06
20 m^3 VC + UF1 (FT6)	21.95	0.81	1.28
20 m^3 VC+ UF2 (FT7)	21.02	0.14	1.16
20 m^3 VC + UF3 (FT8)	19.96	0.11	0.93
10 m^3 FYM + 10 m^3 VC + Soluble N (FT9)	22.25	0.21	0.72
10 m^3 FYM + 10 m^3 VC + UF1 (FT10)	23.23	3.00	1.09
10 m^3 FYM + 10 m^3 VC + UF2 (FT11)	21.45	0.16	0.73
10 m^3 FYM + 10 m^3 VC + UF3 (FT12)	20.30	0.20	0.78
SEm (±)	1.74	0.24	0.02
L.S.D. (5%)	0.91	0.40	NS

Effect of different pre-frying treatments on acrylamide content in potato chips

Maillard reaction occurs during frying process when the active carbonyl group of reducing sugars reacts with the free amino group of amino acids, particularly asparagine. This reaction gives rise to various intermediates responsible for the browning in foods (**Feather, 1994**), which is closely related with the formation of acrylamide, as previously suggested in previous studies (**Mottram** *et al*.**, 2002; Zyzak** *et al*.**, 2003 and Stadler** *et al*.**, 2004**). Conversely, during the thermal degradation of certain products such as aspartic acid, acrylamide can be generated through acrylic acid. Subsequently, acrylic acid combines with ammoniac acid to form acrylamide (**Yaylayan** *et al*.**, 2005**). Therefore, this experimental procedure focused on examining the effect of pre-frying treatments that could minimize the chemical reactions of reducing sugars and amino acids in potatoes for lowering acrylamide generation.

According to the data presented in Table (3), potato tubers produced from the following three fertilization treatments exhibited high levels of both reducing sugars and aspartic acid:1) 20 m^3 FYM + 180 kg Soluble N/fed. 2) 20 m^3 VC + 180 kg N/fed. in the form of UF. 3) 10 m^3 FYM + 10 m^3 VC + 180 kg N/fed. in the form of UF. Consequently, tuber samples from these fertilization treatments were selected for pre-frying treatments.

As shown in Fig. (1), the acrylamide content in potato chips significantly affected by the pre-frying treatments. In this respect, soaking potato slices for 30 minutes in a saline solution (5g / l) + lysine acid (10 g / l) followed by frying in oil containing 1 g / l of olive leaves (T4) significantly decreased the acrylamide contents in potato chips followed by the treatment of soaking potato slices in a saline solution containing (5g / l) + lysine acid (10 g / l) for 30 minutes (T3). Soaking potato slices in a saline solution (5 g / l) for 30 minutes (T1) gave a highly acrylamide concentration in potato chips without significant differences with the treatment of soaking potato slices in a saline solution (5 g / l) followed by frying in oil containing 1 g / l of olive leaves (T2). Such reduction in acrylamide concentration is assumed to be caused by both actions of water dissolution of acrylamide precursors, in addition to the action of lysine acid anions, which surrounded the partial positively charged carbonyl carbon in sugar, so, they hindered its activity to be attacked by the lone pair of electrons from amino group in asparagine molecule and consequently it hindered Maillard reaction (**Soliman and hamed, 2022**). Olive leaves are known to contain antioxidants, which interfere with the reaction between reducing sugars and amino acids, thus reducing the formation of acrylamide. Antioxidants neutralize free radicals that accelerate the chemical reactions that generate acrylamide (**Talhaoui** *et al*.**, 2015**). The results of **Hongwei** *et al*. **(2013)** illustrated that cysteine, glycine and lysine amino acids were most effective on eliminating acrylamide among the amino acids tested. Cysteine showed the highest efficiency in reducing acrylamide, with acrylamide disappearance of 94.6%, followed by glycine (72.1%) and lysine (69.6%). Same trend of results were also detected by **Kim** *et al*. **(2005)**, where the authors found that lysine and glycine were effective at inhibiting the formation of acrylamide in wheat-flour snacks. Soaking potato slices in a 3% solution of either lysine or glycine reduced the formation of acrylamide by more than 80% in potato chips fried for 1.5 min at 185°C. These results indicate that the addition of certain amino acids by soaking the uncooked products in appropriate solutions is an effective way of reducing acrylamide in processed foods.

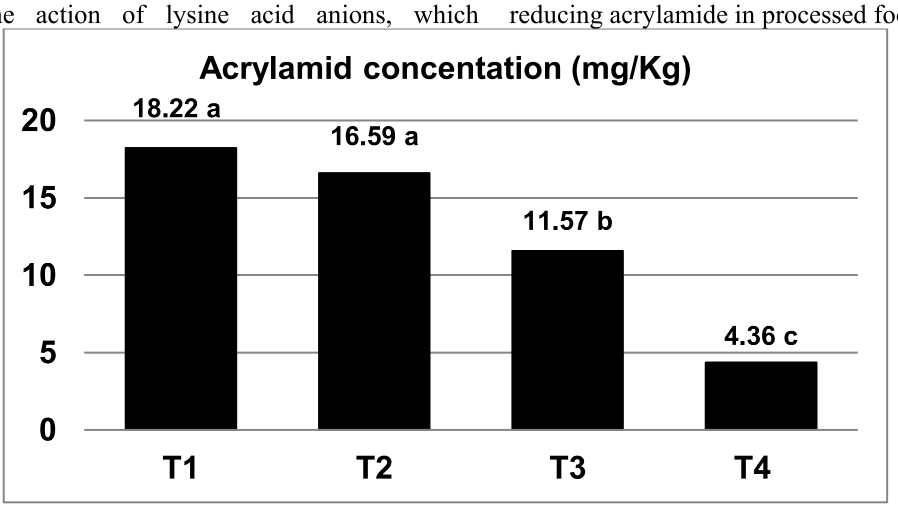

Fig.1. Effect of pre-frying treatments on acrylamide contents in potato chips

Means having different superscript are significantly differ at $p \leq 0.05$

1: Soaking potato slices in 1 liter of water containing 5 grams of salt for 30 minutes.

2: Soaking potato slices in 1 liter of water containing 5 grams of salt for 30 minutes followed with frying in oil contain 1 gram of olive leaves.

3: Soaking potato slices in 1 liter of water containing 5 grams of salt and 10 grams of Lysine acid for 30 minutes.

4: Soaking potato slices in 1 liter of water containing 5 grams of salt and 10 grams of Lysine acid for 30 minutes followed with frying in oil contain 1 gram of olive leaves.

CONCLUSION

It is worth noting that adding environmentally friendly urea-formaldehyde fertilizer in a single dose during soil preparation reduces potato production costs, while conventional soluble nitrogen fertilizers are applied in multiple doses during the growing season. According to the findings of this research, potato plants treated with a combination of 10 m^3 of farmyard manure, 10 m^3 of vermicompost and 180 units of nitrogen per feddan provided in the form of urea-formaldehyde demonstrated an average yield increase of 7.28% over the two growing seasons, as compared to the control treatment applied by Egyptian potato farmers , which consists of adding 20 m^3 of farm yard manure and conventional soluble nitrogen fertilizers at the rate of 180 kg N per feddan. Generally, amino acids and antioxidants are highly effective components in soaking solutions prior to frying potato slices. This process significantly helps in reducing the levels of carcinogenic acrylamide present in the chips.

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الملخص العربي

تأثير الأسمدة العضوية و اليوريا فورمالدهيد على محصول البطاطس، وتقييم معاملات ما قبل القلي على مستويات الأكريلاميد فى الشيبس

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يهدف هذا البحث إلى تقييم تأثير الأسمدة العضوية واليوريا فورمالدهيد (سماد بطيء الإطلاق) على محصول البطاطس، إلى جانب دراسة تأثير معاملات ما قبل القلي على مستويات الأكريلاميد في شرائح البطاطس المقلية (الشيبس). أجريت تجربتان حقليتان خلال الموسمين الصيفيين 2023/2022 و2024/2023 في مدينة شبرا خيت، بمحافظة البحيرة ، مصر . أجريت التجربة بتصميم القطع المنشقة ذو ثلاث مكررات. تم ترتيب ثلاثة أنواع من الأسمدة العضوية عشوائيًا في القطع الرئيسية؛ بينما تم توزيع أربع معاملات تسميد نيتروجيني عشوائيًا في القطع الفرعية.

أوضحت النتائج ما يلي :

تأثرت معظم الصفات الخضرية، وصفة المحصول ومكوناته، وخصائص جودة البطاطس المدروسة بشكل كبير بإضافة الأسمدة العضوية، واختلاف معدلات التسميد النيتروجيني، وتداخلهما معا. استخدام 10 م^3 من سماد الماشية و10 م^3 من سماد الفيرمي كمبوست مع 180 وحدة من النيتروجين على هيئة يوريا فورمالدهيد للفدان أعطى أعلى إنتاج كلى لمحصول البطاطس للفدان. أشارت النتائج إلى أنه يمكن خفض 20٪ من النيتروجين المضاف لكل فدان دون آثار سلبية على إجمالي إنتاج الفدان من البطاطس، وقد تحقق ذلك من خلال إضافة خليط من كل من سماد الماشية وسماد الفيرمي كمبوست بمعدل 10 م^3 لكل منهما، إلى جانب إضافة 144 وحدة من النيتروجين لكل فدان على هيئة يوريا فورمالدهيد. إضافة إلى ذلك، أشارت النتائج الى أن نقع شرائح البطاطس قبل القلي لمدة 30 دقيقة في محلول مائي يحتوي على 5 جرام من الملح/ لتر ماء و 10 جرام من حمض الليسين/ لتر ماء متبوعا بالقلي في زيت يحتوي على 1 جرام من أوراق الزيتون قد قلل بشكل ملحوظ من محتوى الأكريلاميد في شرائح البطاطس المقلية (الشيبس) مقارنة بمعاملات ما قبل القلي الأخرى التي تم تقييمها.