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Evaluation of yield and some physiochemical traits in four cultivars of potatoes

(*Solanum tuberosum* L.)

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Abstract

The study was carried out to evaluate the physical, chemical, and quality properties of four potato cultivars (Jelly, Donata, Hermes, and Caruso), cultivated in an open field during the spring season of 2022. A completely randomized block design RCBD with three replications was used in this experiment. The obtained results could be summarized as follows: the cultivar of Jelly obtained the maximum values of plant yield 1.025 kg, tuber weight 162.50 g, total yield 34.14 t ha^{-1}, tuber equatorial diameter 57.80 mm, TSS 6.20%, maturity index 13.14, and pH 7.13. While the Donata cultivar gave a higher value of a tuber polar diameter of 94.72 mm, shape index of 1.82 and moisture 81.17%, wherase the Hermes cultivar gave the maximum values of parameters such as dry matter 30.79%, starch 23.44% and protein content in tubers 7.17%. Caruso cultivar recorded the maximum values of the number of tubers 4.67 tuber $plant^{-1}$, hardness 12.83 kg cm^2, total acidity 0.62%, and carotene content 0.64 µg g^{-1} FW. Amongst the four tested potato cultivars, the Jelly variety revealed the best performance due to it gives high values of plant yield, tuber weight, total yield, tuber equatorial diameter, TSS%, TSS/TA, and pH, content in tubers. While the Hermes variety recorded the highest value in TA%, moisture% and carotenoid content in tubers.

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Introduction

The potato (*Solanum tuberosum* L.) is the most important vegetable that comes under the family Solanaceae and ranked fourth in terms of production in the world after wheat, rice and maize. It is a distinctive and essential food crop of the world. (Sinha *et al*., 2022). It is a productive and well-adapted crop in different climatic conditions worldwide that requires balanced nutrient management for its growth and development. The potato has been strongly recommended by the Food and Agriculture Organization for food safety, the world production of potatoes was about 376.12 million metric tons in 2021 (FAOSTA, 2021). In Iraq, it was estimated at (674840 tons) or more, on 24120 hectares of cultivated area, and the average yield was (27.978 t ha^{-1}) (Central Statistical Organization, 2020). According to the Ministry of Agriculture and Water Resources in the Kurdistan Region over (250 metric tons) of potato crops were produced in the Kurdistan Region in 2020.

The development of potato varieties with improved quality after harvesting is important to all segments of the potato industry. Potato processors and other consumers will benefit from a consistent product when varieties have the same specific gravity when grown in different environments. (Kabira and Lemaga, 2003), Potato chips are not very common in the

country, except in bigger hotels and restaurants. But lately, there are lots of small potato chip processors in cities and big towns. During variety development, the focus was on productivity per unit area and late blight reaction (Asefa *et al.*, 2016). Regardless of its economic importance and great utility, potato is considered one of the most palatable, nutritious vegetables and minerals (Fabbri and Crosby, 2016). Not all varieties are suited to make processed products. Therefore, emerging economies are necessitated to develop specific cultivars and evaluate their fitness for the end products. The external and internal quality is often mentioned to evaluate the quality of potato tubers (Kabira and Lemaga, 2003). The presence of wide variations among varieties for tuber specific gravity, dry matter and starch contents indicated that genetic and environmental factor was important to influence the tuber internal quality traits. In general, potato varieties with a starch content of 13% and above are the most preferred for processed products (Kirkman, 2007; Mohammed, 2016).

Starch is of special importance for the nutritional value ranges between 15-20% (Schafer-Pregl *et al*., 1998); (Abebe *et al*., 2013) mentioned that the starch content of 25 potato genotypes ranged from 7.63 to 21.59%, and the important role in the cooking quality and healthy food processing and consumption in relation to moderating blood glucose levels (Binner *et al*., 2000); (Liu *et al*., 2003).

Hence, the process of evaluating potato cultivars is a necessary process for the internal tuber quality traits across locations and over seasons. Currently, the most important traits of potato production are the quality of tubers, that includes tuber shape, texture, cold sweetening, sensorial flavour, proteins, carbohydrates, starch quality and minerals, potato use besides table consumption (more than 50% of yields) and processing products in the global markets (Carputo *et al*., 2005).

Mainly in developed countries, due to the changes in consumers' behavior and their preference for more convenient products, about 60% of potatoes are consumed in a processed form (Kirkman, 2007; Storey, 2007). There are various improved potato commercial cultivars produced by putting more weight on high yield and resistance to diseases while less emphasis was given to quality. While many other factors affect the quality and chemical composition of potato tuber by several factors, including production area, genetic factors, soil fertility, climate conditions, agricultural practice, storage, commercialization conditions and applying chemical treatments (Arvanitoyannis *et al*., 2008; Brazinskiene *et al*., 2014). For instance; the quality of the processing depends to a large extent on the color of the potato after frying (Affleck *et al*., 2012). The starch concentration in the tubers is the most important quality parameter. The starch rate in the tubers' dry matter varies due to genetic factors (Stark *et al.*, 2020) which affecton the texture of the processed products (Kadam *et al.*, 1991). As well as, the rate of dry matter content in potatoes, which affects the energy value of potatoes and their culinary properties such as taste, structure, consistency, and color, fluctuates from 15 to 32% depending on the potato variety and cultivars characteristics, agro-climatic factors (Salunkhe *et al.*, 1989), and agricultural practices such as mineral fertilization and irrigation methods (Kannan *et al*., 2015), sowing and harvesting time (Sogut and Ozturk, 2011).

Potatoes with more than 20% of tuber dry matter produce crispy French fries considered ideal for making chips (Sharkar *et al*., 2019). According to Davydenko (2020), the level of dry matter accumulation in potato tubers may be influenced by 46% due to the change in the variety and cultivar of potatoes, weather conditions, and the cultivation location. Furthermore, Total soluble solids have been directly related to quality parameters such as texture (Feltrán

et al., 2004), pH (Pardo *et al*., 2000). Moreover, carotenoids are the main lipophilic constituents that contribute to the total antioxidant activity and provitamin A content of the potato. The carotenoid content of tubers in most potato cultivars ranges between 0.5 and 2.5 µg g^{-1} FW (Nesterenko and Sink, 2003). Variation in tuber potato associated with economic and genetic traits, ranging from (5.5 - 6.2) while wild species were lower (Kiszonas and Bamberg, 2010). Previously, there are many studies investigating the productivity and studies to select the most productive cultivars (Behjati *et al*, 2013), and quality (Kumar *et al*, 2005) of newly introduced cultivars of potato tubers and select the best cultivars for their region climate and market demand. The aim of this study was carried out to evaluate four potato cultivars in respect of yield and tuber quality, as well as, identify their use and consumption as fresh consumption or French fries.

Materials and Methods

Site Characterization

A OR The Field trial was conducted in an experimental area of the Penjwen district, 106 km northeastern of Sulaymaniyah province, Kurdistan Region of Iraq at 1000 m above sea level with latitude: 35° 61' 8458" N, longitude: 45° 95' 5429" E, during the Spring season of 2022. The region presents a climate classified as a semi-arid region (Najmaddin *et al.*, 2017). The weather data obtained from the meteorological station located close to the site, from Jan. to Nov. 2022 are shown in (Table 1). Before the planting of tubers, soil samples were collected from five positions at 0.3 m soil layers, for physical and chemical characterization (Table 2).

Table 1. Meteorological information of Penjwen site from Jan. to Nov. 2022

Months	Air Temp. (°C)			Humidity (%)			Precipitation (mm)	Avg. Sunshine Duration Hours	Avg. Pan Evaporation (mm)	Soil Temp. (°C)
	Avg.	Max.	Min.	Avg.	Max.	Min.				
January	-0.8	14.0	-26.0	81.2	96.0	38.0	309.9	3.6	0.1	3.7
February	4.4	17.2	-10.0	73.4	98.0	31.0	144.9	5.9	1.0	4.2
March	6.2	21.0	-6.8	65.5	96.0	20.0	117.2	3.9	1.7	7.9
April	15.3	28.2	4.00	54.8	95.0	18.0	49.4	6.9	5.4	16.1
May	17.5	32.0	5.40	54.6	95.0	20.0	25.7	7.5	5.1	19.9
June	24.9	38.0	14.0	42.7	67.0	19.0	-	9.7	7.2	29.1
July	29.3	41.8	17.5	39.1	60.0	21.0	-	12.2	8.5	33.3
Augusts	31.3	42.2	19.0	36.5	57.0	20.0	-	11.2	8.4	34.1
September	25.3	38.2	10.0	40.5	72.0	12.0		10.4	6.1	29.7
October	18.7	34.4	5.5	31.4	72.0	8.00	27.0	8.0	3.6	22.8
November	10.4	21.8	0.00	44.4	72.0	13.0	149.5	6.0	1.2	13.1

Table 2. Soil characterizations (physical and chemical) in the Penjwen area in 0.30 m depth

Characters	Quantities	Units
Sand	12.23	%
Silt	50.17	%
Clay	37.60	%
Texture	Silty Clay Loam	
pH	7.8	
CaCO3	6	%
Organic matter	1.6	%
EC	0.28	dS m^{-1}
Total N^{+}	0.14	%
Available P	40.3	ppm
Soluble K^{+}	0.80	meq L^{-1}
Soluble Na^{+}	0.53	meq L^{-1}
Soluble Ca^{++}	1.9	meq L^{-1}

Soluble Mg^{++}	0.68	meq L^{-1}
Soluble Cl^{-}	0.45	meq L^{-1}
$HCO3^{-}$	2.15	meq L^{-1}
$CO3^{2-}$	0.00	meq L^{-1}
SO_4^{2-}	0.83	meq L^{-1}
CEC	40.25	Cmole kg^{-1}

Experimental Characterization

The experimental design was a randomized complete block design (RCBD) (Al-Rawi and Khalaf Allah, 1980) with three replications for each treatment. The collected data on various parameters were subjected to the analysis of variance (ANOVA) to determine the difference between the cultivars. The means were compared for significant differences with Duncan's new multiple range test ($P \leq 0.05$). Statistical software (XLSTAT) was used for computing. The distance between the plants and the two furrows was 0.3m and 0.8m, respectively. The area of each experimental unit was $4m^2$ (5× 0.8m) containing 16 plants; the total number of plants in one hectare was (33333 plants). The tubers were sown on June 5, 2022, using four Elite cultivars of potatoes includeJelly and Donata, Hermes and Caruso. Each experimental unit was given the same agricultural practice applications such as fertilization, 600 Kg ha^{-1} of Di-Ammonium Phosphate (DAP) 18:18:0 (Esho, 2009), irrigation, weeding, and spraying against insects and diseases. Tubers were harvested on September 25, 2022.

Measurements

After tubers were harvested calculate the following parameters.

1. Quantitative yield parameters

Tuber weight (g), Number of tubers $plant^{-1}$, Plant yield (kg), and Total yield (t ha^{-1}).

2. Physical parameters

Tuber size (cm^3), Tuber hardness (kg cm^{-2}), Polar diameter (mm), Equatorial diameter (mm), Shape index.

3. Chemical parameters

Total soluble solid (TSS %), Total acidity (TA %), Maturity index, Dry matter in the tubers (%), Moisture content (M%), Starch content (Starch%), Protein content (Protein%), and carotene μg g^{-1} FW.

Results and discussion

Table 3 shows the evaluation of potato cultivars on quantitative yield characteristics, the Jelly cultivar obtain high values of yield per plant, tuber weight, and total yield (1.025 kg, 162.50 g, and 34.14 t ha^{-1}) respectively. While the Hermes cultivar gave the minimum values of plant yield, number of tuber $plant^{-1}$, and total yield (0.668 kg, 4.67 g, and 22.25 t ha^{-1}), respectively. Donata cultivar had a minimum value of tuber weight (112.68 g). Furthermore, the Caruso cultivar gave the maximum number of tuber $plant^{-1}$ (6.67 tuber $plant^{-1}$) than other cultivars, the differences among Jelly and Donata cultivars with the Caruso cultivar were not significant. The variation in the total yield of potato cultivars might be associated with genotypes difference among cultivars. In agreement with the present findings, a significant difference in total yield among potato cultivars was reported by (Bilate and Mulualem, 2016) and (Gebreselassie *et al*., 2016). Also, Elfinesh, (2008) stated yield differences among genotypes were attributed both to the inherent yield potential of genotypes and the growing environment as well as the interaction between genotypes and with environment. Changes in temperature, humidity, and day length at the study site have a direct impact on yield and its components among cultivars, as shown in Table (1). On the other hand, the soil texture and the quantities of nutrients present in the soil also have a significant effect on the

amount of potato production in the spring season, especially the macro elements needed to increase production, In the case of potatoes are soil stressful plants as mentioned in the Table 2.

Table 3. Evaluation of quantitative yield characteristics on four potato cultivars

cultivars	plant yield (kg)	no. of tuber plant^{-1}	tuber weight (g)	total yield (t ha^{-1})
Jelly	1.025a	6.33 a	162.50 a	34.14 a
Donata	0.711bc	6.33 a	112.68 c	23.69 bc
Hermes	0.668c	4.67 b	143.81 b	22.25 c
Caruso	0.758b	6.67 a	115.36 c	25.27 b

Means with the same letters are not different significantly according to Duncan's multiple ranges test ($p \leq 0.05$).

Table 4 shows the evaluation of potato cultivars on physical traits, the cultivars have a significant effect on characters except for the tuber size character. The Caruso cultivar gave the higher value of hardness with 12.83 (kg cm^2), while the Jelly cultivar obtained the lowest value (8.30 kg cm^2). The longest tuber polar diameter and shape index were recorded in the Donata cultivar (94.72 mm) and (1.82), respectively,

Whereas the minimum value of tuber polar diameter (68.26 mm) was obtained in the Caruso cultivar and the minimum value of the tuber shape index (1.34) was achieved in the Hermes cultivar. The results indicate that the maximum tuber equatorial diameter (57.80 mm) was observed in the Jelly cultivar, whereas a or the minimum value of tuber equatorial diameter (44.94 mm) was in the Caruso cultivar. Additionally, all cultivars have no significant difference in terms of tuber size. Flesh hardness evaluations are one of the most important factors of qualitative attributes in fruits, which is generally referred as the second rank according to morphological characteristics, in particular for the purpose of long distancing export and storage (Roubos and Aravanopoulos, 2010). This may be due to differences between potato varieties and genotypes primarily due to their genetic traits.

Table 4. Evaluation of the physical parameters of four cultivars of potato tubers

Cultivars	Hardness (kg cm^2)	Size (cm^3)	Polar diameter (mm)	Equatorial diameter (mm)	Shape index
Jelly	8.30 c	140.00 a	82.81 b	57.80 a	1.43 bc
Donata	9.22 c	113.00 a	94.72 a	52.01 b	1.82 a
Hermes	10.80 b	120.00 a	72.26 c	53.58 ab	1.34 c
Caruso	12.83 a	106.33 a	68.26 c	44.94 c	1.52 b

Means with the same letters are not different significantly according to Duncan's multiple ranges test ($p \leq 0.05$).

The results indicate that the cultivars significant in terms of chemical parameters, it can be noticed from the data presented in Table 5 the cultivars undertaken in this investigation have differed in pigment contents. The Jelly cultivar was superior significantly as compared with other cultivars in TSS%, maturity index, and pH in the tubers which were (6.20%, 13.14%, and 7.13) respectively. Furthermore, the maximum value (81.17%) of moisture content was found in the Donata cultivar.

Contrariwise, the Hermes cultivar gave the lowest of TSS and moisture content (4.60 and 69.21%), respectively. With them, the Caruso cultivar gave the minimum values of maturity index, and pH (7.70 and 5.10), respectively. On the other hand, the minimum TA% (0.47) was obtained in the Jelly cultivar, and the highest TA% (0.388) was in the Caruso cultivar. In the same table, the Hermes cultivar recorded maximum dry matter, starch, and protein (30.79%, 23.44%, and 7.17%), respectively. In contrast, the Donata cultivar achieved

minimum values of the last parameters (18.83%, 12.78%, and 5.67%) respectively. The Caruso cultivar gave the highest value of carotene content in the tuber (0.64 µg g^{-1} FW). Whereas the Hermes cultivar obtained the lowest value (0.21 µg g^{-1} FW).

The results of TSS, moisture content and starch percentage in this study were agreed with founded by (Hussein and Hamideldin, 2014). Which reported that the ranges of TSS is between (6.5-8.0%) before storage, the moisture raged between (76.0-83.0%) and starch was between (5.5-7.2%). The pH of potato tuber which had found in the study was agreement with the finding by Kiszonas and Bamberg (2010), who reported the range values were between 5.5-6.2 in different potato cultivars.

These results are in agreement with the findings of Muthoni *et al*., (2014), who descripted that many factors affect the quality and chemical composition of potato tuber likes; genetic factors, soil fertility, weather conditions, and applying chemical treatments. These results are in agreement with those obtained in potato by Ibrahim *et al*. (2015) and Youssif (2017).

Respect, the level of dry matter accumulation in potato tubers can be affected by 46% due to the change in the variety and cultivar of potatoes, weather conditions, and the cultivation location, according to Davydenko (2020). The results of starch in our study agree with Schafer-Pregl *et al*., (1998), they had found the ranges between 15-20%. As well as, the carotene content in tuber obtained in the analysis of the data agree with the range founded by Nesterenko and Sink (2003) which was between (0.5 and 2.5 mg g FW), also with Breithaupt *et al*., (2002) reported the total concentration of the four main carotenoids reached 175 µg$100g^{-1}$ FW, whereas the sum of carotenoid esters accounted for 41-131 µg$100g^{-1}$ FW. Therefore, carotenoid esters are regarded as quantitatively significant compounds in potatoes. The rate of dry matter content in potatoes, which affects the energy value of potatoes and their culinary properties such as taste, structure, consistency and color, fluctuates from 15 to 32% depending on the potato variety and cultivars characteristics, agro-climatic factors (Salunkhe *et al.*, 1989).

Table 5. Evaluation of chemical characteristics of four potato cultivars

Cultivars	TSS%	TA%	Maturity index	pH	M%	Dry matter %	Starch%	Protein %	Carotene (µg g^{-1} FW)
Jelly	6.20 a	0.47 c	13.14 a	7.13 a	79.73 a	20.27 b	14.06 b	5.77 b	0.50 b
Donata	5.77 ab	0.49 bc	11.88 b	6.33 b	81.17 a	18.83 b	12.78 b	5.67 b	0.44 b
Hermes	4.60 c	0.56 ab	8.32 c	5.87 b	69.21 b	30.79 a	23.44 a	7.17 a	0.21 c
Caruso	4.80 bc	0.62 a	7.70 c	5.10 c	71.54 b	28.46 a	21.36 a	6.90 a	0.64 a

Means with the same letters are not different significantly according to Duncan's multiple ranges test ($p \leq 0.05$)

Conclusion

Amongst the four tested potato cultivars, the Jelly variety revealed the best performance due to it gives high values of plant yield, tuber weight, total yield, tuber equatorial diameter, TSS%, TSS/TA, and pH, content in tubers. While the Hermes variety recorded the highest value in TA%, moisture% and carotenoid content in tubers. The significant correlation among different quality traits may be useful in further research on the economic significance of potato varieties.

Conflict of Interest

The authors declare that they have no conflict of interest.

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