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Morpho-chemical characterization of new confectionery sunflower (*Helianthus annuus* L.) genotypes from Argentina

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SUMMARY

Argentina is the world's leading exporter of confectionery sunflower. This work characterized the morphometric and nutritional composition of sunflower seeds from new confectionery genotypes. Average morphometric variables per seed were: weight 0.11 and 0.06 g with and without achene, respectively; length 15.2 mm; and width 8.50 mm, with most calibers greater than 9.51 mm. Proximate analysis indicated that seeds without shell were an important source of lipids (49 %), as well as proteins (28 %), carbohydrates (11 %), and minerals (4.8 % ashes). Fatty acid composition showed that polyunsaturated fatty acids were the major components (56 %), followed by monounsaturated ones (34 %), and saturated ones (11 %). The mid-oleic genotype developed by INTA showed significantly greater oleic acid (47 %) and lower linoleic acid (42 %) than the commercial hybrid. Proteic composition showed 33 % of essential amino acids (EAA) while fiber and sugars represented 3.9 % and 7.3 % respectively; macroelements such as K, Mg and Ca, and microelements such as Mn, Fe, Cu, Zn, Se, Co, Mo and Na. New confectionery sunflower hybrids developed by INTA stand out for their high quality in edible oil, proteins and essential components, all very valuable for the food industry.

Keywords: kernel chemical content, sugars, fatty and amino acids, protein, oil, yield

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RESUMEN

Argentina es el principal exportador mundial de girasol confitero. Este trabajo caracterizó la composición morfométrica y nutricional de nuevos genotipos de girasol confitero. Las variables morfométricas promedio por semilla fueron: peso 0,11 g y 0,06 g, con y sin aquenio respectivamente; longitud 15,2 mm; ancho 8,50 mm; la mayoría de calibres superiores a 9,51 mm. El análisis composicional

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indicó que las semillas sin cáscara aportan 49 % de lípidos, 28 % de proteínas, 11 % de carbohidratos y 4,8 % de minerales. La composición de ácidos grasos mostró que los poliinsaturados fueron los componentes principales (56 %), seguidos de los monoinsaturados (34 %) y los saturados (11 %). El genotipo medio oleico presentó porcentaje de ácido oleico significativamente mayor (47 %) y porcentaje de ácido linoleico menor (42 %) que el híbrido comercial. La composición de proteínas fue de 33 % de aminoácidos esenciales (AAE); fibra y azúcares de 3,9 % y 7,3 %, respectivamente; macroelementos K, Mg y Ca, y microelementos Mn, Fe, Cu, Zn, Se, Co, Mo y Na. Los nuevos híbridos de girasol confitero desarrollados por INTA se destacan por la alta calidad del aceite, proteínas y componentes esenciales, todos estos de importancia para la industria alimenticia.

Palabras clave: contenido químico del grano, azúcares, ácidos grasos y aminoácidos, proteínas, aceite, rendimiento

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INTRODUCTION

Apart from the predominant cultivation of sunflower for oil production, other types of sunflowers are widely cultivated in the world. Non-oil type *Helianthus annuus* L. var. macrocarpus (DC.) Cockerell is also called confectionery, protein, nibbling, or large-seed sunflower (Jocić and Miladinovi, 2015). This type of sunflower is mainly preferred in Turkey, Eastern Europe, US, Canada, and in some Asian countries, such as China, Pakistan, Iran, Middle East countries, etc. Confectionery sunflower hybrid breeding is directed towards the increase of protein content and quality (>25 %), 1000 seeds weight (>100 g), hectoliter mass, oil stability with decrease of its content in the seed (<40 %), increase of kernel ratio and decrease of shell ratio, uniformity in seed size and color, unshelled seeds, as well as tolerance to dominant diseases in the cultivation region (Hladni et al., 2009a). Hundred seeds weight belongs to the major yield components, breeding for increasing 1000 seeds weight leads to seed yield increase, so this trait is used as selection criterion for breeding sunflower hybrids (Hladni et al., 2016). Confectionery sunflower seed should ideally have over 80 g 1000-seed weight, oil content less than 30 %, high seed size, low cadmium rate, and high protein, oleic acid, and vitamin E (tocopherol) content (Lofgren, 1997; Jovanović et al., 1998). The seed size is the main criterion for the quality of confectionery sunflower. While larger size (>15 mm) seeds go into the inshell market to be used as snacks, medium-size seeds are hulled for the kernel market both for consumption as snacks and for bakery use, and smaller seeds go for bird and pet feeding markets (Hofland and Kadrmas, 1989). Besides their seed oil content, sunflower seeds of confectionery and oily types are distinguished by their hull thickness, shell color, seed weight and morphology, and kernel-to-pericarp weight ratio (Hladni et al., 2011a). Aquenes of confectionery sunflower are usually black with stripes of white or other color and significantly bigger than the aquenes for oil production, with thicker hull loosely connected to the kernel. The shell is easily separated from the kernel and allows the whole seed to be dehulled (González-Pérez and Vereijken, 2007). The best confectionery types should have oil content lower than 30 %, and husk content up to 50 % (Kaya, 2004).

The main parameters in defining oil quality are fatty acid composition, arrangement of fatty acid models within the triglyceride molecule and total content and profile of several polyisoprenoid lipids that are present in the oil. Likewise, tocopherols and sterols composition is also of great importance as well (Fernández-Cuesta et al., 2012). Standard sunflower oil contains on average about 70 % of polyunsaturated linoleic acid (C 18:2), which is an essential fatty acid that cannot be synthesized by the human organism; therefore, it has to be incorporated through food. Sunflower oil also contains monounsaturated oleic acid (C 18:1) at about 20 %. Although the content of linoleic and oleic acids could vary due to environmental effects, together they constitute about 90 % of total fatty acid content. Meanwhile palmitic acid (C 16:0) at about 4–9 % and stearic acid (C 18:0) at about 1–7 %, plus traces of other fatty acids such as myristic (C14:0), myristoleic (C 14:1), palmitoleic (C 16:1), arachidic (C 20:0), and behenic (C 22:0) make up 10 % of total fatty acid content in sunflower oil (Jocić and Miladinovi, 2015). However, commercial hybrids have a regular low oleic content, which could undermine oil stability and the long-term quality of derived products. Linoleic acid is more susceptible to oxidation than oleic acid (Frankel, 2005). A higher oleic/linoleic ratio confers greater stability and shelf life to the product, while a lower ratio contributes to the oxidation of lipids transmitting unpleasant taste to products for consumption. On the other hand, a high concentration of oleic acid helps to prevent various cardiovascular diseases such as cerebrovascular accidents as well as coronary and cardiac problems, by reducing blood cholesterol levels (Shramko et al., 2020).

Sunflower seeds are also rich in protein, vitamins (E, B1 and B5), and minerals such as potassium, manganese, magnesium, copper, selenium, zinc, iron, and calcium, folic acid, soluble sugars, and dietary fiber. The antioxidants, vitamin E and selenium present in seeds have the ability to neutralize harmful free radicals and, thus, protect the body from numerous diseases. The regular consumption of sunflower seeds significantly boosts the immune system and, therefore, constitutes a functional food (Hladni et al., 2011b). In Argentina, the National Institute of Agricultural Technology (INTA) has a breeding program for sunflower whose aims are to obtain parental lines to develop hybrids for different uses and high sustainable productivity in a wide range of environments in the crop area. The aim of this work was to characterize new confectionery sunflower germplasms developed by INTA regarding morphological and nutritional kernel properties.

MATERIALS AND METHODS

Data

A field trial was carried out at Manfredi Experimental Station of INTA, located in the eastern center of the province of Córdoba, Argentina (31.5° W, 63.5° S; 292 m a.s.l.). The climate is semi-arid, with an average annual rainfall of 750 mm highly concentrated in the summer months. INTA confectionery advanced and experimental hybrids (EH) were regularly sowed between November and January with a plant density of 37,000 plants per ha and a randomized complete block design, with three blocks of plots made of two rows, spaced at 0.70 m and 5.40 m in length within rows. New genotypes 101102455, BS58INTA, 101102455-1, and 101333401, and a commercial confectionery widely spread named Grizzly were planted (Figure 1).

Grain Analyses

Morphometric traits

The caliber of the achenes was measured with four circular sieves (9.5, 8.75, 8, and 6.5 mm) that separated the seeds into five size classes: greater than 9.5 mm, between 8.75 and 9.5 mm, between 8 and 8.75 mm, between 6.5 and 8 mm, and lesser than 6.5 mm. A total of 100 g of achenes per plot were passed through sieves of different sizes to determine the caliber of achenes, then the portion remaining in each sieve was weighed and each fraction expressed as a percentage of the total sample. On the other hand, five achenes per sample were taken at random and the length (mm) and width (mm) were measured with a caliper. Subsequently, the weighing of fifty (50) whole achenes per plot was carried out, and the hulls were removed and weighted. Moreover, the following values were measured: the number of achenes per capitles, 1000 achenes weight and % of seeds without hulls over 100 achenes. Seed yield (kg/ha) data of five seasons of these confectionary sunflower cultivars from the same field experimental

Figure 1. Pictures showing the five confectionery sunflower hybrids studied in this research

design and location were recorded and used for this work. Seeds were stored in a cold chamber at a temperature between 1 to 4 ºC.

Chemical analysis of the grains

The chemical quality determination of INTA confectionery sunflower germplasm was carried out at the Laboratory of Nutritional Grain Quality at INTA Manfredi Experimental Station. Each sample of the 5 sunflower genotypes, containing 100 g of kernels without hull, was ground and sieved through a 180 µm mesh. Moisture (American Oil Chemists Society [AOCS] protein (AOCS Ai 4 - 91), fat (AOCS Ai 3-75), and ash (AOCS Bc 5- 49) were determined following the procedures detailed by the *Official Methods and Recommended*

Practices (AOCS, 2017). Moisture content was measured using the ground kernels of each sample, previously weighed and placed in an electric stove with forced circulation at 130 °C for 75 min. All chemical results were expressed as a percentage of total dry matter (g/100 g). Total nitrogen was measured using the Kjeldahl method and protein content was calculated as N× 6.25. The equipment used consisted in a digestion unit TecatorTM Auto 1001 3844/Rev 1 (Foss Tecator, Höganäs, Sweden), scrubber unit TecatorTM 1001 4329/Rev 1 (Foss Tecator, Höganäs, Sweden), and distillation unit K-350 (Büchi, Switzerland). Fat content (Oil) was determined using a Twisselmann extraction equipment for 12 h using n-hexane as the solvent. The extract obtained was concentrated at 50 °C under reduced pressure and placed in an oven at 130 °C for 75 min. The percentage of oil was calculated by pre and post-extraction weight difference. Ash content was determined after incineration of the sample in a muffle furnace at 550 °C for 6 h. Total carbohydrates were calculated by difference following the equation: % Carbohydrates = % Protein + % Oil + % Ashes + % Moisture - 100 %.

The fat fraction was extracted from finely ground kernel samples without hull (10 g) with n-hexane in a Soxhlet apparatus for 12 h. The recovered oil was filtered to remove any possible meal contamination before its quantification, and then, saved for fatty acid analysis. Fatty acid profile (FA) was determined following the method described by Haro et al (2020). Briefly, the methyl esters of the fatty acids were prepared according to AOCS Ce 2-66 (2017) and analyzed in a gaseous chromatograph Hewlett Packard GC 6890 equipped with a detector of flame ionization and using a capillary column brand HP-INNOWax (Crosslinked Polyethylene Glycol), 0.32 mm x 30 m long and 0.5 µm thick film, according to AOCS Ce 1e-91 (2017).

Amino acid (AA) identification and quantification was performed at the Laboratory of Biochemistry and Nutrition, Food Technology Institute, at INTA Castelar (Buenos Aires, Argentina), following the methodology described by Moore et al. (1958) modified by Pazos, A. (personal communication) and described by Marioli Nobile et al. (2013). Defatted sunflower meal of each genotype sample (kernel without hull) was weighted into screw-capped hydrolysis tubes with rubber caps to prevent sample loss during hydrolysis. Amino acid separation was performed by cation exchange chromatography with post column derivatization using ninhydrin as a derivatizer. The basic principle of operation was the continuous flow chromatography procedure developed by Moore et al. (1958). Sigma AA-18 amino acid standards and L-Cysteic acid Monohydrate, L-Metionine sulphoxide, L-Methionine sulfone, Trypto&173. phan, LOrnitine monohydro-chloride, 99 % purity grade of all standards were used. Solvents and reagents were Biochrom Ltd. (Cambridge, United Kingdom).

The sugar content was expressed as sucrose, glucose and fructose (SGF) and determined following the method described by Haro et al. (2020) and analyzed by High Performance Liquid Chromatography, using an Agilent 1100 Series equipped with a standard Agilent 1100 series automatic injector. SGF sugars were separated on a Supelco NH2 column at 25 cm x 4.6 mm at a controlled temperature of 25 °C. The solvent system was acetonitrile/water (75:25 v/v) at an isocratic flow of 1.5 ml/min. The detector used was a refractive index detector (RID). Mineral measurements were determined following Marioli Nobile et al. (2016), at the National University Institute for Food Research, Development and Services, National University of Córdoba (Instituto Superior de Investigación, Desarrollo y Servicios en Alimentos, Universidad Nacional de Córdoba).

Statistical analysis

The analysis of variance and the Fisher LSD test (α= 0.05) were carried out for each trait. To detect similarities and differences between genotypes, a principal component analysis (Johnson and Wichern, 2015) was used. Pearson correlation coefficients were calculated to analyze correlations among traits. The statistical analysis was performed using InfoStat statistical software (Di Rienzo et al., 2021).

RESULTS AND DISCUSSION

Morphometric properties of the achene

Statistical significances within genotypes were found for each trait using Analysis of variance and Fisher LSD. The confectionery sunflower stands out for presenting a large seed with a mean 62 % of the grains concentrated in the caliber above 9.5 mm: 97 % of BS58INTA falls into this category, followed by 101333401 with 76 % and the commercial Grizzly with 50 %.

Other morphometric properties evaluated were the weights of achenes and unshelled seeds (Figure 2). The genotype BS58INTA had the highest weight and size of achene and seeds without shell, followed by 101333401 and 101102455, surpassing the commercial hybrid Grizzly in all the variables.

Table 1. Caliber of achene of new confectionery genotypes of *Helianthus annuus* L. from INTA Argentina, and a commercial hybrid as reference (Grizzly)

Hybrid	Achenes (%)				
	>9.5 mm	9.5-8.75 mm	8.75-8 mm	8-6.5 mm	<6.5 mm
101102455	57 bc	25 cd	14 b	3 a	1 ab
BS58INTA	97 d	1 a	1 a	1 a	0 a
101102455-1	32 a	23 c	31 c	12 b	2 b
101333401	76 c	13 b	9 ab	1 a	1 a
Grizzly	50 ab	28 d	18 b	3 a	1 ab
Mean	62	18	15	4	1

By column, different letters indicate statistically significant differences (P < 0.05).

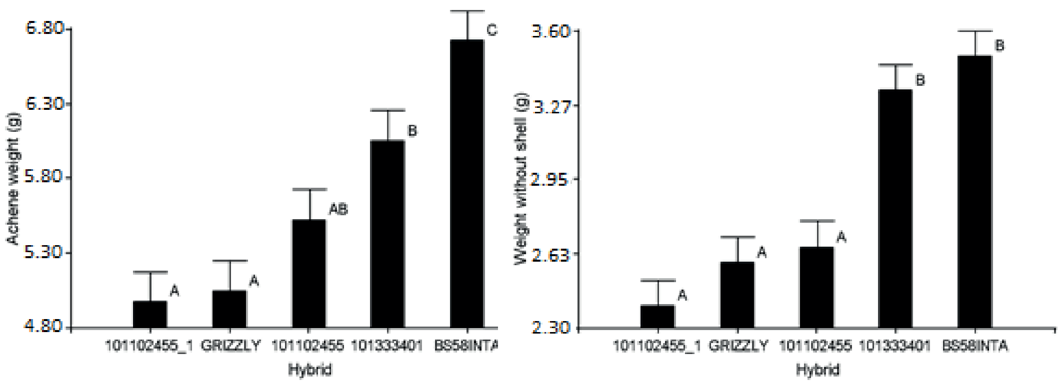

Figure 2. Weight of 50 achenes and unshelled seeds measured in new confectionery genotypes of *Helianthus annuus* L. from INTA Argentina, and a commercial hybrid as reference (Grizzly)

The results indicate the mean ± standard error. Different letters indicate statistically significant differences (p < 0.05).

Regarding length of the achene, a significant difference favoring the new genotypes with respect to Grizzle was observed (Figure 3). The length of the achenes fell in a range of 15-17 mm; while the width varied from 8 to 11 mm. Kaya (2004) affirm that confectionery sunflower seeds with peel should be at least 8-9 mm long and 2.5 cm wide in order to achieve the commercial standard (these

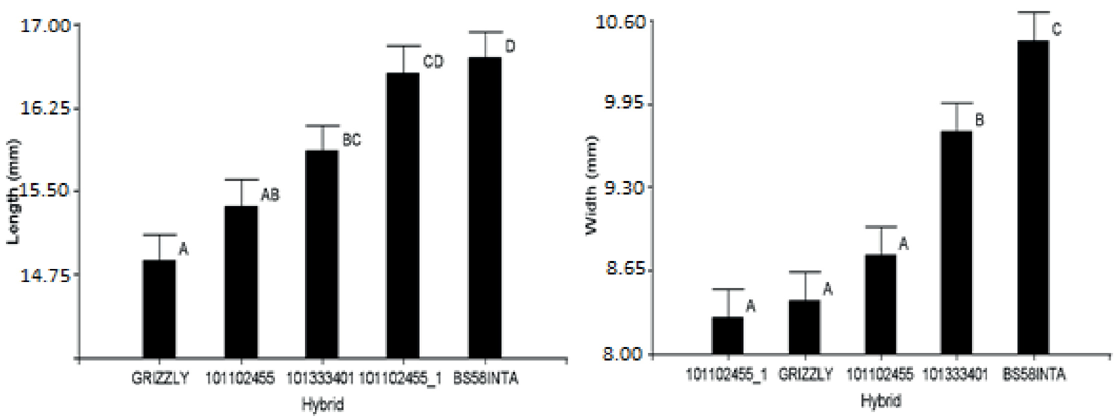

Figure 3. Length and width of achenes measured in new confectionery genotypes of Helianthus annuus L. from INTA Argentina and a commercial hybrid as reference (Grizzly)

The results indicate the mean ± standard error. Different letters indicate statistically significant differences (p < 0.05).

values have fallen behind the new INTA Hybrids).

To produce large seeds, a good genetic potential for this trait is needed. Increased seed length is one of the main goals in confectionery sunflower breeding and it can be achieved by selection. Sun (2009) found a polygenic system controlling seed length in sunflower with few quantitative trait loci (QTL) playing a key role. However, larger seeds could also be obtained by irrigation or enough rain during the growing period or by decreasing plant population per hectare, especially in normal rain-fed areas (Kaya, 2004).

The correlation analysis, which can be visualized by the angles between variable vectors in the biplot of principal component analysis (Figure 4) showed a highly significant positive correlation between achene weight and width (r=0,70**) but not with the achene length. This result is not in agreement with Hladni et al. (2011b, 2017) who reported that width had a strong negative direct effect on 1000 seed weight.

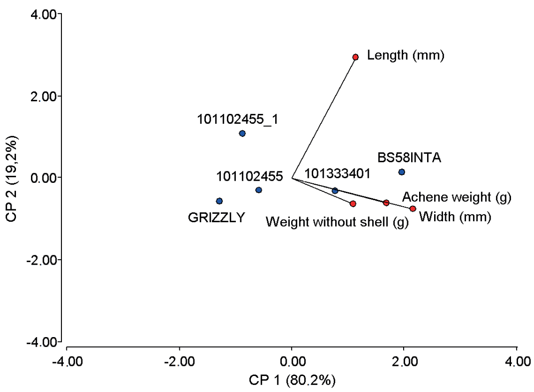

Figure 4. Principal component biplot made with new confectionery genotypes of Helianthus annuus L. from INTA Argentina, and a commercial hybrid as reference (Grizzly)

Interdependence among morphometric confectionery sunflower traits (measured by angles between trait vectors).

Seed yield

New confectionery sunflower hybrids developed by INTA obtained higher yields than the commercial control (Table 2). Seed yield is a complex polygenic trait that is highly affected by environmental factors (Nadarajan et al., 2005). According to the findings of Vanisree et al. (1988) and Kholghi et al. (2011) the yield of the seed was positively and significantly associated with the weight of the seed ($p<0.05$), while in our work the results indicated that the seed weight was negatively associated with seed yield (Figure 3 and 4, Table 2).

Table 2. Yield of confectionery genotypes of Helianthus annuus L. from INTA Argentina, and a commercial hybrid as reference (Grizzly) measured on five crop seasons

Hybrid	Yield (Kg/ha)				
	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018
101102455	1901 c	1793 d	1382 d	1533 d	2879 d
BS58INTA	1502 b	1315 b	1028 a	1169 b	1137 a
101102455_1	1476 ab	1496 c	1312 c	1486 c	1727 b
101333401	1439 a	1341 b	1484 e	867 a	2074 c
Grizzly	1491 ab	841 a	1235 b	2746 e	2969 e

Different letters in the columns indicate statistically significant differences ($p<0.05$).

Proximate composition of the seeds

Proximate composition from dehulled seeds of five hybrid genotypes of confectionery sunflower is summarized in Table 3. Seed oil content (Oil) accounted for approximately 49 % dried weight basis (DWB). The oil content found in dehulled seeds in sunflower germplasm (Table 3) resulted similar to those found by Fernández-Cuesta et al. (2012) in confectionery-type sunflowers showing values within 49.4 to 54.2%. The total protein content of sunflower seeds measured in this study was 28.60 g/100g DWB, which, compared with oil-bearing seeds, was higher than whole-seed meal from cultivated rapeseed (23–24%) and similar to conventional sunflower, which ranges between 26–34% (Park et al., 1997; Wanasundara, 2011). Seed protein content is one of the indicators of confectionery sunflower seed quality. According to Hladni et al. (2009a) protein content varies depending on the genotype, agroecological conditions and the interaction of the genotype with external environment conditions and it falls in the range between 16-28%. With larger kernels, the amount of protein in the seed also rises so breeding for increased seed protein amount should aim at the selection of genotypes with bigger kernels (Hlandi et al., 2009b). Sunflower seed proteins have high digestibility and biological value, thus the interest in their use as a component of functional foods and a nutritionally balanced diet (Petraru et al., 2021).

Higher protein yield is another crucial objective of confectionery sunflower breeding. This work did not find a significant correlation between protein content and seed yield ($p>0.05$, Table 2 and 3). However, Hladni et al. (2015) reported a positive direct effect on protein yield for hull ratio.

Soluble sugars (7.34% SGF) and Total fiber (3.86%) of the new sunflower hybrids seeds without the hull, and the commercial one were lower than the values described by Muttagi and Joshi (2020), who

Table 3. Proximate composition measured in dehulled kernels of confectionery genotypes of *Helianthus annuus* L. from INTA Argentina

Hybrid*	% Oil	% Protein	% SGF	% Ashes	% Moisture	% Total Fiber
101102455	48.4 a	27.9 ab	6.30 a	4.84 a	7.13 a	5.50 b
BS58INTA	47.4 a	29.9 b	7.80 b	4.85 a	7.51 a	2.54 a
101102455-1	48.5 a	29.2 b	7.69 b	4.87 a	7.49 a	2.23 a
101333401	53.7 b	27.0 a	6.93 a	4.30 a	6.01 a	2.09 a
Grizzly	47.3 a	26.1 a	8.02 b	4.83 a	6.79 a	6.96 c
Mean	49.1	28.0	7.34	4.75	7.02	3.86

*Seeds without the hull. SGF: sucrose, glucose and fructose. Different letters in the columns indicate statistically significant differences ($p < 0.05$).

found that crude fiber ranges from 2.86 to 4.30g 100 g. The food fiber characteristic of sunflower confectionery has demonstrated to have beneficial effects on health since it reduces the levels of cholesterol or glucose and the risk of suffering diseases such as diverticulosis, colon cancer, irritable bowel or ulcerative colitis. Ashes content showed an average of 4.75 %, which resulted similar to the values described by Martínez-Force et al., 2015).

The content of minerals such as magnesium oscillated between 5054 and 5879 µg/g and calcium between 1292 and 1989 µg/g (Table 4). The amount of potassium fluctuated between 10335 µg/g and 13401 µg/g. The macronutrient values of new genotypes were similar to the commercial cultivar, except for the hybrid 101102455 which showed the highest performance in all three macronutrients. For the copper element, the quantities obtained ranged from 20.4 to 24.1 µg/g, which are lower than Grizzle (25.1 µg/g). From the manganese and iron measurements as well as cobalt, selenium and molybdenum, the new hybrids showed higher contents than Grizzly. Muttagi and Joshi (2020) found contents of 11.4, 14.3 and 17.5 µg/g for Cu, Fe and Mn respectively, which are significantly smaller than the values found in this study. The zinc content was 55.0-60.5, similar to those reported by Oerise et al. (1974). The toxic lead elements showed values under the detection limit of the method (LDM), while values for cadmium were low in all Argentinian sunflower genotypes. The average values of Cd and Pb were less than 50 ng/g (nanogram per gram), which represent values much lower than those considered a risk for human consumption (Marioli Nobile et al., 2016).

Fatty acid profile

The fatty acid profile of five confectionery sunflower hybrids' unshelled seeds is shown in Table 5. The oil (MG) contained mainly linoleic and oleic fatty acids, followed by saturated fatty acids, palmitic and stearic.

Table 4. Mineral composition in dehulled kernels of confectionery genotypes of *Helianthus annuus* L. from INTA Argentina

Nutrients		Hybrid*				
(µg/g)		101102455	BS58INTA	101102455-1	101333401	Grizzly*
	Mg	5879 c	5490 b	5054 a	5067 a	5073 a
Macro	K	13401c	10667a	10761a	10335 a	11549 b
	Ca	1989 d	1292 a	1767 c	1628 b	1610 b
	Al	26.8 d	0.67 a	18.9 c	4.9 b	0.51 a
	Mn	45.0 b	47.0 b	42.3 b	41.5 b	32.0 a
	Fe	48.8 b	50.9 b	70.0 c	30.6 a	56.0 b
	Co	0.23 c	< LCM	0.06 a	0.14 b	< LCM
	Cu	24.1 a	22.0 a	20.4 a	22.2 a	25.1 a
Micro	Zn	55.0 a	60.0 a	60.5 a	59.2 a	70.2 b
	Se	0.86 b	0.57 a	0.51 a	0.62 a	0.57 a
	Mo	1.13 b	0.75 a	0.87 a	0.87 a	< LDM
	Cd	0.26 a	0.21 a	0.21 a	0.27 a	0.18 a
	Pb	< LDM	< LDM	< LDM	< LDM	< LDM
	Na	< LDM	92.0 a	86.0 a	< LDM	101.0 b

*Seeds without the hull. Mineral content expressed as mean values of µg/g. Different letters in the columns indicate statistically significant differences ($p < 0.05$).

Table 5. Fatty acid content measured in confectionery genotypes of Helianthus annuus L. from INTA Argentina

FATTY ACIDS	Content %				
	101102455	BS58INTA	101102455-1	101333401	Grizzly
C16:0 (palmitic)	6.15 ab	6.45 b	5.8 a	5.35 a	5.39 a
C18:0 (estearic)	3.19 a	3.16 a	3.47 a	3.51 a	3.83 a
C18:1 (oleic)	28.1 a	27.2 a	31.4 b	47.1 c	31.6 b
C18:2 (linoleic)	60.7 c	61.2 c	57.4 b	42.2 a	57.2 b
C18:3 (linolenic)	0.14 a	0.16 a	0.12 a	0.08 a	0.12 a
C20:0 (arachidic)	0.29 a	0.29 a	0.31 a	0.30 a	0.31 a
C20:1 (eicosenoic)	0.17 a	0.17 a	0.19 a	0.19 b	0.19 a
C22:0 (behenic)	0.81 a	0.82 a	0.84 a	0.89 a	0.89 a
C22:1 (erucic)	0.09 a	0.09 a	0.08 a	0.09 a	0.09 a
C24:0 (Lignoceric)	0.35 a	0.36 a	0.37 a	0.36 a	0.38 a
O/L	0.46 a	0.44 a	0.54 a	1.13 b	0.55 a
IY	136.0 b	136.2 b	132.8 b	119.3 a	132.9 a
∑SFA[a]	10.8 a	11.1 a	10.9 a	10.4 a	11.0 a
∑MUFA[b]	28.4 a	27.5 a	31.6 b	47.3 c	31.5 b
∑PUFA[c]	60.8 c	61.4 c	57.5 b	42.3 a	57.5 b

Content is expressed as mean values in percentage. Different letters for the rows indicate statistically significant differences ($p < 0.05$).
[a]Saturated fatty acids [b]Monounsaturated fatty acids [c]Polyunsaturated fatty acids.

The most abundant fatty acids in the sunflower seed of new confectionery germplasms were linoleic (54%) and oleic acids (averaging 35 %), followed by palmitic acid (6 % in average) and stearic acid (3% in average), which together accounted for 98% of the total fatty acids. The new confectionery sunflower named 101333401 presented mid-oleic with oleic values of 47.1% (Table 5). The results found in this research are similar to those described by Fernández-Cuesta et al. (2012) who reported that sunflower oil naturally has a fatty acid profile consisting of palmitic acid (4-8% of total fatty acids), stearic acid (2-6%), oleic acid (20-45%), and linoleic acid (45-70%). Similar results were reported by Rosa et al. (2009) in dehulled sunflower seeds from Brazilian varieties developed by EMBRAPA.

Amino acid profile

Table 6 shows the amino acid composition from dehulled whole (not defatted) ground seeds of the sunflower genotypes. The results indicated that the essential amino acids represented between 5 % and 7 % of the total amino acid content, percentages lower than those recommended by FAO/WHO/UNU (Livesey, 1987). Leucine had the highest amino acid score, followed by phenylalanine, valine and lysine; while tryptophan ranked last.

The non-essential amino acids represented 12 % to 15 % of the total amino acid content. The highest levels were recorded for glutamine, followed by arginine, asparagine, glycine, serine, alanine and proline. Rosa et al. (2009) found similar results for amino acid values.

Sugar content

The sugar content in sunflower seeds fluctuated between 6.3-7.8 g/g% dry weight. Hybrids BS58INTA, 101102455_1, and Grizzly presented a higher concentration of total sugars (Table 7). Most of the four new hybrids surpassed Grizzly regarding fructose content; BS58INTA surpassed it regarding sucrose. Sucrose and mainly fructose are mostly responsible for the sweet flavor.

Synthetizing the main results of this research, it was found that the mean values of morphometric properties for the in-shell seed (achenes) were the following: weight 0.11 g; length 15.2 mm; and width 8.50 mm, with most seeds having calibers greater than 9.51 mm and a weight of 0.06 g for the unshelled seed. Proximate analysis indicated that confectionery sunflower seeds without shell are an unusually rich source of lipids (49%) as well as proteins (28%), carbohydrates (11%), and minerals (4.8% ashes), all expressed on dry weight basis (DWB). Potassium was the predominant mineral, followed by magnesium and calcium. Fatty acid composition showed that polyunsaturated fatty acids were the major components (56%) followed by monounsaturated ones (34%), and saturated ones (11%). Mid-oleic genotype 101333401 developed by INTA resulted in significantly greater oleic acid (47%) and lower linoleic acid (42%) content than the widely dispersed commercial

Table 6. Content of amino acids in dehulled whole kernels of confectionery genotypes of *Helianthus annuus* L. from INTA Argentina

ESSENTIAL AMINO ACIDS	Amino acid content (g/100g)				
	101102455	BS58INTA	101102455-1	101333401	Grizzly
Histidine (His)	0.55 a	0.68 a	0.66 a	0.68 a	0.62 a
Isoleucine (Ile)	0.65 a	0.87 a	0.81 a	0.82 a	0.74 a
Leucine (Leu)	1.18 a	1.41 a	1.46 a	1.42 a	1.31 a
Lysine (Lys)	0.80 a	0.84 a	0.91 a	0.83 a	0.82 a
Methionine (Met)	0.28 a	0.42 b	0.47 b	0.27 a	0.14 a
Phenylalanine (Phe)	0.85 a	1.14 b	1.14 b	1.09 ab	0.97 a
Threonine (Thr)	0.67 a	0.68 a	0.78 a	0.79 a	0.79 a
Tryptophan (Trp)	LDM	0.15 a	0.10 a	0.15 a	0.11 a
Valine (Val)	0.85 a	1.08 a	1.00 a	1.05 a	0.94 a
NONESSENTIAL AMINO ACIDS					
Alanine (Ala)	0.90 a	0.97 a	1.07 a	1.03 a	0.94 a
Asparagine (Asp)	1.75 a	2.10 b	2.06 b	2.17 b	2.03 b
Glutamine (Glu)	3.69 a	4.58 b	4.80 bc	5.04 c	4.51 b
Arginine (Arg)	1.59 a	2.14 c	2.23 c	2.08 bc	1.92 b
Cysteíne (Cys)	0.33 a	0.42 a	0.37 a	0.47 a	0.41 a
Tyrosine (Tyr)	0.57 a	0.67 a	0.70 a	0.69 a	0.61 a
Glycine (Gly)	1.08 a	1.24 b	1.34 b	1.36 b	1.25 b
Ornitine (Orn)	0.04	LDM	LDM	LDM	LDM
Proline (Pro)	0.86 a	0.97 a	0.79 a	1.03 a	1.02 a
Serine (Ser)	1.07 a	1.24 ab	1.19 a	1.30 b	1.22 a
Total essential AA	5.83 a	7.27 c	7.33 c	7.10 c	6.44 b
Total nonessential AA	11.88 a	14.33 c	14.55 c	15.17 d	13.91 b
Total Essential AA / Total AA	32.91 b	33.65 c	33.50 c	31.88 a	31.64 a

By row, different letters indicate statistically significant differences ($p < 0.05$). LDM: limit of detection of the method.

Table 7. Sugar content in grains of confectionery dehulled and defatted kernels of *Helianthus annuus* L. hybrids from INTA

Hybrid	Fructose	Glucose	Sucrose	Total sugars
101102455	1.24 c	1.14 b	3.92 a	6.30 a
BS58INTA	0.47 a	0.51 a	6.82 c	7.80 b
101102455_1	1.12 c	1.15 b	5.42 b	7.69 b
101333401	0.82 b	0.68 a	5.43 b	6.93 a
*Grizzly	0.73 b	0.86 a	6.43 c	8.02 b

Content is expressed as mean values (g/g% dry weight). For the column total sugars. hybrids with a common letter are not significantly different ($p > 0.05$). * Grizzly is a commercial hybrid used as reference.

cultivar. Confectionery sunflower seed proteins were a rich source of essential amino acids (33 % of the total amino acid content). Sunflower seeds also contained significant amounts of some essential macro-elements (K, Mg, Ca) and micro-elements (Mn, Fe, Cu, Zn, Se, Co, Mo, Na). Total amount of fiber and sugars were 3.9 % and 7.3 %, respectively.

CONCLUSIONS

Based on the general nutritional profile and essential components such as minerals, amino acids, protein and healthy fats, the new confectionery sunflower hybrids have value-added potential as a source of edible oil, proteins for food and snack supplements of industrial applications. The fatty acids contain mainly linoleic fatty acid with a great contribution of oleic acid. The sunflower hybrid 101333401 resulted in higher oleic acid, amino acid and fructose contents than the commercial one Grissly, being those nutritional variables important features for food bioproducts. It surpasses the properties of the commercial confectionery hybrid Grizzly and constitutes a good resource for nutritional and industrial applications.

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