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SEED TRAITS IN CONFECTIONERY TYPE SUNFLOWER VARIETIES AND HYBRIDS

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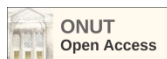
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Introduction. Formulation of the problem

In the global production of sunflower, the share of large-seed and confectionery varieties is increasing, and in recent years it has remained at the level of 4–5% of the cultivated area [1]. Modern studies of proteins from oilseeds and grist significantly expand the source of food protein for human consumption [2-4].

The largest sown areas of large-fruited sunflower are noted in Turkey and China. In these countries, production has been developed for consumption in the

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Abstract. In the global production of sunflower, the share of large-seed and confectionery varieties is constantly increasing due to their high nutritional value. In many countries, the replacement of varieties with high-yield confectionery hybrids is being actively implemented to increase the cultivated area. In Ukraine, to satisfy the high demand for confectionery sunflower, large-sized fractions of oilseed varieties and hybrids are usually used, but such raw materials often do not meet the requirements due to their biochemical composition, therefore the use and cultivation of varieties and hybrids of the confectionery type is being actively developed. In the article, a comparative analysis of the indicators of seeds and kernels, which determine the taste qualities and usefulness for health when consumed as food, is carried out in different varieties and hybrids of sunflower. As a result of the study, it was established that among the six genotypes studied, the highest values of the weight of 1000 seeds and kernels were the 'Zaporizkyi kondyterskyi' variety, 121.7 g and 82.5 g, respectively. High values according to these indicators, which correspond to the demands of the confectionery and food industries, were obtained by the confectionery variety 'Kamelot' and hybrids 'Smak' and 'Kosmos'. It was found that the oil hybrid 'Rehion' (51.3%) and the variety 'Prometei' (49.7%) had the highest oil content in the seeds, the confectionery hybrids 'Smak' (20.2%) and 'Kosmos' (20.2%) were characterized by the highest protein content, and the total amount of oil and protein in the seeds of all studied genotypes exceeded 60%. The highest values of oil (52.2 g) and protein (19.1 g) per 1,000 kernels were found in the 'Zaporizkyi kondyterskyi' variety. The highest yield of 3.02 t/ha was obtained in the 'Kamelot' variety, which also provided the highest yield of kernels of 2.26 t/ha of large size and the highest yield of 1.658 t/ha of total oil and protein per unit area of cultivation.

Key words: confectionery sunflower, variety, hybrid, oil content, protein content.

form of fried seeds and confectionery products from whole kernels or crumbs [5-9]. It is very difficult to track the information on the planted area under confectionery sunflower, because usually the total area under sunflower crops is indicated. But there is a high demand for the production of confectionery sunflower due to its high nutritional value. That is why in the countries of Eastern Europe it is proposed to replace the varieties with high-yielding confectionery hybrids to increase the cultivated area [10].

A similar trend is observed in Ukraine. There is no accurate information on the area of sowing of large-

fruited sunflower varieties according to statistical reporting, since farms do not allocate the share of these varieties from the total volume of produced products. But this segment is economically attractive and already around 9% of farms sow confectionery varieties up to 100% of the total area under sunflower [11]. For sale, these farms offer calibrated product in large batches.

Currently, in Ukraine, to satisfy the demand for confectionery sunflower, large-seed fractions of oil varieties and hybrids are usually used, but such raw materials often do not meet the requirements due to high oil content and small seed mass. The demand for large-fruited sunflower seeds for the food and confectionery industry in our country is stable and high, therefore the use and cultivation of varieties and hybrids of the confectionery type can be considered a separate direction that is developing very actively.

Analysis of recent research and publications

The variety of directions for the use of sunflower confectionery forms and the growing market stimulated the deployment of selection programs in many countries of the world. If in the late 1990s and early 2000s these were breeding programs for the creation of large-seed varieties, hybrids have been appearing more and more actively in the last ten years. The transition to heterosis selection and the creation of confectionery hybrids is complicated by a decrease in the size of seeds and a decrease in yield compared to varietal selection, which is associated with the genetic control of these traits. But the constant high commercial success in the cultivation of hybrids, due to uniformity and better suitability for harvesting, leads to the expansion of breeding programs for the creation of hybrids both in Ukraine and in the world [12-14].

Analysis of changes in the assortment of varieties and hybrids of confectionery sunflower in the Register of Plant Varieties of Ukraine shows a significant increase in the varieties of this direction over the past twenty years. Thus, in 2006, five genotypes were presented, including one variety and two hybrids of foreign selection. In 2016, the assortment expanded to include seventeen genotypes, including 6 varieties and eleven hybrids, two of which were created in Ukraine. Since 2022, the Register already includes twenty-three genotypes. Only five of them are varieties and all of them are of Ukrainian selection. And eighteen are hybrids, of which only three ('Smak', 'Kosmos' and 'Fenom') are of Ukrainian origin, and the other fifteen are of foreign selection [14]. Such an active expansion of the varietal range indicates a high demand among seed producers and significant economic profitability of the production of this type of crop. A large number of foreign hybrids and increase of their number emphasizes the relevance

of such breeding programs. It is important to note the constant presence in the Register of the Zaporizhzhya Confectionery variety, which was bred at the Institute of Oilseed Crops of the National Academy of Sciences of Ukraine and registered in 1998.

Confectionery sunflower is a large-seeded form of this crop with specific properties and quality of seeds such as size, color, shell quality, etc. When processing seeds, usually the largest fraction of seeds enters the market in unbroken raw or toasted form and is sold as a light snack. This part makes up about 25% of the total volume of confectionery sunflower production. A smaller average fraction of seeds with a weight of 1000 kernels over 80 g is used for de-shelling, the share of which is 60% of the total mass. Most often, those kernels are packaged and sold in fried and salted form, or in raw, unsalted form for use as salad ingredients, for baking bread and in culinary products [15].

The nutritional value of confectionery sunflower kernels allows them to be included in the category of health products. One of the main features is the high content of iron, zinc, potassium, thiamin, vitamin E. In addition, they are also a source of dietary fiber. Sunflower seeds contain a reduced amount of saturated fatty acids, which lowers the level of cholesterol in the blood [16].

The smallest fraction of confectionery sunflower seeds is from 15 to 20% of the total mass. It is used as feed for birds and small pets both in its pure form and in various mixtures [17,18].

In Ukraine, the main consumers of sunflower are confectionery factories, food factories, engaged in the production of halva. Halva with the best taste qualities, balanced in terms of oil and protein content, is obtained from confectionery sunflower seeds [19]. It is promising to use seed kernels as a substitute for nut raw materials, which is widely practiced in the countries of Western Europe, but has not yet been used in Ukraine [20]. Most of the confectionery and large-fruited sunflowers seeds produced in Ukraine are exported to the countries of the European Union, where they are used in the confectionery industry to obtain kernels [11,21].

Cultivation of large-fruited and confectionery sunflowers is of obvious economic interest due to the 1.5–2.0 times higher purchase price for these products compared to traditional varieties. But success in growing confectionery sunflower with a high protein content depends not only on domestic geneticists and breeders, but also to a large extent on agronomists, harvesters, traders and processors.

In this regard, **the purpose** of our study was to compare the indicators of seeds and kernels, which determine the taste qualities and health benefits when consumed as food, in different varieties and hybrids of sunflower.

Objectives of the study:

- to determine the weight of seeds and kernels of different varieties and hybrids of sunflower.
- investigate the indicators of oil and protein content in the seeds and kernels of the studied genotypes.
- to establish and compare indicators of productivity and output of total oil and protein from a unit of cultivation area in studied varieties and hybrids.

Research materials and methods

Genetically pure material included from the collection of the laboratory of genetic resources of the Institute of Oilseed Crops of the National Academy of Agrarian Sciences of Ukraine – confectionery sunflower varieties ‘Zaporizkyi kondyterskyi’ (year of registration 1998, originator Institute of Oilseed Crops, Ukraine, Zaporizhzhia) and ‘Kamelot’ (2019, originator Institute of Oilseed Crops, Ukraine, Zaporizhzhia) was used for research and confectionary hybrids ‘Kosmos’ (2021, originator of the Institute of Crop Production, Ukraine, Kharkiv) and ‘Smak’ (2015, originator Institute of Oilseed Crops, Ukraine, Zaporizhzhia). For comparison, the usual oilseed hybrid ‘Rehion’ (2011, originator of the Institute of Oilseed Crops, Ukraine, Zaporizhzhia) and the variety ‘Prometei’ (2015, originator Institute of Oilseed Crops, Ukraine, Zaporizhzhia)

The seeds of hybrids and varieties were studied for oil content [DSTU 7577:2014. Nasinnia oliine], weight of 1000 seeds [HOST 12042-80 Semena selskokhoziaistvennukh kultur], shell ratio, and protein content [DSTU ISO 5983:2003. Kormi dla tvarin].

To establish a field experiment and the yield of hybrids and varieties, generally accepted methods were used [22].

Experiments were performed in triplicate. Statistical analysis of the results was performed using Libre Office Calc.

Results of the research and their discussion

The main plant breeding traits that distinguish confectionary sunflower varieties and hybrids from oilseeds include, first of all, the size and weight of the seeds, because this sunflower is grown for the consumption of seed kernels, and not for obtaining oil. The mass of 1,000 seeds should be at least 80 g. In addition, in confectionary sunflower, the kernel does not fit as tightly to the shell as in oil sunflower, and therefore the shell ratio is quite large and amounts to 30–40%. In our research, the highest value of the weight of 1000 seeds was 121.7 g for ‘Zaporizkyi confectionery’ variety (Table 1). Sufficiently high seed weight indicators were also noted for the ‘Kamelot’ variety, 98.6 g, and the ‘Smak’ hybrid, 93.4 g.

An equally important indicator for confectionery use is the mass of kernels, which depends on both the size of the seed and its shell ratio. Thus, in the studied varieties and hybrids, the shell ratio varied and ranged from 22.5% to 32.2%. At the same time, the highest percentage of shell ratio was noted in the ‘Zaporizkyi kondyterskyi’ variety, while the others were significantly inferior in terms of this indicator.

Taking into account the weight of 1000 seeds and shell ratio, the weight of 1000 kernels in the studied varieties and hybrids differed significantly and ranged from 37.3 g to 82.5 g. In the case of oil genotypes, the weight of 1000 kernels was the smallest and was 37.3 g for the ‘Rehion’ hybrid and for the ‘Prometei’ variety – 46.2 g. In confectionary hybrids, the mass of 1000 kernels was significantly higher and it was 60.1 g for ‘Kosmos’, and 72.1 g for ‘Smak’. And in confectionary varieties, this indicator was the highest for ‘Kamelot’ – 73.7 g, and 82.5 g for ‘Zaporizkyi kondyterskyi’ and exceeded the oil genotypes by almost two times. Thus, in terms of the size of the kernels, regardless of the high shell ratio, the highest value was noted for the ‘Zaporizkyi kondyterskyi’ variety. It is important to emphasize that confectionary varieties and hybrids are valued in the food industry for their large kernels.

Table 1 – Indicators of the mass of seeds and kernels of different varieties and hybrids of sunflower

Variety, hybrid	Mass of 1000 seeds, g	Shell ratio, %	Kernel, %	Mass of 1000 kernels, g
‘Zaporizkyi kondyterskyi’ ¹	121.7	32.2	67.8	82.5
‘Kamelot’ ¹	98.6	25.3	74.7	73.7
‘Smak’ ²	93.4	22.8	77.2	72.1
‘Kosmos’ ²	78.7	23.6	76.4	60.1
‘Prometei’ ³	59.6	22.5	77.5	46.2
‘Rehion’ ⁴	49.2	24.1	7.9	37.3
<i>LSD</i> _{0,5}	2.7–3.4	0.4–0.8	0.6–1.1	1.9–2.6

Notes: ¹ – confectionary variety; ² – confectionary hybrid; ³ – oilseed variety; ⁴ – oilseed hybrid

In addition to the size of the seeds for confectionary sunflower, such indicators as the content of oil and protein in the seed and kernel and their ratio are important. In the seeds of modern sunflower varieties and hybrids, the oil content is on average 49.0–52.0%, and the protein content is 16.0–18.0%, so their sum is 67.0–69.0%. The oil content of confectionary genotypes is lower than that of oilseed genotypes and is 40.0–45.0%, with protein up to 20.0% [23, 24].

According to our data, the oil content in the seeds was 42.9–51.3%, and the protein content was 15.7–20.2%, depending on the genotype. Their total content in seeds was 58.6–68.0% (Table 2). According to the data we received, the highest oil content in the seeds was noted for hybrid ‘Rehion’ (51.3%) and the variety ‘Prometei’ (49.7%). And confectionary hybrids ‘Smak’ (20.2%) and ‘Kosmos’ (20.0%) were characterized by the highest protein content. The total amount of oil and protein in the seeds of most studied genotypes of sunflower exceeds 60%.

According to other researchers, the protein content in sunflower seeds is a very variable trait. In modern varieties, its content can vary from 9.5 to 25.0%. Almost all researchers indicate a positive correlation between protein content in sunflower seeds and the weight of 1000

seeds, and a negative correlation between protein content and oil content [23,24].

For the confectionery and food industries, the content of oil and protein in the kernel is more important. In our studies, depending on the genotype, the content of oil in the kernel was between 57.6% and 67.8%, and protein between 21.8% and 26.2%. Thus, their total had the main share of the nucleus and it was equal to 83.5–89.8%.

Taking into account the mass of sunflower kernels and the content of oil and protein in them, the mass of oil from 1000 kernels was in the range from 25.3 g to 52.2 g. The mass of protein from 1000 kernels was between 8.2 g and 19.1 g (Figure 1). We noted that the highest values of these indicators were for ‘Zaporizkyi kondyterskyi’ variety, which is associated with the largest mass of 1000 kernels in this variety.

It is important to emphasize that the reserve proteins of sunflower have high digestibility (90%) and biological activity (60%), which favorably differs from most vegetable proteins, including soy protein. The quality of sunflower protein in the composition of essential amino acids is not inferior to soy protein, which is considered the standard for protein quality. And in terms of some amino acids (histidine, lysine), sunflower protein exceeds such crops as wheat and corn [25].

Table 2 – Indicators of oil and protein content in seeds and kernels of different varieties and hybrids of sunflower in comparison with the standard variety

Variety, hybrid	Content in seeds, %			Content in kernels, %		
	oil	protein	oil and protein combined	oil	protein	oil and protein combined
‘Zaporizkyi kondyterskyi’ ¹	42.9	15.7	58.6	63.3	23.2	86.5
‘Kamelot’ ¹	46.1	16.3	62.4	61.7	21.8	83.5
‘Smak’ ²	47.7	20.2	67.9	61.9	26.2	88.1
‘Kosmos’ ²	44.0	20.0	64.0	57.6	26.1	83.7
‘Prometei’ ³	49.7	17.1	66.8	64.1	22.1	86.2
‘Rehion’ ⁴	51.3	16.7	68.0	67.8	22.0	89.8
<i>LSD</i> _{0.5}	0.3–0.6	0.1–0.3	0.4–0.8	0.4–0.6	0.2–0.4	0.4–1.0

Notes: ¹ – confectionary variety; ² – confectionary hybrid; ³ – oilseed variety; ⁴ – oilseed hybrid

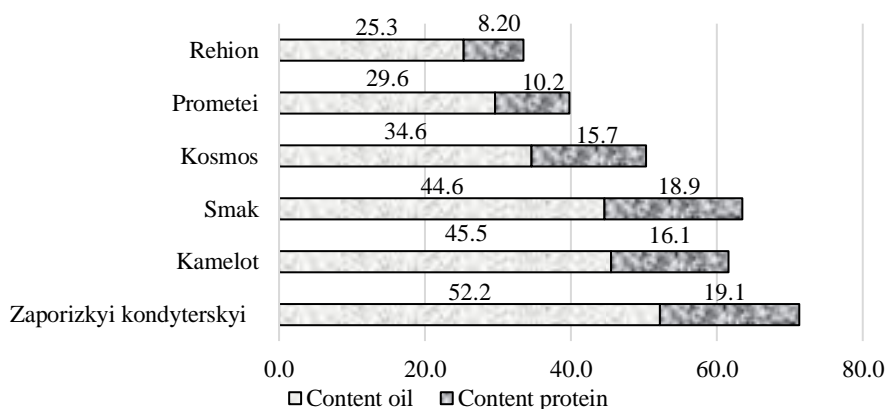


Fig.1. Mass of oil and protein from 1000 kernels of sunflower varieties and hybrids studied, g

In our opinion, the ratio of the mass of oil to the mass of protein in sunflower kernels is also interesting (Table 3). Thus, in oilseed genotypes, this indicator is close to three and is 2.9 in 'Prometei' and 3.09 in 'Rehion', which indicates a significant excess of the mass of oil over the mass of protein in the kernel. In confectionery varieties, this indicator is lower and is 2.83 for 'Kamelot' and 2.73 for 'Zaporizkyi kondyterskyi'. This ratio is the smallest in confectionery hybrids – 2.36 for 'Smak' and 2.20 for 'Kosmos', which indicates the most balanced content of protein and oil in the seed kernel. When the oil content in the kernel is reduced to 60%, negative evaluations occur when tasting fried seeds, because the seeds do not become sufficiently sweet and tasty. Therefore, preserving not only protein, but also a sufficient amount of oil is important for the food industry in order not to attract additional flavor impurities [23,24].

The variability of the protein content in sunflower seeds is significantly influenced by the ecological conditions of the place of cultivation and the weather conditions of the year. Unfavorable conditions for oil synthesis (high air temperature, lack of moisture in the soil) contribute to an increase in protein. In the conditions of the South of Ukraine in dry years, irrigation provides an increase in oil yield by 0.6–0.9 t/ha, and protein yield by 0.25–0.40 t/ha. The protein content of sunflower seeds when

grown under irrigation increases by an average of 7% compared to rainfed [26].

The area of plant nutrition has a great influence on the protein content. The expansion of the row spacing, as well as the increase in the distance between plants in a row (when sowing with a width of 70 cm between the rows), is accompanied by an increase in the size of the seeds and the protein content of the seeds. Thickening of sowing, on the contrary, leads to a decrease in the area of plant nutrition, increases the oil content and decreases the protein content of the seeds [27-30].

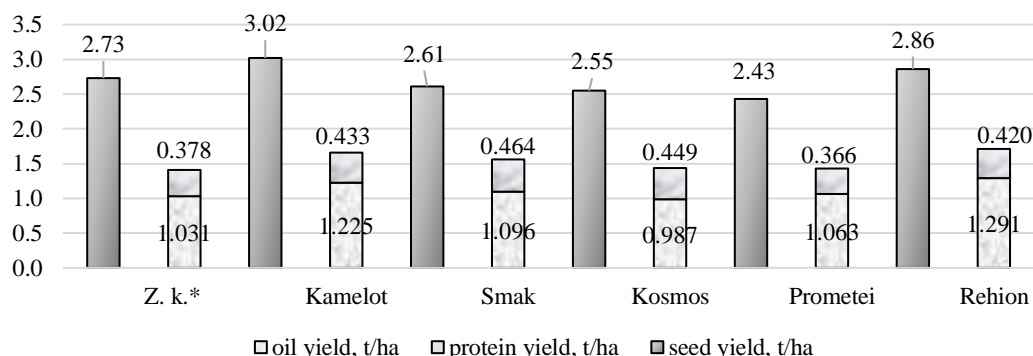
The use of nitrogen fertilizers on almost all types of soil is accompanied by an increase in sunflower yield. But at the same time, the absolute content of oil in seeds decreases, and protein content increases [31-33].

Considering the yield indicators of sunflower seeds, we noted that confectionery type varieties were almost not inferior to the studied oilseed genotypes (Figure 2). Thus, the highest yield of 3.02 t/ha was obtained in the 'Kamelot' variety. The oilseed type hybrid 'Rehion' 2.86 t/ha and the variety 'Zaporizkyi kondyterskyi' 2.73 t/ha also had high indicators. Confectionery-type hybrids 'Smak' and 'Kosmos' had lower yield rates of 2.61 t/ha and 2.55 t/ha, respectively. But the yield level of all sunflower genotypes in our research ensures high economic indicators of its cultivation.

Table 3 – Indicators of the mass of oil and protein in the kernel of different varieties and hybrids of sunflower

Variety, hybrid	Mass of oil from 1000 kernels, g	Mass of protein from 1000 kernels, g	Ratio of mass of oil / mass of protein
'Zaporizkyi kondyterskyi' ¹	52.2	19.1	2.73
'Kamelot' ¹	45.5	16.1	2.83
'Smak' ²	44.6	18.9	2.36
'Kosmos' ²	34.6	15.7	2.20
'Prometei' ³	2.6	10.2	2.90
'Rehion' ⁴	25.3	8.2	3.09
LSD _{0.5}	0.4–0.7	0.1–0.2	

Notes: ¹ – confectionary variety; ² – confectionary hybrid; ³ – oilseed variety; ⁴ – oilseed hybrid



Note: * 'Zaporizkyi kondyterskyi'

Fig.2 Indicators of seed yield, yield of oil and protein of the researched varieties and hybrids, t/ha

Indicators of yield of seed kernels are directly related to the level of productivity, which is very important for meeting the demand of the confectionery and food industries. Thus, the largest yield of large sized kernels of 2.26 t/ha for confectionary use was formed by the 'Kamelot' variety. The hybrids 'Smak' with 2.02 t/ha and 'Kosmos' with 1.95 t/ha have slightly lower indicators. The lowest yield of kernels was obtained for the 'Zaporizkyi kondyterskyi' variety, 1.85 t/ha, but this is compensated by its largest kernels.

Regarding the total yield of oil and protein per unit area of sunflower cultivation, the 'Kamelot' variety stands out significantly, the cultivation of which ensures the production of 1.658 t/ha of total oil and protein. The 'Rehion' oil hybrid also has high indicators, but at the expense of high oil content, which is important for the oil industry.

Varieties 'Zaporizkyi kondyterskyi' and 'Prometei' and hybrids 'Smak' and 'Kosmos' were previously studied with our participation, but without comparison with varieties and hybrids of the oilseed type [34]. Cantisán S.'s research also showed that confectionary varieties have a larger seed size compared to oil varieties [35]. However, in this study, the main aspect was the study of correlations of traits with the composition of fatty acids in the oil. In our study, we did not take into account the fatty acid composition of the oil, since the varieties in our study did not have mutations that changed the composition of the oil.

Modern research by Chinese scientists on the search for molecular markers and genes for the weight of 100 seeds is known [36]. Unfortunately, the studies used a small amount of genetic diversity and cannot compare the quality of seeds of varieties of different uses, as it was done in our study.

Conclusions

In the group of investigated varieties and hybrids, the highest values of the weight of 1000 seeds and kernels were 121.7 g and 82.5 g, respectively. High values according to these indicators, which correspond to the demands of the confectionery and food industries, were obtained by the confectionery type variety 'Kamelot' and the hybrids 'Smak' and 'Kosmos'. Oil type genotypes had the smallest size of seeds and kernels.

The hybrid 'Rehion' (51.3%) and the variety 'Prometei' (49.7%) had the highest oil content in the seeds, while the confectionery hybrids 'Smak' (20.2%) and 'Kosmos' (20.0%) were characterized by the highest protein content, and the total amount of oil and protein in the seeds of the studied genotypes exceeded 60%.

The highest values of oil content (52.2 g) and protein content (19.1 g) per 1,000 kernels were found in the 'Zaporizkyi kondyterskyi' variety, which is associated with the largest mass of this variety.

The index of the ratio of the mass of oil to the mass of protein in sunflower kernels in confectionary hybrids and varieties was 2.20–2.83, which indicates a more balanced content of protein and oil in the seed kernel, compared to oilseed genotypes.

The highest yield of 3.02 t/ha was obtained in the 'Kamelot' variety, which also provided the highest yield of large sized kernels of 2.26 t/ha and the highest yield of 1.658 t/ha of total oil and protein per unit area of cultivation. Confectionery-type hybrids 'Smak' and 'Kosmos' and the variety 'Zaporizkyi kondyterskyi' had lower productivity indicators, but nevertheless, this level of productivity ensures high economic indicators of their cultivation.

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ОСОБЛИВОСТІ НАСІННЯ СОНЯШНИКУ СОРТІВ І ГІБРИДІВ КОНДИТЕРСЬКОГО ТИПУ

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Анотація. У світовому виробництві соняшнику частка великоплідних та кондитерських сортів постійно збільшується через його високу харчову цінність. У багатьох країнах для збільшення посівних площ активно впроваджується заміна сортів високопродуктивними кондитерськими гібридами. В Україні для задовільнення високого попиту на кондитерський соняшник зазвичай використовують великі за розміром фракції олійних сортів і гібридів, але така сировина часто не відповідає вимогам по біохімічному складу, тому використання і вирощування сортів і гібридів саме кондитерського типу інтенсивно розвивається. У статті проведено порівняльний аналіз показників насіння та ядер, які визначають смакові якості і корисність для здоров'я при споживанні в їжу, у різних сортів та гібридів соняшнику. В результаті дослідження встановлено, що серед досліджуваних шести генотипів, найвищі значення маси 1000 насінин та ядер мав сорт 'Запорізький кондитерський' 121,7 г та 82,5 г, відповідно. Високі значення за цими показниками, які відповідають запитам кондитерської та харчової промисловостей, мали сорт кондитерського типу 'Камелот', й гібриди 'Смак' і 'Космос'. Виявлено, що найбільший вміст жиру в насінні мали олійні гібрид 'Реґіон' (51,3%) та сорт 'Прометей' (49,7%), найбільшим вмістом білку характеризувалися кондитерські гібриди 'Смак' (20,2%) та 'Космос' (20,0%), а загальна сума жиру і білка в насінні усіх досліджуваних генотипів перевищувала 60%. Найвищі значення вмісту жиру (52,2 г) та білку (19,1 г) в 1000 ядер виявлено у сорту 'Запорізький кондитерський'. Найвищу урожайність 3,02 т/га отримано у сорту 'Камелот', що забезпечило також і найбільший вихід ядер 2,26 т/га великого розміру і найвище отримання 1,658 т/га сумарного жиру та білку з одиниці площі вирощування.

Ключові слова: соняшник кондитерський, сорт, гібрид, вміст жиру, вміст білку.