UDC [635.35:631.526.325]:581.192
DOI: 10.15587/1729-4061.2018.147748

STUDY INTO FORMATION OF NUTRITIONAL VALUE OF CAULIFLOWER DEPENDING ON THE AGRI-BIOLOGICAL FACTORS

L. Pusik
Doctor of Agricultural Sciences, Professor
Department of technologies of processing of food production named after T. P. Yevsiukova**
E-mail: Ludmilap@gmail.com

V. Pusik
Doctor of Agricultural Sciences, Professor*
E-mail: kysmish @ gmail.com

N. Lyubymova
Doctor of Technical Sciences, Professor*
E-mail: nina.lioubimova@gmail.com

V. Bondarenko
PhD, Senior Researcher
Laboratory of genetics, biotechnology and quality
The Plant Production Institute
named after V. Y. Yuryev of National Agrarian Academy of Sciences
Moskovsky ave., 142, Kharkiv, Ukraine, 61060
E-mail: zim-hot@rambler.ru

L. Gaevaya
Teacher***
E-mail: Gaevaaludmila9@gmail.com

O. Sergienko
PhD, Senior Researcher, Head of Laboratory
Laboratory for the selection of solanaceous and cucurbitaceous cultures
Institute of vegetables and melon growing
National Academy of agricultural sciences of Ukraine
township Selektsiyne, Kharkiv region, Kharkiv district, Ukraine, 62478
E-mail:oksana.sergienko71@ukr.net

O. Romanov
PhD, Associate professor***
E-mail: romanovaleksey@mail.ru

L. Gryn
Associate Professor*
E-mail: sporthntusg1968@gmail.com

L. Kononenko
PhD, Associate Professor
Department of Crop Production
Uman National niversity of Horticulture
Institutska str., 1, Uman, Ukraine, 20305
E-mail: lidiyakononenko@ukr.net

*Department of Agrotechnology and Ecology**
**Kharkiv Petro Vasylenko National Technical University of Agriculture
Alchevskykh str., 44, Kharkiv, Ukraine, 61002
***Department of fruit and vegetable and storage
Kharkiv National Agrarian University named after V. V. Dokuchaev
township Dokuchaevsky, Kharkiv region, Kharkiv district, Ukraine, 62483

Досліджено вплив суми активних температур вище 10 °С, кількості опадів та гідротермічного коефіцієнта (ГТК) на формування сухих, сухих розчинних речовин, цукрів та аскорбінової кислоти капусти цвітної, залежно від особливостей гібрида. Встановлено, що у середньому за три роки досліджень сухих розчинних речовин у головках ранньостиглих гібридів капусти цвітної накопичувалося від 7,2 % (у гібрида Кул F1) до 8,3 % (у гібрида Опал F1). Дисперсійним аналізом установлено, що особливість гібрида впливала на вміст сухих розчинних речовин у головках капусти цвітної на 10 %, тоді як умови вегетаційного періоду – на 77 %.

У середньому за роки досліджень більшим загальним вмістом цукрів характеризувався Лівінгстон F1. Дисперсійним аналізом встановлено, що 55 % впливу на загальний вміст цукрів у головках капусти цвітної чинила особливість гібрида. Вплив умов вегетаційного періоду становив 4 %.

Гібриди істотно різнились за вмістом редукувальних цукрів.

Виявлено залежність впливу погодних умов на вміст компонентів хімічного складу в головках гібридів капусти цвітної. У період формування головки: вміст сухих речовин має сильний обернений зв'язок із вологістю повітря у r=–0,89…–0,93, прямий середній зв'язок із середньодобовою температурою повітря і сумою активних температур, а також сильні прямі зв'язки із сумою опадів та ГТК вегетаційного періоду.

Вміст сухих розчинних речовин у головках капусти цвітної має сильний обернений зв'язок із вологістю повітря: r=–0,78…–0,97. Вміст аскорбінової кислоти – сильну пряму залежність від вологості повітря в період формування головки (r=0,67–0,75). З іншими погодними показниками зв'язок був слабкий. Дисперсійним аналізом установлено, що вміст аскорбінової кислоти у головках капусти цвітної на 56 % залежав від особливостей гібрида, на 15 % – від умов вегетаційного періоду

Ключові слова: капуста цвітна, сухі речовини, сухі розчинні речовини, цукри, аскорбінова кислота

1. Introduction

Vegetables are the basic vitamin food product for people. Vegetables account for up to 3 % of the structure of crop land in the world, and their value cannot be overestimated. China is the leader in global vegetable production; the average person there consumes 170 kg of vegetables and 100 kg of watermelons annually. Cauliflower has a delicate taste; it outperforms white-head cabbage by the versatility of cooking. The fruits of cauliflower are the shoots with embryo inflorescences containing a large amount of useful substances [1, 2].

In Europe, cauliflower first appeared in the XVI-th century. The largest areas with cauliflower are in Italy, France, Germany, Great Britain, the Netherlands. In Germany, cauliflower accounts for 10 % of the area used for vegetable plants. Cauliflower is widespread in America, Asia; in India, it is grown on 32 % of world land [3, 4].

Among all types of cabbage, cauliflower ranks first in terms of nutrients content, digestibility, and taste properties. Cauliflower has a gentle consistency and is highly digested by the human body. The content of protein in cauliflower is 1.5–2.0 times higher than that in white-head cabbage, it is 2–3 times richer in ascorbic acid and mineral salts of alkaline character. The valuable feature of this plant is that fresh produce can be obtained over 6–8 months a year [2].

Cauliflower is used as a raw material in the processing industry. It is marinated, fermented, frozen, added to assorted vegetables. Fermented cauliflower is used mainly for the preparation of assorted marinates. One can also use it for the first and second meals.

The industry of frozen and canned vegetables depends on the regular supply of raw materials. Quality and yield of vegetables depend on factors in the environment during their growth and development. As stated by the European Association of Fruit and Vegetable Producers (PROFEL), the extreme drought that had recently occurred in Europe led to the most serious problems in the EU vegetable sector in the past 40 years. Due to the hot and dry weather that lasted throughout July and August in most parts of the continent, vegetables continued to suffer and the yield dropped sharply. Under such conditions, produce rotted in the fields, which led to a decrease and irregular supply of fresh vegetables to processing enterprises, with the result being an increase in production costs and a decrease in the volumes of processed produce. At present, the situation for vegetable producers, as well as for processing in general, has become the most serious over the past 40 years. Particularly affected by drought are France, Belgium, the Netherlands, Germany, Great Britain, Hungary, and Poland [5]. Thus, studying the impact of agricultural and biological factors on formation of the nutritional value of cauliflower heads is a relevant task.

2. Literature review and problem statement

Modern science study vegetables as essential food products, while some of them are used for therapeutic purposes. Certain vegetables are rich in antioxidants, others are quite successful in preventing the development of diseases. Some varieties of cabbage contain useful substances for long-term preservation of health and active human life [6]. Cauliflower reduces the risk of cancer and diseases of the cardiovascular system (coronary insufficiency, hypertension), as well as reduces the probability of occurrence of congenital malformations [7].

The growth, development and yield of vegetable crops are significantly affected by surrounding factors. Quality and harvest level are the result of complex interaction between the plant and the combination of these factors. It is impossible to develop a rational system of agrotechnical measures to obtain a sufficiently high yield of vegetables and retain their quality without a knowledge of the state and changes in the ratio of needs of plants. Varieties or hybrids that are strongly dependent on the environmental factors will not be able to implement their potential under stressful conditions. The most successful in terms of industrial conditions would be to cultivate specimens with a high reaction norm [8]. Since at farms, during all years of agricultural research, a vegetable growing technique has remained practically unchanged, the main influence on the variation in quality of vegetable produce was exerted by meteorological factors. Essential influence on the formation of the chemical composition of vegetables is produced by weather conditions of the vegetation period. They are characterized by the sum of active temperatures above 10 °C, the amount of precipitation, as well as the hydrothermal coefficient of Selyaninov. The influence of air temperature on the growth and development of vegetable plants depends on biological characteristics [9]. It is impossible to control abiotic factors under conditions of open soil. Therefore, there is a need to study the influence of abiotic factors on the process of formation of biologically active compounds in tissues of cauliflower, which would make it possible to predict its value and its suitability for storage in order to be consumed fresh.

Cauliflower belongs to a group of cold-resistant vegetable plants. Frost resistance of cauliflower is less than that of other types of cabbage. The plant is damaged at a temperature of minus 2...3 °C. In hot weather, at insufficient amount of moisture, small leaves and small heads are formed on the plants. Cauliflower can withstand high temperatures only at high soil and air humidity; it has extremely high demands to them. A well-seasoned seedling can withstand a short-term drop in temperature to minus 5...7 °C while the unseasoned seedling is damaged at minus 1 °C. Its early varieties are damaged during the formation of inflorescences by a frost of 2...3 °C, while its late varieties withstand a decrease in temperature to minus 5 °C. The formation of cauliflower heads is delayed when a low temperature period lasts for at least two weeks [10].

For the normal growth and development of cauliflower throughout the entire vegetation period, it is important to provide moisture for plants. The plants grow and develop well when relative air humidity is between 80 and 90 %, and the moisture content of soil is in the range of 75–80 % HB [11]. The lack of moisture in soil slows the growth of plants and leads to a premature formation of inflorescences (heads). Excessive humidity causes damage to the plants by vascular bacteriosis. Compared with white head cabbage, cauliflower is more sensitive to the conditions of the environment [12].

However, the abiotic factors that have a dominant influence on the growth and development of plants, remain uncertain for cauliflower depending on the special features of a hybrid. The given data are generalizing in character.

Up to 70 % of all dry soluble substances in the heads of cauliflower are represented by sugars. The content of sugars in cauliflower significantly depends on the special features of a variety and conditions of the vegetation period, it varies from 2.5 to 6.0 %, including sucrose 1.1–2.0 %. An important indicator of nutritional value is ascorbic acid, which characterizes the antioxidant activity of vegetables. It is known that ascorbic acid (L – ascorbic acid) is a water-soluble vitamin, which is required for human life but is not synthesized by the body. Its biological role is to protect the plant organism from oxidative stress. The content of ascorbic acid in the heads of cauliflower ranges from 40 to 180 mg/100 g. The raw protein content is from 1.6 to 2.5 %, in which pure protein is 83 %.

The energy value of 100 g of products is 29 kcal or 121 kJ. Very rich in nitrogenous substances are the upper parts of the shoots, which form a bumpy surface of the head [3]. However, the author did not investigate formation of the nutritional value of cauliflower under various weather conditions during a vegetation period of the plant.

Cauliflower is a valuable dietary food product. A given kind of cabbage contains riboflavin – a vitamin that has the capability to accumulate in the liver, kidneys, heart, brain; it participates in oxidative-recovering processes in all tissues of the body. Its deficit leads to a metabolic disorder. Cauliflower is one of the main sources of nicotinic acid (vitamin PP), which provides oxidative-recovering processes in the body and normalizes carbohydrate metabolism. The heads of cauliflower contain vitamin H_1 (biotin). Biotin is involved in the metabolism of fats and carbohydrates, it is produced by the useful intestinal microflora and comes in large quantities with food. In addition, cauliflower is characterized by the optimal ratio of calcium and phosphorus, which is needed for better assimilation. In addition to enzymes and vitamins, this kind of cabbage contains salts of cobalt, magnesium, iodine [13]. However, the work describes cauliflower as a valuable dietary food product. It should be noted that biological value is formed in the field and depends on the abiotic environmental factors that were not investigated.

The influence of air temperature on the growth and development of vegetable crops depends on biological characteristics. For example, sweet pepper forms a high-quality yield when the sum of temperatures above 15 °C is over 1,900 °C, eggplant – 2,000 °C, and melon crops – 2,200–2,700 °C. The required sum of active temperatures above 10 °C for cauliflower fluctuates in a wide range of 650–1,000 °C. The degree of negative influence of suboptimal temperatures on the quality of fruit and vegetable produce is determined by the duration of exposure to an unfavorable factor [14]. A short-term effect of the stress temperature can stimulate the plant's protective forces, which leads to an increase in the synthesis of antioxidant compounds [15]. Prolonged exposure to critical temperatures leads to the disruption of normal metabolic processes and the occurrence of physiological disorders [14].

Thus, the above studies do not answer the questions related to the nutritional value of cauliflower. The formation of components of the chemical composition of cauliflower depending on the special features of a hybrid and conditions of a vegetation period has been studied insufficiently. Under existing conditions, when climate becomes warmer, extended and more detailed research into the formation of quality of cold-resistant vegetable plants is a relevant task.

3. The aim and objectives of the study

The aim of this study was to investigate the formation of the nutritional value of cauliflower, depending on weather conditions of the vegetation period and the special features of a hybrid.

To accomplish the aim, the following tasks have been set:

– to determine the content of certain components of chemical composition in the heads of cauliflower, depending on the special features of a hybrid and conditions of the vegetation period;

– to find the hybrids of cauliflower with the best nutritional value.

4. Materials and methods to study the formation of the nutritional value of cauliflower, chemical, organoleptic parameters

Field experiments were conducted in accordance with generally accepted procedures. The research was carried out using the hybrids of early-ripening cauliflower: Livingstone F_1, Kul F_1, Opal F_1 (control – Livingstone F_1). The term of planting seedlings of early-ripening hybrids is the 1st decade of May. The cultivation technique is by seedlings (we planted seedlings with four or five actual leaves). The technique of plant arrangement is ribbon-like with a layout of (40+100)×50 cm. Plant density is 28.6 thousand pcs/ha. We repeated experiments four times. It was a two-factor experiment: we studied the influence of factor A – special features of the hybrid, factor B – conditions of a vegetation period. The area of each sowing area is 21 m^2. The arrangement of variants is systematic.

5. Results of research into the formation of nutritional value of cauliflower

5.1. The content of certain components of chemical composition in the heads of cauliflower, depending on special features of the hybrid and conditions of a vegetation period

The content of components of the chemical composition in the heads of cauliflower defines its nutritional and dietary value. The content of a component in produce depends on special features of the hybrid and the weather conditions under which it was formed. The optimal temperature for forming the heads of cauliflower is 15...18 °C; small heads form and quickly break at a temperature above 20 °C. Prolonged growing of cauliflower at a temperature below 8 °C leads to the slower head formation [11].

Over the period when the heads of early hybrid cauliflower ripened in 2015, air temperature was 2.7 °C lower compared to a long-term indicator; precipitation rate was 81 % of the normal level; air humidity was 52 %. Under such conditions, dry substances accumulated in the heads of cauliflower in the amount of 8.4–10 % (Fig. 1). More dry substances, depending on the hybrid, accumulated over the arid and hot year of 2017: 10.0–12.3 %. The drought during head ripening in 2016 contributed to the accumulation of dry substances at the level of 9.8–16.0 %. At the same time, the difference between the hybrids, as regards this indicator, was significant (HIP_{05}=0.3 %).

It was found by using a dispersion analysis that the accumulation of dry substances in the heads of cauliflower depends by 18 % on special features of a hybrid (factor A), by 50 % – on conditions of a vegetation period (factor B); the combined effect of factors AB accounts for 29 %, other factors (elements of a cultivation technology, etc.) – 3 %.

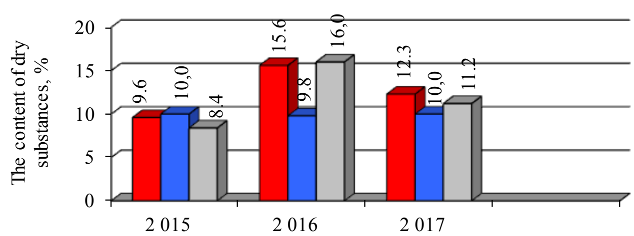

Fig. 1. Content of dry substances in the heads of early-ripening hybrids of cauliflower, %: ■ – Livingstone F_1, ■ – Kul F_1, ■ – Opal F_1

Dry soluble substances are carbohydrates, nitrogenous substances, acids, tannins, enzymes, mineral salts, water-soluble vitamins, etc. A larger part of this group of compounds is represented by carbohydrates, mainly sugars [3]. It was established that the content of dry soluble substances in the heads of the early-ripening hybrids of cauliflower during 2015–2017 was in the range of 6.1–10.9 % (Fig. 2), depending on the hybrid. They accumulated in larger amounts in 2016 and 2017. In this case, 2017 was characterized by hot and dry conditions of the vegetation period, and 2016 – by hot weather and uneven precipitation. The difference between hybrids was significant (HIP_{05}=0.2 %). A similar effect of weather conditions during vegetation period on the accumulation of dry soluble substances and sugars was demonstrated in the fruits of eggplant and sweet pepper [16] and berry cultures [17–19].

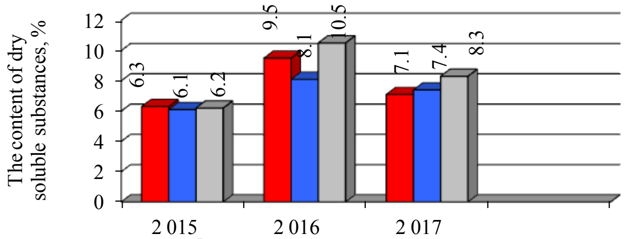

Fig. 2. Content of dry soluble substances in the heads of early-ripening hybrids of cauliflower, %: – Livingstone F_1, – Kul F_1, – Opal F_1

We analyzed a ratio of the content of dry soluble substances to the content of dry substances in the heads of cauliflower. The ratio factor was 1.48. The content of dry soluble substances is determined by an express analysis at a refractometer. Thus, taking into consideration the coefficient, it is possible to rapidly determine the content of dry substances in the heads of cauliflower, which is of practical importance.

The regression equation was constructed, by using which one can predict the content of dry substances in the heads of cauliflower, depending on the content of dry soluble substances.

$$y=0.267x^2-2.803x+16.7,$$

where y is the content of dry substances, %; x is the content of dry soluble substances, %.

Correlation coefficient is R^2=0.892; error in the correlation coefficient is 0.173, criterion of significance of the correlation coefficient (t_{05}) is 5.16, at γ=n–2=7, t_{05}=1.65.

Thus, there is a close correlation between the content of dry substances and dry soluble substances in cauliflower, which is essential at a 5 % level of significance of $t_{05f}>t_{05t}$. A mathematical dependence could form a basis for decision-making.

Sugars underlie energy metabolism in a plant cell. During 2015–2017, a difference between the cauliflower hybrids (Fig. 3) in terms of the total content of sugars in the heads was significant (HIP_{05}=0.2 %).

On average, over the years of our research, Livingstone F_1 was characterized by the larger total sugar content – 4.6 %, Kul F_1 had a smaller content – 3.1 %.

A dispersion analysis revealed that 55 % of the effect on the total content of sugars in the heads of cauliflower was exerted by a hybrid special feature (factor A). Influence of conditions of the vegetation period (factor B) accounted for 4 %; the combined effect of factors AB – 31 %; other factors – 11 %.

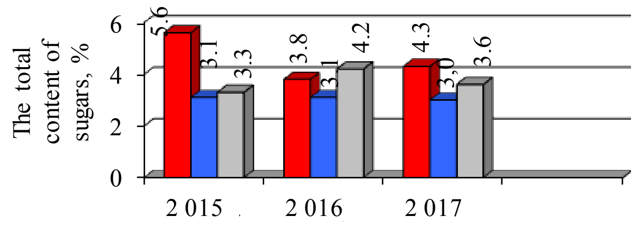

Fig. 3. Total sugar content in the heads of early-ripening hybrids of cauliflower, %: – Livingstone F_1, – Kul F_1, – Opal F_1

During 2015–2017, the content of reducing sugars in the cauliflower heads of the hybrid Livingstone F_1 fluctuated within a range of 2.3–3.1 %; Kul F_1 – 2.0–2.3 %; Opal F_1 – 1.8–2.8 % (Fig. 4). At the same time, the hybrids differed significantly for this indicator (HIP_{05}=0.1 %). The highest content of reducing sugars was found in Livingstone F_1, it was 2.6 % on average over the years of our research. Opal F_1 and Kul F_1 had a lower content of reducing sugars – 2.4 and 2.1 %, respectively.

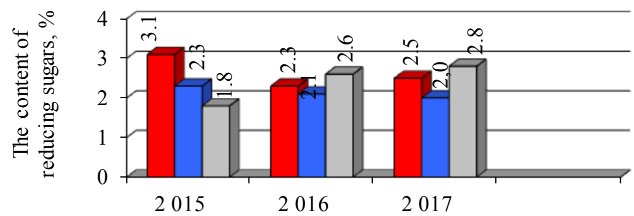

Fig. 4. Content of reducing sugars in the heads of early-ripening hybrids of cauliflower, %: – Livingstone F_1, – Kul F_1, – Opal F_1

It was established using a dispersion analysis that the content of reducing sugars in the heads of cauliflower (factor A) was affected by 23 % by a special feature of the hybrid; a proportion of effect from the conditions of a vegetation period (factor B) was 1 %; the combined effect of factors AB accounted for 60 %, others – 17 %.

The sucrose content in the heads of cauliflower over the years fluctuated in a range of 1.4–2.4 % for Livingstone F_1, 0.8–1.0 % – for Kul F_1, 0.7–1.7 % for Opal F_1 (Fig. 5); in this case, the difference between the hybrids was significant (HIP_{05}=0.1 %).

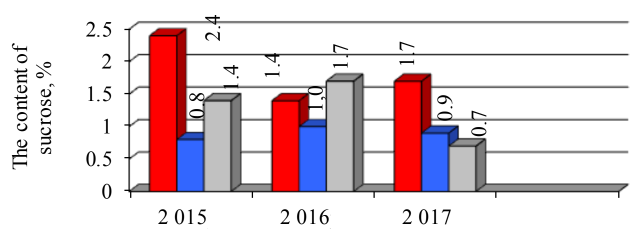

Fig. 5. Sucrose content in the heads of early-ripening hybrids of cauliflower, %: – Livingstone F_1, – Kul F_1, – Opal F_1

A dispersion analysis revealed that a special feature of the hybrid (factor A) influenced the content of sucrose in the heads of cauliflower by 47 %; conditions of the vegetation period accounted for 10 % (factor B); the combined action of factors AB accounted for 28 %, other factors – 14 %.

The largest amount of ascorbic acid in the heads of cauliflower was found in Kul F_1; over the years, its content ranged from 147.1 to 232.3 mg/100 g (Fig. 6).

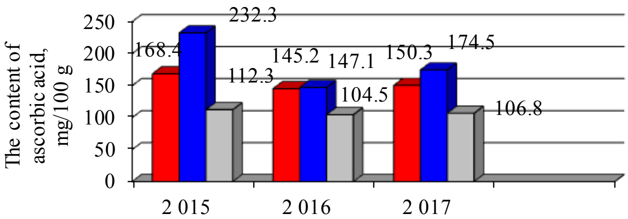

Fig. 6. Content of ascorbic acid in the heads of early-ripening hybrids of cauliflower, mg/100 g: – Livingstone F_1, – Kul F_1, – Opal F_1

It should be noted that for the early-ripening hybrids a given indicator was the highest in 2015, when weather conditions at the time of head ripening were less arid compared to others. On average, over the years of research, the highest content of ascorbic acid was found in the Kul F_1 hybrid – 184.6 mg/100 g, for Livingstone F_1 and Opal F_1 – by 30.0 and 76.7 mg/100 g less, respectively. A dispersion analysis revealed that the content of ascorbic acid in the heads of cauliflower depended by 56 % on special features of the hybrid (factor A), by 15 % – on the conditions of a vegetation period (factor B), the combined effect of factors AB accounted for 11 %, other factors – 19 %.

5. 2. Comparative evaluation of cauliflower heads in terms of nutrition value.

On average, over the years of research, dry substances accumulated in the heads of cauliflower hybrids in the amount of 9.9–12.5 %. The largest content of dry substances was found in the hybrids Livingstone F_1 and Opal F_1: 12.5 and 11.9 %, respectively; a smaller amount, in Kul F_1 – 9.9 %.

The dry soluble substances accumulated in the heads of the early-ripening cauliflower hybrids in the amount of 7.2–8.3 %, depending on the hybrid: the highest content – in Opal F_1 – 8.3 %, the lowest – in Kul F_1, 7.2 %.

It was established that the content of dry substances in the heads of cauliflower depends, by 10 %, on special features of the hybrid; by 77 % – on weather conditions of the vegetation period.

The total content of sugars in the hybrids fluctuated in the following manner: for Livingstone F_1 – in a range of 3.8–5.6 %, for Opal F_1 – 3.3–4.2 %, for Kul F_1 – 3.0–3.1 %.

On average, over 2015-2017, the heads of Livingstone F_1 contained sucrose in the amount of 1.8 %, which is 0.5 and 0.9 % higher that that for Opal F_1 and Kul F_1, respectively.

The hybrid Livingstone F_1 accumulated significantly less ascorbic acid (HIP_{05}=12.8 mg/100 g): 145.2–168.4 mg/100 g and Opal F_1: 104.5–112.3 mg/100 g.

Thus, among the examined hybrids of cauliflower, the hybrid Livingstone F_1 ranked first by the content of dry substances, sugar, sucrose, while Opal F_1 differed a little.

6. Discussion of results of studying the formation of nutritional value of cauliflower

Formation of the components of chemical composition of cauliflower over 2015–1017 occurred within the range of the following indicators for thermal resources of the vegetation period: average daily temperature was 20.5...21.1 °C, the sum of temperatures was 2,490.5–2,560.5 °C, the sum of precipitation was 97.5–279.5 mm, HTC=0.4–1.1, relative air humidity was 26–52 %.

We conducted a correlation analysis of the dependence of weather conditions of a vegetation period on the content of components of chemical composition in the heads of cauliflower. It was found that the content of dry substances for the hybrids Livingstone F_1 and Opal F_1 had a strong inverse relationship to air humidity during head formation: r=–0.89...–0.93; a direct average relation to the average daily air temperature and the sum of active temperatures; as well as strong direct relations to the amount of precipitation and HTC of the vegetation period.

The content of dry substances in the heads of Kul F_1 hybrid had a strong direct correlation with air humidity during their formation (r=0.99) and a strong inverse dependence on the remaining indicators for a vegetation period: r=–0.76...–0.91.

The content of dry soluble substances in the heads of cauliflower had a strong inverse relationship to air humidity: r=–0.78...–0.97. In the hybrids Livingstone F_1 and Opal F_1 we observed a strong direct correlation between a given indicator and the sum of precipitation and HTC of the vegetation period. The content of dry soluble substances in Livingstone F_1 had a relation of average power to the average daily temperature of air and the sum of active temperatures during vegetation period: r=0.63 and 0.58, respectively (Table 1).

Table 1

Correlation coefficients (r) between the content of components of chemical composition of cauliflower heads and conditions of vegetation period

Indicator	Hybrid	Dry substances, %	Dry soluble substances, %	Total content of sugars, %	Ascorbic acid, mg/100 g
HTC	Livingstone F_1	0.62	0.78	–0.35	–0.30
	Kul F_1	–0.90	–0.48	–0.80	–0.99
	Opal F_1	0.69	0.58	0.71	–0.36
Σ_{act} t>10 °C	Livingstone F_1	0.45	0.63	–0.15	–0.17
	Kul F_1	–0.80	0.23	0.92	–0.20
	Opal F_1	0.53	0.41	0.56	–0.17
Sum of precipitation, mm	Livingstone F_1	0.62	0.78	–0.35	–0.30
	Kul F_1	–0.91	0.42	0.82	–0.39
	Opal F_1	0.69	0.58	0.72	–0.37
Air humidity, %	Livingstone F_1	–0.89	–0.97	0.71	0.67
	Kul F_1	0.99	–0.78	–0.50	0.75
	Opal F_1	–0.93	–0.87	–0.94	0.73
Average daily t, °C	Livingstone F_1	0.38	0.58	–0.80	–0.20
	Kul F_1	–0.76	0.16	0.94	–0.13
	Opal F_1	0.47	0.34	0.50	–0.1

The total content of sugars in the heads of Kul F_1 hybrid had a strong direct dependence on the average daily temperature and the sum of active temperatures during vegetation period (r=0.92–0.94). The hybrid Livingstone F_1 showed a strong direct correlation between the total sugar content and air humidity during head formation (r=0.71). Other hybrids had an inverse dependence on a given indicator: Opal F_1 – strong, Kul F_1 – medium. The content of ascorbic acid had a strong direct dependence on air humidity during head formation (r=0.67...0.75). As regards other weather indicators, the correlation was weak (Tabl 1). Similar observations over other vegetable crops were performed by some scientists. Temperatures above 30 °C suppress the normal ripening of vegetables. Thus, fruits of tomato demonstrate the insufficient development of color, softening, an increase in the intensity of breathing and production of ethylene. It is known that the maximum temperatures of vegetation, close to 40 °C, cause metabolic disorders in tomato fruits and contribute to the development of fungal and bacterial diseases during storage. The clear symptoms of thermal burns of tomatoes are yellowish-white spots at the fruit surface [20]. High vegetation temperatures also lead to sunburns and wilting of pepper fruits [14]. Elevated temperatures during vegetation also affect the determinants of vegetable quality. Titrated acidity increases by 20 %, while the content of dry soluble substances is reduced by 10 % in the tomatoes that were exposed to direct sunlight [20]. Solar radiation and temperature exert a great influence on the accumulation of sugars. Under normal growing conditions, it is difficult to separate the effect of these factors. Higher temperatures (from 26 to 30 °C) lead to an increase in the amount of sugars in the process of fruit formation. Increasing the temperature several days before harvesting sometimes lowers the sugar content, presumably due to the increased breathing at higher temperatures [21, 22].

The accumulation of sugars in Brussels sprouts is also suppressed by high air temperatures. More to the point, vegetable crops grown at high temperatures during a ripening period are more susceptible to physiological disorders during storage [23].

Under conditions of a stressful elevated temperature, tomatoes form fruits with a higher content of phenolic compounds, vitamin C, potassium, magnesium, and sugars. Under such conditions, they have a higher antioxidant activity, but are characterized by a lower level of lycopene, responsible for the red color of tomatoes [24].

However, lower temperatures of cultivation favorably affect the coloration of cucumber peel. The fruits grown at an average temperature of 23 °C (winter season) had a darker skin color than the fruits grown at 28 °C (spring season) [25]. Such results are explained by authors by that the critical temperature for degradation of chlorophyll is 28 °C, which contributes to the loss of green coloration. The cucumbers grown during winter season had a 0.2–0.4 % larger content of dry soluble substances. Many studies indicate that the beneficial effect on increasing the concentration of ascorbic acid is due to low temperatures.

Low stressful temperatures enhance the synthesis of ascorbic acid in pepper [26]. Low temperatures can also directly affect the organoleptic properties of vegetables. The pepper, grown at temperatures below 17 °C, is characterized by smaller fruits and by the increased level of risk for the development of gray rot. Low temperatures lead to the emergence of curvaceous cucumbers and distorted shape of pepper [27]. It was found that cucumbers grown at low temperatures often have bitter taste. This is due to the acceleration of synthesis of proteins and the high activity of HMGCoA reductase, which provokes the synthesis of cucurbitacin, responsible for the emergence of bitter taste [28].

Thus, it is needed for each plant to determine the duration of a vegetation period, and at certain stages of development – determining the number of days with a temperature higher than the minimum.

However, the study was conducted within a limited range of daily average temperature – 20.5...21.1 °C, the sum of active temperatures above 10 °C – 2,490.5–2,560.5 °C, the sum of precipitation over a vegetation period – 97.5–279.5 mm, HTC=0.4–1.1.

Further promising directions of our research are the scientific approach to programming the crop of cauliflower with the predefined indicators of quality. A prerequisite is the comprehensive consideration of all factors and living conditions of plants for each specific territory, taking into account the ratio of environmental factors.

7. Conclusions

1. The result of research is the established fact that growth and development of the early-ripening hybrids of cauliflower occurs within the range of average daily temperature of 20.5...21.1 °C, the sum of active temperatures above 10 °C – 2,490.5–2,560.5 °C, the amount of precipitation over a vegetation period – 97.5– 279.5 mm, HTC=0.4–1.1.

The content of dry substances in the heads of the early-ripening hybrids has a strong inverse relationship to air humidity during head formation: r=–0.89...–0.93, as well as strong direct relations to the sum of precipitation and HTC of the vegetation period. The content of dry soluble substances had a strong inverse relationship to air humidity: r=–0.78...–0.97.

2. On average, over the years of our research, the largest content of dry substances was noted in the hybrids Livingstone F_1 and Opal F_1: 12.5 and 11.9 %, respectively. The content of dry soluble substances was the highest in Opal F_1 – 8.3 %. Livingstone F_1 was characterized by the highest overall content of sugars – 4.6 %. The highest content of ascorbic acid was observed in the hybrid Kul F_1 – 184.6 mg/100 g.

References

1. Dydiv O., Dydiv I., Dydiv A. Komertsiyna kultura brokoli // Ovoshchevodstvo. 2018. Issue 3. URL: http://www.ovoschevodstvo.com/journal/browse/201803/article/1695/
2. Muhin V. Bez kapusty shchi ne gusty. Putevoditel' po vidam kapusty // Sad i ogorod. 2003. Issue 4. P. 17–19.
3. Lebedeva A. Sparzhevaya kapusta – brokkoli // Sad i ogorod. 2003. Issue 5. P. 2–4.
4. Klymenko K. Vyroshchuiemo tsvitnu kapustu // Ahroohliad. 2005. Issue 5. P. 20–21.
5. Yevropu ochikuie naisylnisha za 40 rokiv "ovocheva kryza". URL: http://nk.org.ua/ekonomika/evropu-ochikue-naysilnisha-za-40-rokiv-ovocheva-kriza-157422
6. Bondareva L. L. New varieties and heterosis hybrids of cole crops of VNIISSOK'S breeding // Vegetable crops of Russia. 2013. Issue 3. P. 32–33. doi: https://doi.org/10.18619/2072-9146-2013-3-32-33
7. Cauliflower by-products as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks / Stojceska V., Ainsworth P., Plunkett A., İbanoğlu E., İbanoğlu Ş. // Journal of Food Engineering. 2008. Vol. 87, Issue 4. P. 554–563. doi: https://doi.org/10.1016/j.jfoodeng.2008.01.009

8. Zhuchenko A. A. Biologizaciya i ekologizaciya intensifikacionnyh processov v sel'skom hozyaystve // Vestnik agrarnoy nauki. 2009. Issue 3. P. 8–12.
9. Prichko T., Chalaya L. Formation of qualitative indicators of the apple-tree fruits depending on weather conditions of the vegetation period // Plodovodstvo i vinogradarstvo Yuga Rossii. 2012. Issue 13 (1). P. 91–99. URL: http://journalkubansad.ru/pdf/12/01/10.pdf
10. Neporozhnaya E. Nezhenka sredi kapust // Ovoshchevodstvo. 2018. Issue 3. URL: http://www.ovoschevodstvo.com/journal/browse/201803/article/1692/
11. Zabara L. Yu. Sposoby vyrashchivaniya rassady ranney kapusty // Ovoshchevodstvo i teplichnoe hozyaystvo. 2006. Issue 1. P. 20–21.
12. Puzik L. M., Bondarenko V. A. Ekolohichna stabilnist hibrydiv kapusty brokoli // Visnyk KhNAU. Seriya: Roslynnytstvo, selektsiya i nasinnytstvo, plodoovochivnytstvo i zberihannia. 2015. Issue 1. P. 15–20.
13. Ivanova M. I., Kovylin V. M. Pishchevaya cennost' i kachestvo sortov cvetnoy kapusty i brokkoli // Kartofel' i ovoshchi. 2000. Issue 2. P. 10–11.
14. Climate changes and potential impacts on postharvest quality of fruit and vegetable crops: A review / Moretti C. L., Mattos L. M., Calbo A. G., Sargent S. A. // Food Research International. 2010. Vol. 43, Issue 7. P. 1824–1832. doi: https://doi.org/10.1016/j.foodres.2009.10.013
15. Isidoro N., Almeida D. P. F. α-Farnesene, conjugated trienols, and superficial scald in 'Rocha' pear as affected by 1-methylcyclopropene and diphenylamine // Postharvest Biology and Technology. 2006. Vol. 42, Issue 1. P. 49–56. doi: https://doi.org/10.1016/j.postharvbio.2006.05.003
16. Osokina N. M., Kostetska K. V. Vplyv pohodnykh umov na formuvannia vmistu osnovnykh komponentiv khimichnoho skladu plodovykh ovochiv // Zbirnyk naukovykh prats Umanskoho natsionalnoho universytetu sadivnytstva. 2012. Issue 81 (1). P. 144–149.
17. Yanchuk T. V., Makarkina M. A. Vliyanie meteorologicheskih usloviy vegetacionnogo perioda na nakoplenie saharov i organicheskih kislot v yagodah smorodiny chernoy // Sovremennoe sadovodstvo. 2014. Issue 2. P. 62–69. URL: http://journal.vniispk.ru/pdf/2014/2/25.pdf
18. Effects of fertilization and climatic factors in a long-term experiment with blackcurrant (Ribes nigrum L.) cv. Ben Tron / Opstad N., Nes A., Måge F., Hageberg B. // Acta Agriculturae Scandinavica, Section B – Soil & Plant Science. 2007. Vol. 57, Issue 4. P. 313–321. doi: https://doi.org/10.1080/09064710600984171
19. Effects of Latitude and Weather Conditions on Contents of Sugars, Fruit Acids, and Ascorbic Acid in Black Currant (Ribes nigrum L.) Juice / Zheng J., Yang B., Tuomasjukka S., Ou S., Kallio H. // Journal of Agricultural and Food Chemistry. 2009. Vol. 57, Issue 7. P. 2977–2987. doi: https://doi.org/10.1021/jf8034513
20. Getinet H., Seyoum T., Woldetsadik K. The effect of cultivar, maturity stage and storage environment on quality of tomatoes // Journal of Food Engineering. 2008. Vol. 87, Issue 4. P. 467–478. doi: https://doi.org/10.1016/j.jfoodeng.2007.12.031
21. Beckles D. M. Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit // Postharvest Biology and Technology. 2012. Vol. 63, Issue 1. P. 129–140. doi: https://doi.org/10.1016/j.postharvbio.2011.05.016
22. How Does Tomato Quality (Sugar, Acid, and Nutritional Quality) Vary with Ripening Stage, Temperature, and Irradiance? / Gautier H., Diakou-Verdin V., B nard C., Reich M., Buret M., Bourgaud F. et. al. // Journal of Agricultural and Food Chemistry. 2008. Vol. 56, Issue 4. P. 1241–1256. doi: https://doi.org/10.1021/jf072196t
23. Puzik L. M., Bondarenko V. A. Ekolohichni umovy vyroshchuvannia kapusty briusselskoi // World Science. 2018. Vol. 2, Issue 1 (29). P. 4–9.
24. The effect of environmental conditions on nutritional quality of cherry tomato fruits: evaluation of two experimental Mediterranean greenhouses / Rosales M. A., Cervilla L. M., Sánchez-Rodríguez E., Rubio-Wilhelmi M. del M., Blasco B., Ríos J. J. et. al. // Journal of the Science of Food and Agriculture. 2010. Vol. 91, Issue 1. P. 152–162. doi: https://doi.org/10.1002/jsfa.4166
25. Gómez-López M. D., Fernández-Trujillo J. P., Baille A. Cucumber fruit quality at harvest affected by soilless system, crop age and preharvest climatic conditions during two consecutive seasons // Scientia Horticulturae. 2006. Vol. 110, Issue 1. P. 68–78. doi: https://doi.org/10.1016/j.scienta.2006.06.021
26. Metabolism of reactive oxygen species and reactive nitrogen species in pepper (Capsicum annuum L.) plants under low temperature stress / Airaki M., Leterrier M., Mateos R. M., Valderrama R., Chaki M., Barroso J. B. et. al. // Plant, Cell & Environment. 2011. Vol. 35, Issue 2. P. 281–295. doi: https://doi.org/10.1111/j.1365-3040.2011.02310.x
27. Hodges D. M., Toivonen P. M. A. Quality of fresh-cut fruits and vegetables as affected by exposure to abiotic stress // Postharvest Biology and Technology. 2008. Vol. 48, Issue 2. P. 155–162. doi: https://doi.org/10.1016/j.postharvbio.2007.10.016
28. Kano Y., Goto H. Relationship between the occurrence of bitter fruit in cucumber (Cucumis sativus L.) and the contents of total nitrogen, amino acid nitrogen, protein and HMG-CoA reductase activity // Scientia Horticulturae. 2003. Vol. 98, Issue 1. P. 1–8. doi: https://doi.org/10.1016/s0304-4238(02)00223-6