The measurement uncertainty analysis of the oil concentration in the sunflower seed

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***Abstract* — The results of the quality research of the new line sunflower seed are presented. The five quality parameters of the sunflower seed were investigated by implementation of the physical and chemical methods. The measurements of the check parameters at the reference conditions were done, the additional errors were absent. The example of the measurement uncertainty analysis of the oil concentration in the sunflower seed was given.**

Keywords* — *sunflower seed, physical and chemical parameters of the quality, parallel experiments, measurement uncertainty

Introduction

The oil of an animal and a vegetable origin takes the fourth position in the main group of the products was exported by Ukraine in 2018 year. The potential of the export of the sunflower oil in 2018-2019 marketing years was been reconsidered at the direction of the increase – to 5,9 mln. of tons. More over, the export of the sunflower oil will be able to obtain the absolute maximum and exceed the record of the 2016-2017 marketing years (5,85 mln. of tons) by the estimations of the experts. The rise of the volume of the production is explained by increase of the harvest and increase of the concentration of the oil in the seed of the sunflower. It is undeniable that the selection of the sunflower must be aimed to increase the concentration of the saturated fat acids. It will allow to replace the hydrogenized vegetable fats by solid natural oils that don't content the harmful trans-isomers of the fat acids.

The new line of the sunflower developed by the Plant Production Institute nd. a. V. Ya. Juryev of National Academy of the Agrarian Sciences of Ukraine is researched in this work.

The measurement uncertainty evaluation of the oil concentration in the sunflower seed is the purpose of this article.

I. Research of the sunflower seed parameters

The main requirements to the sunflower-seed oil are requirements to the parameters of the quality and of the safety [1-6].

In this work five physical and chemical parameters of the quality of the of the sunflower's seed were investigated: the humidity, %; the concentration of the oil in the sample of the seed re-counted to the dry substance, %; the volume mass, g; the mass of the 100 pieces of the sunflower seed, g; the mass part of the shell in the sunflower's seed, %.

The measured values of the quality parameters of the sunflower's seed of the new line X 114 B are presented in the table I.

TABLE I. THE MEASUREMENTS OF THE PHYSICAL AND CHEMICAL PARAMETERS OF THE SUNFLOWER SEED

The name of the parameter of the quality	The results of the measurements of the parameters
humidity, %	7,2
concentration of the oil in the sample of the seed re-counted to the dry substance, %	40,61
volume mass, g	475,07
mass of the 100 pieces of the sunflower seed, g	42,95
mass part of the shell in the sunflower's seed, %	32,7

According to [2], the concentration of the oil in the seed cleaned from the rubbish and dried is defined by the equation:

$$X = \frac{(m - m_1)}{m_2} \cdot 100\%, \qquad (1)$$

where m is the mass of the vessel with oil, g; m_1 is the mass of the empty vessel, g; m_2 is the mass of the dried seed in the extract patron, g.

Five parallel experiments were done to calculate X by formula (1). The initial data for the calculations of the oil concentration are presented in the table II.

TABLE II. THE MEASUREMENT RESULTS OF THE MASS

The number of the parallel measurements	The measurement results of the mass
1	m=145,7984 g m_1=143,4263 g m_2=6,0612 g
2	m=104,8702 g m_1=102,4981 g m_2=5,9901 g
3	m=101,1455 m_1=98,7734 m_2=6,0205
4	m=115,6502 m_1=113,2781 m_2=6,0053
5	m=130,1158 m_1=127,7437 m_2=6,0358

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The result obtained is re-counted to the dry substance by the formula

$$X^* = \frac{X \cdot 100\%}{100\% - W}, \quad (2)$$

where X is the oil concentration in the sample of the seed, %; W is the mass part of the humidity in the sample of the seed, %.

The humidity is determined by the formula

$$W = \frac{(m - m_1)}{(m - m_2)} \cdot 100\%, \quad (3)$$

where m is the mass of the vessel with seed before drying, g; m_1 is the mass of the vessel with seed after drying, g; m_2 is the mass of the empty vessel, g.

To obtain the humidity W two parallel measurements were done.

The initial data for the calculations of humidity W in the sample of the seed are presented in the table III.

TABLE III. THE MEASUREMENTS OF THE MASS TO ACCOUNT THE HUMIDITY W

The number of the parallel measurements	The results of the measurements of the mass
1	m=15,8922 g m_1=15,7945 g m_2=12,5864 g
2	m=15,3618 g m_1=15,2622 g m_2=12,0321 g

The measured values of the humidity at the realization two parallel measurements are the following: $W_1 = 2{,}955\%$, $W_2 = 2{,}991\%$.

The average value of the measurement result of the humidity was determined by the formula:

$$\overline{W} = \frac{1}{2}\sum_{i=1}^{2} \frac{(m - m_1)}{(m - m_2)} \cdot 100\ \%, \quad (4)$$

where m is the mass of the vessel with seed before drying, g; m_1 is the mass of the vessel with seed after drying, g; m_2 is the mass of the empty vessel.

The average value of the humidity $\overline{W}$ is equal $2{,}9734\ \%$.

The calculation of the average value of the oil concentration in the sample of the seed was performed by the formula:

$$\overline{X}^* = \frac{1}{5}\sum_{i=1}^{5} \frac{X_i \cdot 100\ \%}{100\ \% - \overline{W}}, \quad (5)$$

where X_i is the oil concentration in the seeds at the realization of i-th experiment, %; $\overline{W}$ is the average value of the measurement result of the humidity, %.

The average value of the oil concentration in the sample of the seed $\overline{X}^*$ is equal $40{,}607\ \%$.

The measurement results of the oil concentration in the seed obtained from formulas (1) and (2) are presented in the table IV.

TABLE IV. THE MEASUREMENT RESULTS OF THE OIL CONCENTRATION IN THE SEED

The number of the parallel measurements	The results of the measurements	
	X_i ,%	X_i^* ,%
1	39,2	40,40
2	39,6	40,81
3	39,4	40,61
4	39,5	40,71
5	39,3	40,50

II. MEASUREMENT UNCERTANTY EVALUATION OF THE OIL CONCENTRATION

The measurements of the check parameters were done at the reference conditions, the additional errors were absent.

The demands to the conditions of the measurements of the parameters of the quality of the seed are the following: the temperature of the air is $(20 \pm 5)^0 C$; the atmospheric pressure is from $84{,}0 \times 10^3$ Pa to $106{,}7 \times 10^3$ Pa; the relative humidity of the air (at the temperature $25^0 C$) mustn't be accede 80%.

The results of the repeated measurements were used to determine the type A measurement uncertainty, the data from the measurement instrument's specifications – to determine the type B measurement uncertainty [7].

The calculation of the measurement uncertainties of the type A u_A and the measurement uncertainties of the type B u_B was done, using the following formulas:

$$u_{A\bar{x}} = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}, \quad (6)$$

where $\bar{x}$ is the average value of the result of the multiple measurements; n is number of the multiple measurements;

$$u_B = \frac{\Theta}{\sqrt{3}}, \quad (7)$$

where Θ is the maximum permissible error of the measuring instrument; $\sqrt{3}$ is the coefficient associated with the rectangular distribution of the probability density function.

The total standard uncertainty of the measurement of the humidity $u_c(\overline{W})$ was determined using the formula:

$$u_c^2(\overline{W}) = u_B^2(m)\sum_{i=1}^{2} C_{mi}^2 + u_B^2(m)\sum_{i=1}^{2} C_{m1i}^2 +$$

$$+u_B^2(m)\sum_{i=1}^{2} C_{m2i}^2 + u_A^2(\overline{W}),$$

where C_{m_i}, C_{m1_i}, C_{m2_i} are the sensitivity coefficients of the measurement uncertainty of the accurate value of the humidity to the measurement uncertainty of the mass *m, m1, m2* accordingly; $u_B(m) = \frac{0,0001}{\sqrt{3}}, g$ is the standard uncertainty of the type B of the measurement of the mass; $u_A(\overline{W})$ is the standard uncertainty of the type A of the measurement of the humidity.

The value of the combined standard uncertainty of the humidity measurement $u_C(\overline{W})$ is equal $0,01797$ %.

The combined standard uncertainty of the measurement of the oil concentration in the sample of the seed was determined by the formula:

$$u_C(\overline{X}^*) = \sqrt{u_A^2(\overline{X}^*) + C_{\overline{W}}^2 \cdot u_C^2(\overline{W}) + u_B^2(X_i)\sum_{i=1}^{5} C_{X_i}^2}, \quad (8)$$

where $u_A(\overline{X}^*)$ is the uncertainty of the type A of the measurement of the concentration of the oil in the sample of the seed at the re-count to the dry substance, %; $C_{\overline{W}}$, C_{X_i} are the coefficients of the sensitivity of the uncertainty of the measurements of the accurate value of the concentration of the oil to the uncertainty of the measurements of the humidity and the mass; $u_B(X_i) = \frac{0,0001}{\sqrt{3}}$ g is the standard uncertainty of the type B of the measurement of the mass; $u_C(\overline{W})$ is the total standard uncertainty of the measurements of the humidity, %.

The account of the uncertainty of the type A of the measurement of the concentration of the oil in the sample of the seed was done by the formula:

$$u_{A\overline{x}^*} = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}(X_i^* - \overline{X}^*)^2},$$

where $\overline{X}^*$ is the average value of the measurement of the concentration of the oil in the sample of the seed; n is number of the multiple measurements ($n = 5$).

The value of the total standard uncertainty of the measurement of the concentration of the oil in the sample of the seed is equal $u_C(\overline{X}^*) = 0,07329\%$.

The calculations of the expanded uncertainty of the measurement of the oil concentration in the sample of the seed was done by the formula

$$U = k \cdot u_C(\overline{X}^*), \quad (9)$$

where k is t-coefficient, that is determined at the confidence probability $P = 0,95$ and at the effective degrees of the freedom.

The calculations of the effective degrees of freedom was performed using the following Welch-Satterthwaite formula:

$$\nu_{\text{eff}} = \frac{u_C^4(\overline{X}^*)}{\frac{u_A^4(\overline{X}^*)}{n-1} + \frac{u_C^4(\overline{W})\cdot C_{\overline{W}}^4}{\nu_{\text{eff}\,\overline{W}}}}, \quad (10)$$

where $\nu_{\text{eff}\,\overline{W}}$ is the effective degrees of freedom at the measurement of the humidity; n is number of the multiple measurements of the concentration of the oil in the sample of the seed ($n = 5$).

The value of the effective degrees of freedom is equal $\nu_{\text{eff}} = 4,09$. Using the data of the table of the t-distribution the value of the effective degrees of the freedom is accepted $\nu_{\text{eff}} = 4$. In this case the t-coefficient is equal $t_{0,95} = 2,78$.

The effective degrees of the freedom at the measurement of the humidity $\nu_{\text{eff}\,\overline{W}}$ was determined by the formula:

$$\nu_{\text{eff}\,\overline{W}} = \frac{u_C^4(\overline{W})}{\frac{u_A^4(\overline{W})}{n-1}}. \quad (11)$$

Using the formula (11) the effective degrees of the freedom at the measurement of the humidity is equal $\nu_{\text{eff}\,\overline{W}} = 1,01$.

Defined from formula (9) the expanded uncertainty of the measurement of the concentration of the oil in the sample of the seed U is equal $0,20$ %.

Therefore, the result of the measurement of the oil concentration in the sample of the seed of the sunflower can be presented in the following way:

$$X^* = (40,61 \pm 0,20)\ \%,\ p = 0,95.$$

The account of the accuracy of the measurement of the concentration of the oil in the sample of the seed can be performed using the formula

$$\delta = \frac{\Delta x}{x} \cdot 100\%,$$

where Δx is the absolute error of the measurement; x – the measured value.

The accuracy of the measurement of the concentration of the oil in the sample of the seed is equal $\pm 0,5$ %.

CONCLUSION

The technical and chemical control is very important in the food industry. This control is carried out by using laboratory methods for determining the quality and the safety of the products.

The results of the research of the quality of the new line sunflower's seed were presented in this work. Five parameters of the quality of the sunflower's seed were investigated for an establishment the accordance to the

requirements of the actual regulation standards. The parallel experiments were performed using the physical and the chemical methods. The method of the processing of the indirect measurements was used. The example of the calculation of the measurement uncertainty of the one of the quality parameters (the oil concentration in the sample of the seed) was given. Initially, the total standard uncertainty of the humidity measurement was calculated as the formula of the concentration of the oil include this parameter – humidity.

Therefore, the uncertainty of the measurement of the oil concentration in the sample of the seed was defined; the measurement uncertainty of the oil concentration in the sample of the seed is equal ±0,5% .

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