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THE OPTIMAL RATIO OF CORN AND VEGETABLE ROOTS IN EXTRUDED FORAGE

SHAPOVALENKO O.O., dr.t.s., professor
National University of Food Technologies

ULYANYCH I.F., postgraduate student
Uman National University of Horticulture

The results of investigation on studying the effect on quality parameters of corn extrudate depending on the content of vegetable ingredients such as table beet and table carrots. It is shown that the concentration of additives during extrusion affects the physical and technological properties. Adding vegetables to corn reduces the specific power consumption for extruding process. The optimum ratio of components is established.

***Key words**:* extruder, forage, corn, table beet, table carrot, moisture content, bulk density, water absorption index (WAI), angle of repose, expansion ratio.

Introduction. Today, to obtain ecologically clean meat production, better growth and development, and to improve animal productivity, professionals are increasingly turning to the use of natural feed additives in the feed content. At the same time, our country is constantly accumulating large amounts of raw materials, which is not used in the feed industry. Therefore, the transition to alternative feed production technology is one of the priorities of increasing forage supply and reducing the cost of its production [1,2,5].

Recently, there is lack of modern technology of industrial raw materials like natural feed additive for fattening animals [2,3].

Improving the quality of animal feed products and improving the diet of animals depends on the introduction of new types of fodder plant material containing a balanced complex of proteins, lipids, amino acids, organic acids, minerals, vitamins that play an additional role of acidulante natural and have high nutritional and feed properties, as indicated in their researches leading scientists V.A .Afanas'yev [5], B.V. Ehorov [6], A.P. Levytskyy [1,2], A.N. Ostrykov [4].

The objective of the investigation is to improve the corn feed value due to the enrichment by vegetable components with preservation of physical and technological properties of extrudate.

Object of investigation – grain raw (maize) and vegetable components (beet, carrot).

Methods of investigation. The research was conducted at the Department of Technology of Storage and Processing of Grain of Uman NUH. To obtain extrusion product prototypes and to conduct experimental researches, the laboratory single-screw extruder KESH-1 was used.

Specifications of single-screw extruder KESH-1

Productivity, kg / h.	20-40
Nominal power of the engine (AYRM100L6U2), kW	3.7
Power factor, *cos φ*	0,74
RPM of the shaft electromotor, r/min	945
RPM of the screw, r/min	610
Twisting moment on the shaft of the screw, Nm	31
Barrel diameter, D mm	35
The length to diameter ratio (L/D)	5

Short-extrusion method with the simultaneous effect of intensive mechanical stress and high temperature (120-170°C), were obtained extrusion products made from corn and vegetable components in concentrations of 2,5 %, 5,0 %, 10,0 %, 15,0 %, 22,5 %.

The process was as follows. The extruder was heated to a temperature of 160°C, screw speed was 610 r/min. In receiving extruder hopper lodged previously prepared mixture of whole grain corn and chopped vegetables (thickness – 1–2 mm, length – 4–10 mm). The value of feed mixtures remained constant. Then the product got in to the boot zone, where screw captured mixture, compressed and plasticized it, and pressed through the annular gap. Cross-sectional area was constant and amounted to 19,5 mm^2 (equivalent to a matrix of 5 mm diameter).

Extruded samples was crushed to a particle size of 6–12 mm. We determined the humidity, volumetric mass, coefficients of expansion and water absorption index, the angle of repose. These parameters characterize the technological quality of extrudate.

Specific electricity consumption depend on the productivity and power consumption equipment. It was calculated by the formula:

$$Pt = P / Q \cdot 1000 \text{ kg}$$

where, P – power consumption, kW/h; Q – productivity, kg / h

Active power was calculated by the formula:

$$P = \sqrt{3} \cdot U_L \cdot I_L \cdot cos\varphi, \text{ (W)}$$

where U_L·– linear voltage (380V), I_L – line current; cosφ – power factor of the motor.

Results of researches. An obtained mixture of crushed corn with vegetable ingredients and initial samples were evaluated by a set of physical and technological parameters. They allow to detect structural changes in grain mixtures that occur during the extrusion process and to evaluate the quality of obtained product. Found, that during extrusion significantly reduced the humidity of moisture products (table 1).

Analysis of obtained data, that regardless of the type of vegetable species component and its concentration, mass fraction of humidity of forage after extrusion decreased on the average of 26,0–31,5 %.

1. The change of moisture content during extrusion depending on the composition of the vegetable component

Forage of corn with vegetable roots			Beet			Carrot		
			Mass fraction of humidity,%	to the initial value, %	± to the initial value, %	Mass fraction of humidity,%	to the initial value, %	± to the initial value, %
Vegetable component content	0 (C)*	initial	14,3	100		14,3	100	
		extruded	9,8	68,5	-31,5	9,8	68,5	-31,5
	2,5	initial	16,2	100		16,1	100	
		extruded	11,6	71,6	-28,4	11,1	68,9	-31,1
	5,0	initial	18,2	100		18,0	100	
		extruded	13,4	73,6	-26,4	12,8	71,1	-28,9
	10,0	initial	22,1	100		21,6	100	
		extruded	16,0	72,3	-27,6	15,8	73,2	-26,9
	15,0	initial	26,0	100		25,3	100	
		extruded	18,5	71,2	-28,9	18,1	68,8	-31,2
	22,5	initial	31,8	100		30,8	100	
		extruded	23,2	73,0	-27,0	22,8	74,0	-26,0

*(C) – control

The greatest losses of humidity was received in the grain sample without the addition of vegetable components, where the mass fraction of humidity amounted 68,5 % to the initial value, and the difference reached 31,5 %. Addition to the mixture of shredded beet in different concentrations contributed to increase of mass fraction of humidity in the initial production on 2–17,5 % and carrot – is slightly lower – 1,8–16,5 %.

Thus, during extrusion processing of mixture of corn with vegetable components is significantly reduced moisture content, which contributes to its further storage and sustainable usage for forage.

Determination of the main physical parameters of corn mixture with vegetable components, such as bulk density, water absorption index, angle of repose, showed that during the extrusion process, change of parameters occurs depending on the concentration of the components (Table 2).

Whereas macromolecules of extrudates packed loosely and between them can form cavities into which water penetrates, it causes an increase of volume and degree of water absorption. Analysis of the data of table 2 showed that in extruded corn with vegetable roots, degree of water absorption is 8,53 ml/g, while in unprocessed form

4,17 ml/g. Adding to forage from maize, vegetables roots in different concentration reduced the water absorption of mixture. Thus, with concentration of components of 2,5 %, degree of water absorption depending on the component amounted 8,43–8,49 ml/g.

2. Physical parameters of corn mixture with vegetable components depending of the concentration

Mixture of corn with vegetable roots			Bulk density, kg/m3	WAI, ml/g	The angle of repose, degrees	Expantion ratio
Content of beet,%	0 (C)*	original	637,1	4,17	32,0	–
		extruded	138,4	8,53	41,4	3,23
	2,5	original	654,9	4,13	34,6	–
		extruded	147,7	8,43	41,3	3,06
	5,0	initial	668,7	4,07	36,7	–
		extruded	156,4	8,23	42,7	2,63
	10,0	initial	692,4	3,98	39,8	–
		extruded	198,7	7,40	43,2	1,73
	15,0	initial	732,1	3,89	41,5	–
		extruded	242,8	6,07	43,8	1,53
	22,5	initial	778,7	3,74	46,4	–
		extruded	272,1	4,43	45,4	1,02
Content of carrots,%	0 (C)*	initial	637,1	4,17	32,0	–
		extruded	138,4	8,53	41,4	3,23
	2,5	initial	667,7	4,12	34,6	–
		extruded	145,3	8,49	41,5	3,19
	5,0	initial	700,4	4,06	36,2	–
		extruded	151,5	8,43	42,6	2,28
	10,0	initial	700,4	3,92	39,3	–
		extruded	194,0	7,77	41,2	1,65
	15,0	initial	733,1	3,83	42,4	–
		extruded	245,2	6,65	43,9	1,34
	22,5	initial	774,7	3,73	45,9	–
		extruded	262,7	4,56	45,2	1,05

(C)* – control

Increase of the content of vegetable roots to 10 % led to index decrease to 7,40–7,77%, but increase to 15 % caused a decrease of the degree of water absorption

index to 6,07–6,65 %. Further increase of concentration of the vegetable components in forage to 22,5 % led to a decrease of WAI, which reached the level of 4,43–4,56%.

So water absorption index of corn mixture with vegetable ingredients depending of their conten showed that with increase of content of the added component decreases WAI of extruded product, that shows the decrease of mixture ability with high concentrations of components to absorb water.

Obtained data on determination of bulk density of mixture indicates that the increase of the content of vegetable components causes an increase of bulk density of forage in the feedstock from 637,1 to 778,7 kg/m3 and in extruded – from 135,6 to 272,1 kg/m3.

The angle of repose of the feedstock reached the level of 32 degrees. With the increase of vegetable components content it reached 46 degrees. The process of extrusion caused the index increase to 1-9 degrees. With vegetable component content of 22,5%, indicators of raw mixture and finished extrudate aligned and angle of repose amounted 45-46 degrees.

After product output through the matrix outlet because of the significant pressure drop, considerable release of humidity occurs. This leads to the formation of highly porous structure and a significant increase of the transverse size of the extrudate. The corresponding process is characterized by the degree of increase of the volume of product that depends on the content of starch. Expansion ratio in extrudate from maize was 3,17 and decreased by further increasing of the concentration of vegetables. The lowest index was during introduction of vegetable component with concentration of 22,5% and amounted 1,02–1,05.

3. Technological extrusion process parameters

Index		Concentration of vegetable component, %					
		0,00%	2,50%	5,00%	10,00%	15,00%	22,50%
Productivity, kg / h (Q)	b	26,5	27,6	26,8	22,3	19,6	18,2
	c		26,7	25,4	21,8	18,6	17,8
Amperage, A (I)	b	6,4	6,1	5,4	4,9	4,6	4,8
	c		6,3	5,5	5,0	4,7	4,9
Power consumption, kW/h (P)	b	3,1	3,0	2,6	2,4	2,2	2,3
	c		3,1	2,7	2,4	2,3	2,4
Specific electricity consumption, kW/h·tonne (Pt)	b	117,0	108,7	97,0	107,6	112,2	126,4
	c		116,1	106,3	110,0	123,6	134,8

b – beet

c – carrot

Better productivity was observed in the concentration of vegetable components of 2,5-5,0%. This is due to moisture content in vegetables, which is in moderate concentration (16-18%) improves the process. But further increase of moisture content leads to poor transportation of material by the screw.

The obtained results show that power consumption is reduced by increasing the concentration of vegetable component. The lowest index is 2,2–2,3 kW by adding 15% of vegetables.

Specific electricity consumption – is the ratio of power consumption to productivity. Extruding maize requires more power than in mixture with vegetables. Specific electricity are the lowest by concentration of vegetable component 5–10%. But the most energy-consuming – mixtures with vegetables content of 22,5%.

Conclusions. Found that adding vegetables to corn reduces the unit cost of electricity extrusion process. The optimum concentration of vegetable component is 5-10%. In this concentration, decrease of energy consumption to 15% and improve of physical and technological parameters are observed.

Also during extrusion processing of mixture of corn with vegetable components, significantly reduces moisture content, which contributes to its further preservation and sustainable use on forage.

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Шаповаленко О.И., Ульянич И.Ф.

Влияние различной концентрации овощных компонентов на процесс экструдирования зерна кукурузы

Приведены результаты исследований по изучению влияния на качественные показатели экструдата кукурузы в зависимости от содержания овощных компонентов, в частности, свеклы столовой и моркови столовой.

В процессе экструзионной обработки смеси кукурузы з овощными компонентами значительно снижается массовая доля влаги, что способствует сохранности и рациональному использованию на корм.

Доказано, что на физические и технологические свойства экструдата влияет концентрация добавок. Так, при концентрации компонентов 2,5% степень набухания в зависимости от концентрации компонента составляла 8,43 – 8,49 мл/г. Повышение содержания овощных корнеплодов до 10% способствовало снижению показателя до 7,40 – 7,77%, а повышение до 15% вызывало снижение ступени набухания до 6,07 – 6,65%.

Экструдирование чистого зерна кукурузы нуждается в большем количестве электроэнергии, чем смесь с овощными корнеплодами. Оптимальная концентрация овощного компонента в экструдированных кормах составляет 5 – 10%. При этой концентрации наблюдается уменьшение энергопотребления до 15% и улучшаются физико-технологические показатели. Исследования показали, что наиболее энергозатратным является приготовление кормосмеси с содержанием овощей 22,5%. Добавление овощей к зерну кукурузы снижает удельные затраты электроэнергии на процесс экструдирования. Установлено оптимальное соотношение зерновых и овощных компонентов.

Ключевые слова*: экструдер, кормосмесь, кукуруза, свекла столовая, морковь столовая, массовая доля влаги, объемная масса, набухание, угол естественного откоса, коэффициент расширения.*

Chapovalenko O.I., Ulyanych I.F.

Effect of different concentrations of vegetable components on the process of extrusion of corn

The results of studies on the effect on the quality parameters of extruded corn depending on the content of vegetable components, in particular, beet and carrot.

In the process of extrusion processing of a mixture of maize with vegetable components significantly reduces mass share of moisture, which contributes to preservation and rational use for forage.

It is proved that the concentration of additives affects physical and processing properties of extrudate. So, when components concentration of 2.5% the swelling degree, depending on the concentration of the component was 8,43 – 8,49 ml/g. The increase of the concentration of vegetable roots up to 10% contributed to reduce the ratio to 7,40 – 7,77%, while the increase to 15% caused a decrease of the degree of swelling up to 6,07 – 6,65%.

Extrusion of pure corn requires more electric power than a mixture of vegetable

roots. The optimal concentration of vegetable component in extruded feed is 5 – 10%. In this concentration is observed a decrease of energy consumption up to 15% and physical and technological indicators are improved. Studies showed that the most power consumpting is the preparation of fodder with the content of vegetables to 22.5%. Adding vegetables to the grain of corn reduces the unit cost of energy consumption on the extrusion process. The optimum ratio of grain and vegetable components is set.

***Keywords**: extruder, foodmixture, corn, beet, carrot, moisture content, bulk density, swelling, angle of repose, coefficient of expansion.*