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MODEL OF DISTRIBUTING LIQUID PRESERVATIVES IN A VEGETABLE MASS

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Key words: concentration; non-uniformity; preservative.

Abstract: The paper deals with the way of laying the feeds in by means of their ensilaging with the devised mobile unit being used. The principles of operation of this unit as well as the techniques for determining the depth of penetration and concentration of the preservatives in a silage mass are described. The advantages of application of the proposed unit are discussed.

One of the most important goals of feed production are to provide cattle breeding with high-grade feeds, to lay them in timely and qualitatively as well as to conserve their nutrients. These goals can be achieved by applying liquid preservatives while laying juicy vegetable feeds in. There are many ways of adding preservatives to the vegetable mass, which can be classified according to the type of the preservatives, the place of adding, the manner of adding, etc.

One of the perspective technologies of laying a silage in, with liquid preservatives being added to it, is that according to which the preservative is to be added to the vegetable mass directly when the mass is moved and tamped down in a trench by a tractor. In this case the amount of the preservatives being put in corresponds to the mass of the given portion. This technology is carried out by means of the unit the main elements of which are: feeders, pumps, pumps-feeders, injectors, etc.

The deficiencies of the present equipment are known to be insufficient uniformity of distributing the preservative in the unit of volume (portion) of feed, metal consumption, complexities arising when dose of the preservative is changed.

To solve this problem we have designed the unit which enables to improve the quality of feed being laid in Fig. 1 [2].

On the pendulous tractor frame there is gripping device *1* with injectors *2* connected through pressure pipeline *15* with pump *14* and container for preservatives *13*. A feeder consists of adjusting hydraulic cylinder *7* and controlling hydraulic cylinder *11*. The working inner area of the adjusting hydraulic cylinder *7* is connected with the inner area of the hydraulic cylinder *3* of the pendulous tractor frame. Piston *8* of the adjusting hydraulic cylinder *7* is spring-loaded by spring *6*. There is stop *9* on the rod of piston *8*. The controlling hydraulic cylinder *11* is designed in the form of a cylinder with two cavities separated from a central hole by a partition. One of the cavities of the controlling cylinder *11* is provided with piston *12* on the spring-loaded rod of which there is switch *10* of the electrical circuit which controls pump operation. This cavity is open to pressure pipeline *15* through valve *5*. The other cavity of the controlling hydraulic cylinder *11* communicates with tank for preservative *13* through a fitting pipe at the one end and with pressure pipeline *15* through another fitting pipe at the other end. The cavity is provided with elastic membrane *4* which locks the entrance from the pressure pipeline *15*.

The equipment operates in the following way. Gripping device 1 (Fig. 1) takes a portion of vegetable mass introducing injectors *2* into it. With the help of hydraulic cylinder *3* the pendulous frame with gripping device 1 is raised. The hydraulic pressure in the working cavity of hydraulic cylinder *3* which corresponds to the mass of the vegetable feed portion is transferred into the working cavity of the adjusting hydraulic cylinder *7*. Spring-loaded piston *8* moves until the efforts of the spring compression and hydraulic pressure are balanced. Meanwhile the rod of piston *8* with stop *9* comes out of contact with switch *10* making the electrical circuit of the pump drive be ready. By turning on an electrical switch located in the tractor cabin the electrical circuit controlling the operation of pump *14* is closed and feeding the preservative through pressure pipeline *15* and injectors *2* into vegetable mass starts. The preservative moving inside pressure pipeline *15* gets through valve *5* into the cavity of controlling hydraulic cylinder *11* and simultaneously affects membrane *4* which covers the hole between the two cavities of controlling hydraulic cylinder *11*. Under the pressure of the preservative piston *12* goes up. Pushbutton switch *10* located on the spring-loaded piston rod *12* reaches stop *9* and breaks the electrical circuit controlling pump operation *14*. Feeding the preservative is stopped. Pressure in pipeline *15* falls and membrane *4* opens the hole between the two cavities of hydraulic cylinder *11*. The preservative residing in hydraulic cylinder *11* being affected by the spring of piston *12* and by chute flows down into the tank for preservative *13*. Piston *12* returns to its lower dead point. After unloading the mass and resetting pressure in the working cavity of hydraulic cylinder *3* piston *8* of adjusting hydraulic cylinder *7* goes down until stop *9* comes into contact with switch *10*.

One of the main functions of an injection device consisting of a number of tubular injectors is to provide uniform distribution of preservative solution in the feed mass.

The desired parameters will be the following: the interval of mounting injectors on the mobile frame, the diameter of holes and the interval of their placing on the injectors.

These parameters are affected by many factors, such as pressure provided by pump, physical-mechanical properties of injectors movement in the feed mass.

The critical points in determining design-mode parameters are the depth of

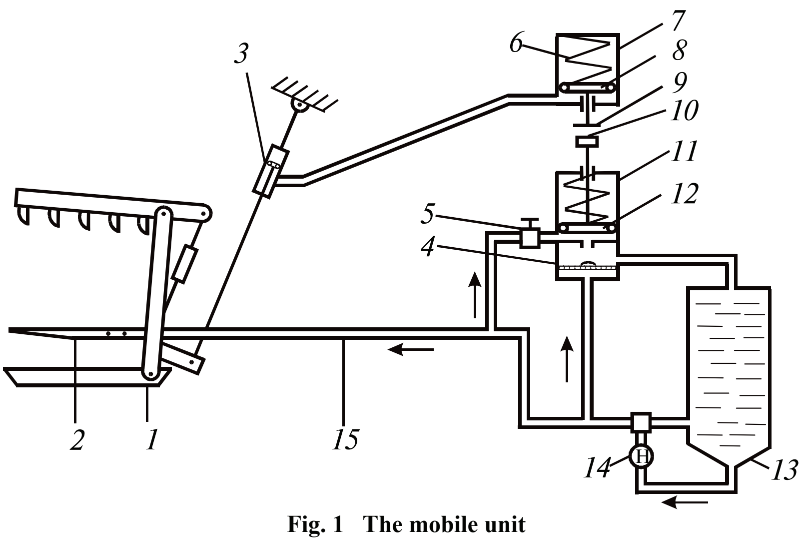

Fig. 1 The mobile unit

penetration of preservatives into the feed mass and the diameter of preservative spray cone.

Taking into consideration the above mentioned factors, the purpose of the research was to define the concentration of the preservative at different points of spray cone. The solution of the stated problem was realized in two stages:

1. Specification of the boundaries of preservative spreading of the supposed unit.
2. Determination of the ways of spreading liquid preservative and its concentration within the cone.

To study the distribution of liquid preservative in the bulk of vegetable feed a process of penetration of the preservative flow into the feed mass was modeled.

Axial velocity of outflow into the fluid of high density in comparison with the density of gas for axis symmetric flow is defined according to formula [3]

$$v = \frac{0,48 v_0}{\frac{ax}{d} + 0,145}, \tag{1}$$

where v_x – velocity in the cross-section being studied at the distance x from the mouth of a nozzle, m/s; x – distance from the nozzle mouth up to the point being studied, m; a_1 – coefficient of turbulence, characterizing the intensity of mixing of flow with fluid; v_0 – velocity of outflow from the nozzle mouth, m/s; d – diameter of a nozzle mouth, m.

Changing a preservative mass in the elementary volume V per unit of time is defined by:

$$dm = \rho(v_1 ds - v_2 ds), \tag{2}$$

where ρ – density of preservative, kg/m^3; v_1, v_2 – flow velocities at the entrance and exit accordingly; ds – an area of cross-section elementary volume dV, perpendicular to the velocity of spreading the flow.

Changing the concentration at the point being studied is defined according to formula

$$dc = dm/dV \cdot dt. \tag{3}$$

Taking in account that $dV = dsdx$, we get the dependence of the velocity of changing preservative concentration per elementary time

$$dc/dt = dm/dsdx. \tag{4}$$

Considering (2) and (4) the expression will be the following

$$dc/dt = -\rho dv/dx. \tag{5}$$

Taking the derivative of velocity (1) on coordinate x

$$\frac{dv}{dx} = -\frac{0,48 v_0 \frac{a}{d}}{\left(\frac{ax}{d} + 0,145\right)^2} \tag{6}$$

and having substituted the received value into formula (5), we get

$$\frac{dc}{dt} = \frac{0,48 v_0 a}{d\left(\frac{ax}{d} + 0,145\right)^2}. \tag{7}$$

Integrating (7) on t, taking into consideration the initial conditions, we get volumetric concentration C [kg/m^3] on torch axis as function of time and distance from a nozzle

$$C = \frac{0,48 v_0 a}{d\left(\frac{ax}{d} + 0,145\right)^2} t. \qquad (8)$$

Expressing v_0 through P and making some transformations, we get:

$$C = \frac{0,48\varphi\sqrt{2P\rho} \cdot at}{d\left(\frac{ax}{d} + 0,145\right)^2}. \qquad (9)$$

Suppose the lines of equal concentration of preservative be described by the conchoid Nikomed equation (3)

$$y^2 = (r - x)\, x^2 A, \qquad (10)$$

where parameter A is defined by the angle of preservative spray close to injector

$$\mathrm{tg}\alpha = \lim_{x \to 0} y/x = \lim_{x \to 0} \sqrt{(r-x)x^2 A / x^2} = \sqrt{rA}. \qquad (11)$$

After having made the corresponding transformations parameter A is defined by the expression

$$A = \mathrm{tg}^2\alpha / r. \qquad (12)$$

The volume of the entire torch (Fig. 4) into which the preservative penetrates under pressure is defined by formula

$$V = \pi \int_0^r y^2 dx. \qquad (13)$$

After substitution of equation (13) in formula (10) and a number of transformations equation (13) will take the form

$$V = \pi \int_0^r (r - x) x^2 A dx. \qquad (14)$$

Formula (14) having been integrated takes the form

$$V = \pi A r^4 / 12. \qquad (15)$$

To carry out further research the area of torch light was divided into n equal in volume sections (Fig. 2), the boundaries of each section being defined by the equation:

$$x_i = \sqrt{(x_{i-1})^4 + \frac{12 V_n}{\pi A}}, \qquad (16)$$

where V_n – volume of n^{th} fraction of torch light $V_n = V/n$.

It is supposed accurately enough that concentration of preservative in volume V_n is equal to the concentration on torchlight axis at the distance x_i from the nozzle mouth.

Since liquid part of silage is a solution of a weak base, then on adding weak acid the calculation of pH is performed according to formula [4]:

$$\mathrm{pH} = \lg(C_{\mathrm{sil}}/C) + \mathrm{pH_a}, \qquad (17)$$

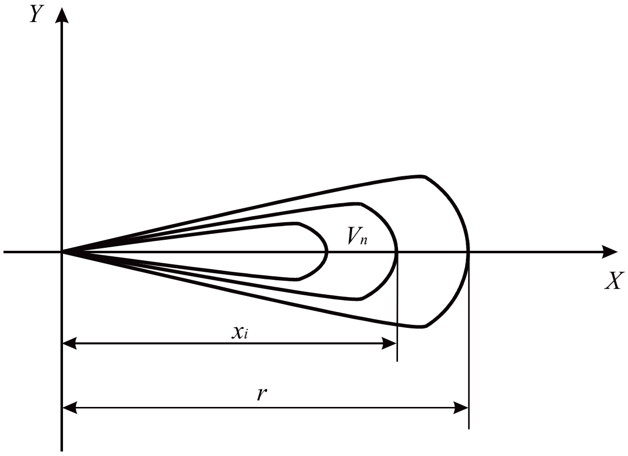

Fig.2 Scheme of spreading the preservative in the mass

for weak acid pH_a is defined

$$\text{pH}_\text{a} = -\lg\sqrt{K_\text{a}C}\ , \tag{18}$$

where K_a - a constant of acid dissociation.

The main reaction for silage until processed is

$$\text{pH}_\text{sil} = -\lg(10^{-14}/\sqrt{K_\text{sil}C_\text{sil})}\ , \tag{19}$$

where K_sil - an average constant of ion dissociation in silage; C_sil - ion concentration in silage:

$$C_\text{sil} = (10^{\text{pHsil-14}})^2/K_\text{sil}. \tag{20}$$

By substituting (20) into (17) the acidity of mass in a given area is defined by formula

$$\text{pH} = -\lg\sqrt{K_\text{a}C} + \lg\frac{\left(10^{\text{pH}} - 14\right)^2}{K_\text{sil}C}\ , \tag{21}$$

where K_sil - generalized constant of dissociation of chemical substances in a vegetable mass.

Having substituted expression (9) into formula (21), we get

$$\text{pH} = -\lg\sqrt{\frac{K_\text{a}0{,}48\varphi\sqrt{2P\rho}\cdot at}{\left(\frac{ax}{d}+0{,}145\right)^2 d}} - \lg\frac{\left(10^{\text{pH}'-14}\right)^2}{\frac{K_\text{sil}0{,}48\varphi\sqrt{2P\rho}\cdot at}{\left(\frac{ax}{d}+0{,}145\right)^2 d}}\ , \tag{22}$$

The coefficient of non-uniformity of preservative distribution in the volume of vegetable mass is defined by formula [5]:

$$K = \frac{\sqrt{\sum\left(\text{pH}_i - \text{pH}_\text{av}\right)^2/\left(n_1 - 1\right)}}{\text{pH}_\text{av}}, \tag{23}$$

where n_1 – a number of tests; pH_av - average acidity; pH_i – acidity in i^{th} point.

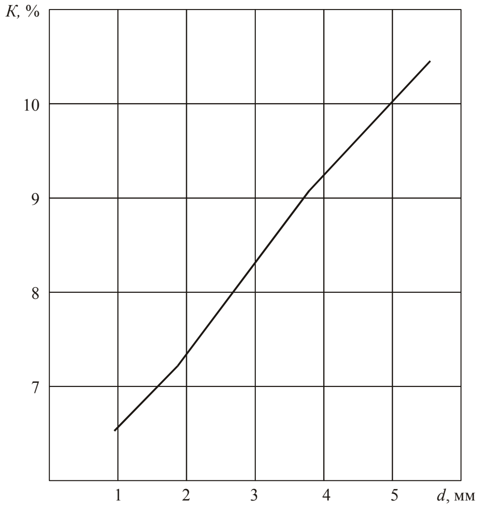

Fig. 3 Graph of changes in the non-uniformity of preservative distribution

On the basis of theoretical research we constructed a graph of changes in the non-uniformity of distributing liquid preservative (*K*) depending on the diameter of the hole (*d*).

From the dependence (Fig. 3) we can conclude that the diameter recommended for the device varies from 1 to 3 mm. Under such a diameter the non uniformity of distributing preservatives ranges from 8 to 9 %.

Theoretical calculations have been confirmed by the experimental research.

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МОДЕЛИРОВАНИЕ ПРОЦЕССА РАСПРОСТРАНЕНИЯ СТРУИ ЖИДКОГО КОНСЕРВАНТА В МАССЕ РАСТИТЕЛЬНОГО КОРМА

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Ключевые слова: консервант; концентрация; неоднородность.

Аннотация: Изложен способ заготовки кормов путем их силосования с применением мобильного агрегата, а также описан принцип работы данного агрегата, приведена методика определения глубины проникновения и концентрации консервирующего препарата в объеме силосной массы. Описаны преимущества применения предложенного агрегата.

Modellierung des Prozesses des Strahlvertriebes des flüssigen Konservierungsmittels in der Masse des Pflanzenfutters

Zusammenfassung: Es ist die Weise der Futtererfassung mittels ihrer Silierung mit der Anwendung des Mobilaggregates dargelegt. Es ist das Arbeitsprinzip des gegebenen Aggregates beschrieben. Es ist die Methodik der Bestimmung der Tiefe der Durchdringung und der Konzentration des Konservierungspräparates im Umfang der Silomasse angeführt. Es sind die Vorteile der Anwendung des angebotenen Aggregates beschrieben.

Modélage du processus de la répartition du jet du conservant liquide dans la masse du fourrage

Résumé: On propose le moyen de la conservation du fourrage par son ensilage à l'aide de l'agrégat mobile et l'on décrit le principe du fonctionnement de cet agrégat. On cite les méthodes de la définition de la profondeur du passage et de la concentration du produit conservant dans le volume de la masse de silo. On décrit les performances de l'application de l'agrégat proposé.
