INFLUENCE OF COMPOSITION AND TEMPERATURE ON THE DRYING AND QUALITY OF PREMIXES FOR FEED BASED ON SUGAR BEET PULP
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INFLUENŢA COMPOZIŢIEI ŞI TEMPERATURII ASUPRA USCĂRII ŞI CALITĂŢII PREMIXURILOR PENTRU FURAJE PE BAZĂ DE PULPĂ DE SFECLĂ DE ZAHĂR

Gyorgy Z.*[1)], Nagy E. M. [1)], Cota C.[1)], Cioica N.[1)], Deac T.[2)], Miclauş V.[3)] [1]
[1)] INMA Bucharest, Branch Cluj-Napoca / Romania
[2)] Technical University of Cluj-Napoca, Faculty of Mechanics / Romania
[3)] Babes-Bolyai University Cluj-Napoca, Faculty of Chemistry and Chemical Engineering / Romania
Tel. 0748545931; E-mail: gyorgy2zoltan@gmail.com
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ABSTRACT

Beet pulp resulting from sugar production is, thanks to the easily assimilable carbohydrate content, an important source of feed, especially for ruminants and pigs. The efficiency of its utilization can be substantially improved by adding macroelements and microelements. In order to preserve and maintain the nutritional value of the resulting premix, a drying operation is required. In the paper are presented the results of experiments on how the percentage of macroelements (Ca^{2+}, Mg^{2+}, PO_4^{3+}) and microelements (Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+}) influence the time variation of moisture and the drying rate of the premix at different drying temperatures and the quality of premixes.

REZUMAT

Pulpa de sfecla rezultata de la fabricarea zaharului reprezintă, datorita conţinutului de carbohidrati usor asimilabili, o sursă importantă de furaj, în special pentru animalele rumegatoare si suine. Eficienţa urilizarii acesteia poate fi substanţial îmbunătăţită prin adăugarea de macroelemente şi microelemente. In vederea conservarii si mentinerii valorii nutritive a premixului rezultat este necesara o operaţie de uscare. In lucrare sunt prezentate rezultatele experimentarilor privind modul în care procentul de macroelemente (Ca^{2+}, Mg^{2+}, PO_4^{3+}) si microelemente (Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+}) influenţează variaţia în timp a umidităţii şi viteza de uscare a premixului la diferite temperaturi de uscare si calitatea premixurilor.

INTRODUCTION

Beet pulp is the fibrous material resulting as a by-product of the technological process of sugar manufacturing, after most of the sugar is extracted from sugar beet (*Asadi M., 2007; Bubnik et al., 1995; Domşa and Iliescu, 1973*).

The use of beet or beet pulp in the feed ration of animals, especially ruminants and swine, is not a new concept. However, so far, no particular attention has been paid to this problem of high economic efficiency, with real development prospects and great possibility to be applied to animal feed.

Sugar beet is a plant with a vegetation cycle of 140-200 days and has, compared to wheat, barley or corn, the advantage that its useful part is the root, which, developing in the ground, is less exposed to climatic caprices (frost, flood, hail), so they affect less production *(Hoffmann et al., 2009; Wahab and Salih, 2012*). Moreover, being a plant that adapts easily to osmotic pressure, sugar beet can be cultivated on saline soils with high alkalinity that not only does not damage but even potentiate production (*Katerji et al., 1997*).

By their chemical composition, beets, as well as the pulp resulting from sugar production, are important sources of energy, proteins, vitamins and minerals essential to the animal's health, noting that they do not contain antinutritional factors that cause them problems (*Evans and Messerschnidt, 2017; Finkenstadt V. L., 2014; Ibáñez et al., 2015; Monteiro et al., 2017; Münnich et al., 2018)*.

In addition to the content of proteins, vitamins and minerals, pulp fibre has high carbohydrate content such as hemicellulose, cellulose and pectin *(Finkenstadt V. L., 2014)*.

[1] *Gyorgy Z., Eng.; Nagy E.M., Ph.D. Stud. Eng.; Cota C., Eng.; Cioica N., Ph.D.Eng., Deac T., Assoc. Prof Ph.D. Eng.; Miclauş V., Assoc. Prof. Ph.D.*

In terms of energy, the nutritional value of the pulp is approaching that of the high-quality hay, mentioning that it is assimilated much easier and with yields exceeding 80% (*Habeeb et al., 2017*). Practically, the pulp is a macromolecular complex of the cell membrane, representing approx. 5% of the sugar beet weight. This macromolecular complex is made up of protopectin which, under the action of pectolytic enzymes in the digestive tract of animals, are easily hydrolysed to pectinic acid and low molecular weight polypectins, soluble compounds that are easily metabolised into useful compounds. These compounds enter directly into the milk composition with a positive effect on both production and fat content, which may increase by 8-11% (*Ertl et al., 2016; Melendez et al., 2015*). In addition, the introduction of pulp into the feed ration of bulls, rams or intensive fattening pigs leads to increased weight gain and quality of meat proteins (*Boucque et al., 1978; Habeeb et al. 2017*). Also, by easily metabolising in useful products, the amount of greenhouse gas (carbon dioxide and methane) that the ruminants produce during digestion is sensibly diminished, which is environmentally beneficial (*Getachev et al., 2004; Ibanez et al., 2015*). Another positive aspect to be highlighted is that beet pulp has an appreciable fibre content (210-240 g/kg dry matter), which has the ability to adsorb and ion exchange, thus regulating the pH in the digestive tract of animals (*Münnich et al., 2017*). Furthermore, the presence of pulp in the feed ration of animals leads to an increase in the use of fibrous feed (*Mogensen and Kristensen, 2003*).

Considering the seasonal character of the sugar factories functioning and the large quantities of the resulting beet pulp, it is necessary to process it in order to increase the storage period. Preservation over longer periods of time, weeks or months, involves drying the pulp by thermal removal of its humidity, using drying techniques and parameters in the fruit and vegetables field *(Ingeaua et al., 2015; Jokić et al. 2013; Yang et al. 2018*).

The efficiency of beet pulp in the feed ration of ruminants and pigs can be substantially improved by adding macroelements and microelements (*Rauch et al. 2012*). The presence of macroelements and microelements in feed rations is particularly beneficial especially for the fact that, by reaction with polyglucuronic acid, organo-mineral complexes are formed which facilitate the absorption of Ca^{2+}, Mg^{2+}, PO_4^{3+}. Among the microelements Zn^{2+} is particularly noticeable as it has a positive effect on fertility and Co^{2+}, which facilitates the synthesis of B-complex vitamins in the final intestinal tract.

The paper presents the results of a kinetic study of the pulp drying process, in which we research the influence of macroelements (Ca^{2+}, Mg^{2+}, PO_4^{3+}) and microelements (Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+}) additions on the time variation of humidity and water removal speed. The influence of these additions on the quality of the dried beet pulp was also monitored.

MATERIALS AND METHODS

One of the main problems to be solved when it comes to drying the pulp is the sizing of the dryer. Performing the sizing calculations involves knowing the time of material stationing in the dryer. In order to determine this time, experimental measurements are needed, with materials and working conditions as close to those of industrial practice, following which is the influence of the main parameters (temperature, composition, material layer thickness) on the variation in time of material humidity and on the drying speed.

The drying process is very complex; it can be carried out according to different laws. Two basic variants are possible:

Fig. 1 - AXIS 100 Moisture

a) the case of the material moisture being eliminated with constant speed, which corresponds to the removal of the free water from the material surface. It is the humidity that does not interact by any force with the material, the process of water evaporation or vapors mass transfer from the material surface in the gas phase volume being the one limiting the speed.

b) The case of the drying process taking place from the very first moments according to a mechanism in which the speed decreases continuously.

Where applicable, the material stationing time in the dryer will be represented by the duration of one or the sum of the two periods.

In order to establish the mechanism according to which the drying process is carried out, experimental measurements were made regarding the variation over time of the material water content. The experimental data were then processed obtaining the drying curves and the drying speed curves for each composition at each of the four temperatures.

The researched material subjected to drying was the pulp obtained from the TEREOS-ROMANIA Sugar Factory, Ludus. The source for Ca^{2+} ions was the lime industrially produced at TEREOS-ROMANIA, Ludus. The source for the Mg^{2+} ions was the dolomite lime obtained in the laboratory by calcination of Vaslobeni dolomite at 850°C. The source for PO_4^{3+} ions was phosphoric acid 85% for analysis purchased from the supplier NORDIC CHEMICALS Cluj Napoca. The microelements Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+} were added as quality sulphates for analysis purchased from NORDIC CHEMICALS Cluj Napoca.

The drying study was carried out with an AXIS 100 moisture balance, having a maximum capacity of 100 g, weighing precision 0.001 g, humidity precision 0.01%, maximum drying temperature 160°C and heating by two halogen radiators (Fig. 1). The AXIS STAT software, the moisture balance is provided with allowed the automatic measurement of the sample mass, every two minutes, as well as the collection and storage of the measured values on the PC connected to the moisture balance.

5 g samples of four different compositions: P1-crude pulp, P2-crude pulp treated with lime ($Ca(OH)_2$), P3 – crude pulp treated with lime and phosphoric acid, respectively P4 – crude pulp treated with lime, phosphoric acid, dolomite lime and sulphates of microelements, were dried at four different temperatures (60, 70, 85 and 95°C). The compositions of the four samples, expressed in organic part, CaO, P_2O_5 and MgO and microelements of the four samples are presented in Table 1.

Table 1

Composition of samples subjected to drying in relation to the dry product

Sample	Organic part [%]	CaO [%]	P_2O_5 [%]	MgO [%]	Microelements
P1	18.7	-	-	-	-
P2	70	30	-	-	-
P3	65.63	28.5	5.85	-	-
P4	61.5	23.2	5.5	9.8	Ca=1.2ppm Zn=2.1ppm Cu=0,75ppm Fe=1.5ppm Mn=0.25ppm

RESULTS

In the diagrams in Fig. 2, 3, 4 and 5 are presented comparatively the drying curves at each of the four temperatures for the four samples P1, P2, P3, P4.

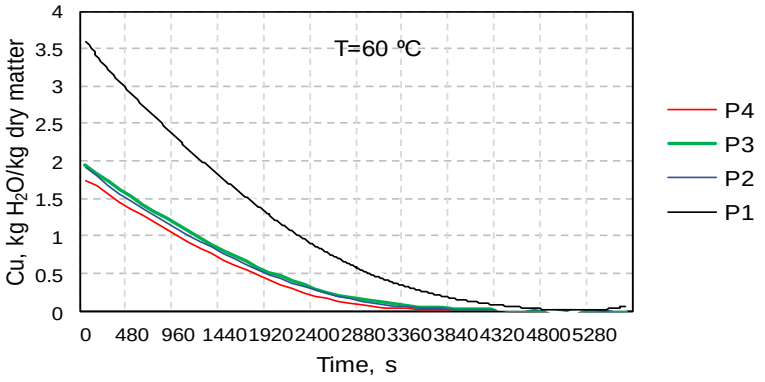

Fig. 2 – Humidity curves of the four samples at 60°C

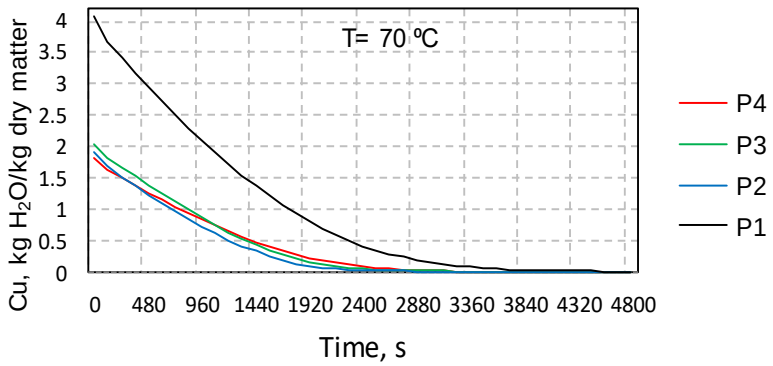

Fig. 3 - Humidity curves of the four samples at 70°C

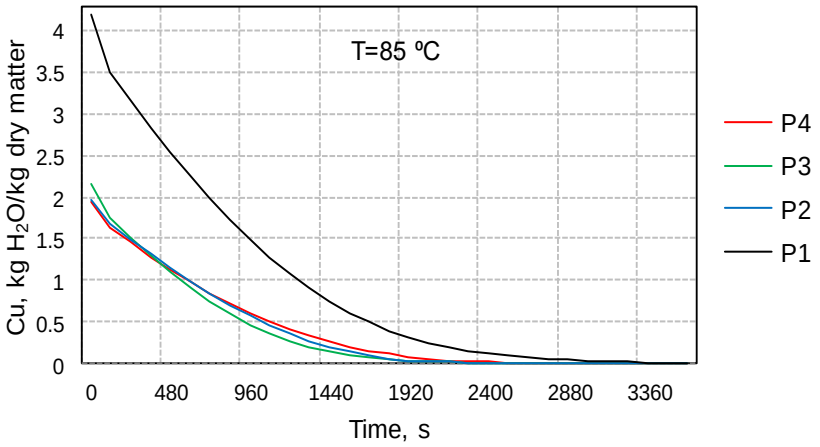

Fig. 4 - Humidity curves of the four samples at 85ºC

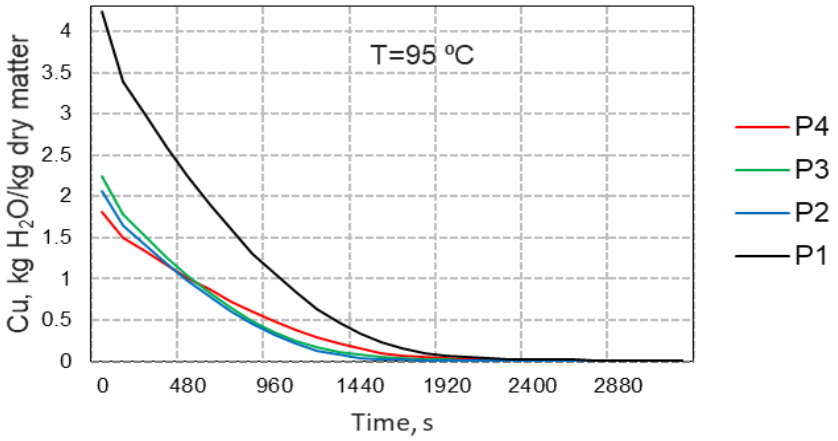

Fig. 5 - Humidity curves of the four samples at 95ºC

From these graphs it can be observed both the variation in humidity reported to the dry matter at each of the four temperatures for the four samples, as well as the great influence of additions of lime, dolomite lime, phosphoric acid and microelements (Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+}) on the time required for the complete elimination of humidity, times the values of which are presented in Table 2.

Table 2

The influence of additions and temperature on the time required to reach the equilibrium state

Sample	P1	P2	P3	P4
Temperature [ºC]	Drying time [s]			
60	5500	3800	3800	3600
70	4500	2250	2200	2500
85	3360	1700	1700	1950
95	2400	1650	1650	1900

A strong influence of these additions on the time required to reach the equilibrium state is manifested especially at low drying temperatures (60ºC and 70ºC). In the case of sample P1, which does not contain macro- and microelements, the influence of temperature remains significant also at temperatures of 85ºC and 95ºC. The addition of phosphoric acid and microelements in the case of sample P4 results in times of the same order of magnitude with those corresponding to samples P2 and P3, with the mention that in the case of sample P4 the times are higher with values between 3 and 12%. This may be due, on the one hand, to the strong interaction between formed phosphates and water and, on the other hand, to the fact that the structure of the P4 sample is less porous.

In the diagrams in Figures 6, 7, 8 and 9 are presented comparatively the variation curves of the drying speed depending on humidity for the four samples P1, P2, P3 and P4 at each of the four temperatures, starting from the moment the temperature of the material reached the operating temperature.

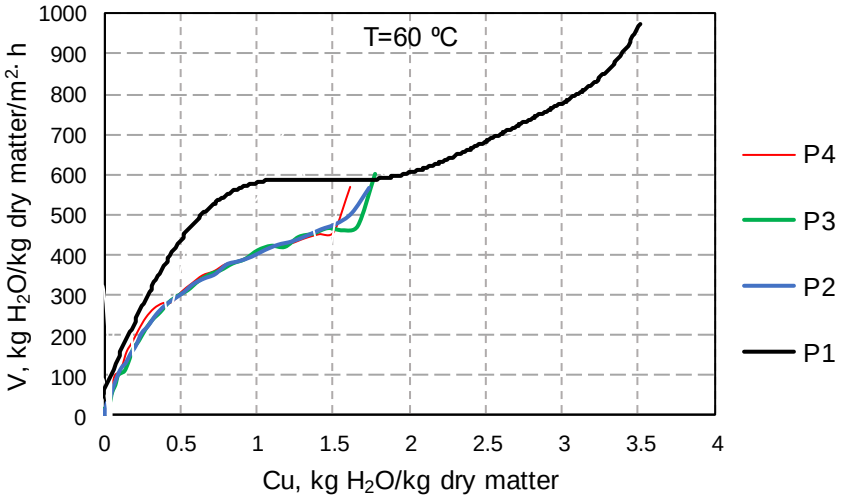

Fig. 6 - Drying speed curves of the four samples at 60ºC

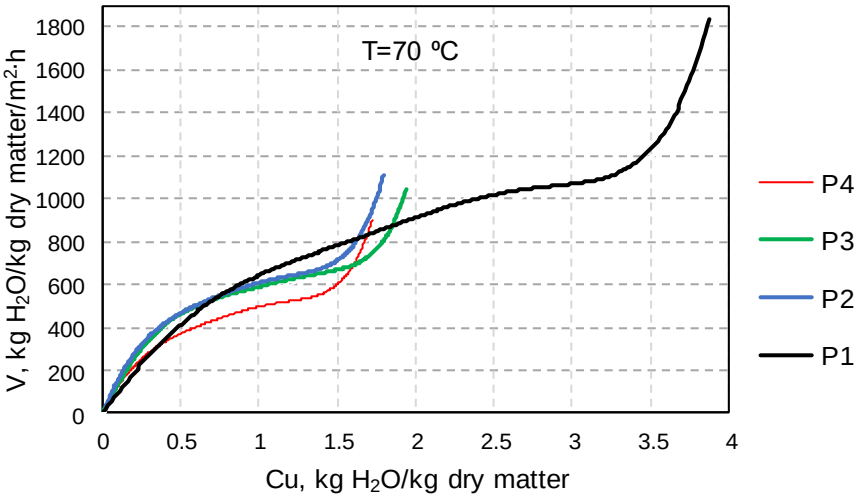

Fig. 7 - Drying speed curves of the four samples at 70ºC

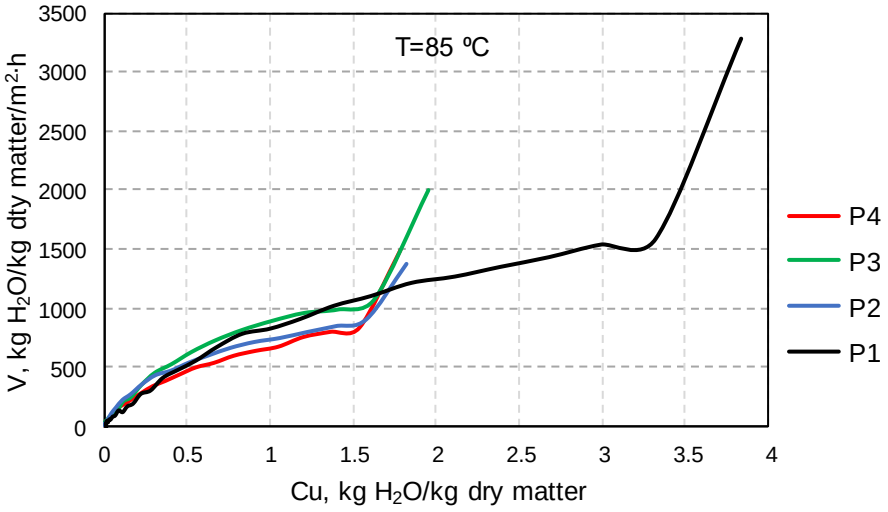

Fig. 8 - Drying speed curves of the four samples at 85ºC

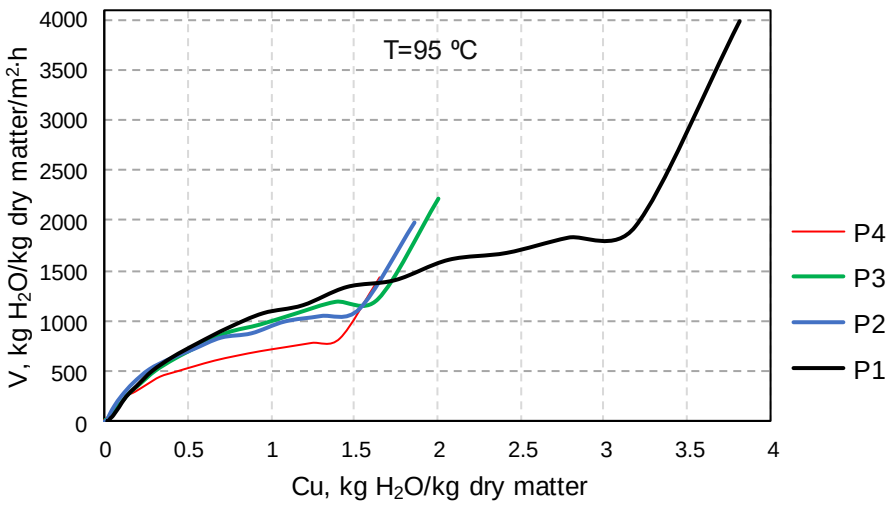

Fig. 9 - Drying speed curves of the four samples at 95ºC

The analysis of the experimental results regarding the speed of the drying process, presented in these graphs, indicates three essential elements:

- for all working conditions (temperatures and compositions of the pulp), the kinetic curves lack the area where the drying process is carried out at constant speed. The lack of this area indicates that there is no free humidity on the surface or inside the layer of material subject to drying. All the humidity of the material is embedded in the porous structure of the pulp.

- from the first moments of the experiment, after the material has reached the operating temperature, the drying process is carried out according to a mechanism in which the drying speed decreases continuously until the equilibrium state is reached or until the complete elimination of humidity. The development of the process according to a mechanism in which the speed decreases continuously throughout its development indicates, on the one hand, that all the humidity is contained in the pulp matrix and, on the other hand, it shows that the diffusion or internal transfer phenomena are speed-limiting.

- the allure of kinetic diagrams, although decreasing throughout the drying, presents two areas:

a) the area corresponding to the beginning of the drying period, on which the kinetic curve decreases, the speed decreases according to a linear law or after a slightly convex curve. In this area the drying is slightly slowed down. This area corresponds to the period when the water is removed from the micropores. The strong interaction of humidity with the walls of the cell membrane slows down the drying speed a little.

b) the area corresponding to the period in which the humidity is eliminated at slightly accelerated speed, in which the kinetic curve is concave, indicating that in this area, although decreasing, the speed is slightly accelerated. This mechanism is explained by the fact that, as the drying process progresses, the free spaces formed by eliminating the humidity increase and, on the other hand, the pulp becomes less porous, due to the formation of macropores after the breakdown of part of the pulp cell walls. As the pore diameter increases, the humidity interaction with the cell membrane walls of the pulp decreases, leading to the intensification of the diffusion processes and, consequently, the drying process is carried out with a slightly accelerated speed. The slightly accelerated speed of the drying process in this area is also determined by the hydrophobic character of the hydrocarbon chain of the pulp.

The quality of the premix according to its composition was determined by measuring the amount of water absorbed by the material after drying. The results of these measurements are presented in Table 3.

Table 3

The amount of water absorbed by the dry material

Sample	P1	P2	P3	P4
The amount of water adsorbed [g/g d.m.]	2.79	1.93	2.08	1.64
Decrease of water absorbed compared to crude pulp [%]	77.5	57.93	59.4	52.5

There is a decrease in water adsorption capacity when adding macro and microelements, which can be explained by the fact that these additions lead to the destruction of the micropores in the pulp.

CONCLUSIONS

The kinetic study on the process of drying premixes based on sugar beet pulp shows that the addition of macroelements (Ca^{2+}, Mg^{2+}, PO_4^{3+}) and microelements (Fe^{3+}, Zn^{2+}, Co^{2+}, Cu^{2+}, Mn^{3+}) substantially reduces the time required for total humidity removal.

The decreasing allure of the drying speed curves since the first drying times indicates that throughout the drying process, the internal diffusion phenomena are limiting.

At 60°C temperature, the curve shows that, although the diffusion phenomena remain speed determinants, once the porous structure of the material changes, the drying process speed changes. The porous structure of the pulp, changing to a small extent, the drying speed and, consequently, the duration for the total removal of humidity is higher.

The adsorption capacity of the water is diminished by the addition of macro and microelements.

The results derived from kinetic curves are useful and create the premises for mathematical modeling and simulation of the drying process of premixes based on beet pulp resulting from the technological process of sugar manufacture.

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