STUDY OF DRYING SUGAR SORGHUM PROCESS

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Abstract*:* This article presents the study of the kinetics of the process of convection drying and the application of microwaves of the sugar sorghum cultivated under the conditions of the Republic of Moldova. The kinetics of the convection drying process were studied at different temperatures: 50°C, 60°C, 70°C, 80°C, 90°C and by microwave application at different magnetron powers: 150W, 240W, 360W, 480W, and 550W. The external appearance of the samples obtained in order to determine optimal drying parameters, both quantitatively and qualitatively, was also analyzed.

Key words: drying process, convection, microwave, sugar sorghum

Introduction

Sorghum is a plant species of the Poaceae family. The main representative, Sorghum bicolor, is the main bread cereal in Africa, Southern Europe, Central America and South Asia. The sorghum originates in Equatorial Africa, being a cereal adapted to the warm and dry climate. A sorghum species used as an energy plant is Sudan Grass (Sorghum Sudanese). Of this family belongs a variety called technical sorghum, known in Moldova between Prut and Nistru as a broom dressing. The sorghum reaches the height of 1.5-2 m (grain sorghum, soris) to 3.5-4 m (sugar sorghum). [1]

Sugar sorghum as object of study

The sorghum is a perennial herbaceous plant with a height of up to 2.5 m, exterior to the corn. The stem is straight, dry, with nodosites, is a well-developed root that penetrates deep into the soil. The sucrose strain contains 12-15% sucrose, which is quite a lot, and sometimes it reaches more than 20%. Usually, the upper part of the strain is not used because it is deficient in sucrose and it is pointless to be processed. It also contains cellulose up to 17%, very high water around 63-75%, starch - 5-7%, protein - 2-4%, gum - 3%, fat 0.02%, pectin - 60%, the juice content is 80-85% of the mass of the slopes. The leaves are alternate, late, pubescent, with sharp edges, green. Flowers are placed in straight, ragged or ablaze bunches, up to 70 cm long. [2]

Materials and methods

To perform the experiments, some samples of sugar sorghum were taken as research samples, which were then cleaned from the leaves and the protective coating, after which they were cut into segments of equal lengths of 10 cm, and split into four equal parts. The use of electronic scales accurate to 0.01 g of each sample is weighed 50g

To study the kinetics of the drying process, convection drying with the working agent temperature (50ºC, 60ºC, 70ºC, 80ºC, 90ºC) and working agent speed (1.5 m / s), [6,7,8] and drying in the field electromagnetic with magnetron power (150W, 240W, 360W, 480W, 550W), ambient temperature (20-25ºC) and humidity 60-65%, [9,10,11]. Experiments carried out at the research facility, Figure 1. The drying product is loaded into the drying chamber 15, opening the lid 21.

For convection drying, it is necessary to connect the scale 19 to observe the decrease of moisture in the product during drying; to connect the inverter 6, which

connects the centrifugal fan 10, via the electric motor 8, to connect the heat generator 13 and the resistor 5; at the same time, the intermediate channel 9 is removed from the centrifugal fan 10. Thus, the air is taken from the outside by the centrifugal fan 10 and directed to the heat generator 13 where it is heated up to a certain temperature due to regulation with the resistor 5; entering the drying chamber 15, it takes up the moisture from the product, transports it through the recycle channel 17 through the condenser 12 and the intermediate channel 9 and evolves it outwards.

For microwave drying it is necessary to connect the scale 19 to monitor the moisture content of the product during drying; to connect the inverter 6, which connects the centrifugal fan 10, via the electric motor 8, to connect the microwave generator 14 and the processor 2; at the same time the intermediate channel 9 is likewise removed from the centrifugal fan 10. Thus, the air is taken from the outside by the centrifugal fan 10 and through the heat generator 13 enters the drying chamber 15 where the moisture outlet of the product takes place due to the generator the microwave 14 which is routed to the processor 2; the humidity is taken up by the air flow generated by the centrifugal fan 10 and conveyed outward through the recycle channel 17 through the condenser 12 and the intermediate channel 9.

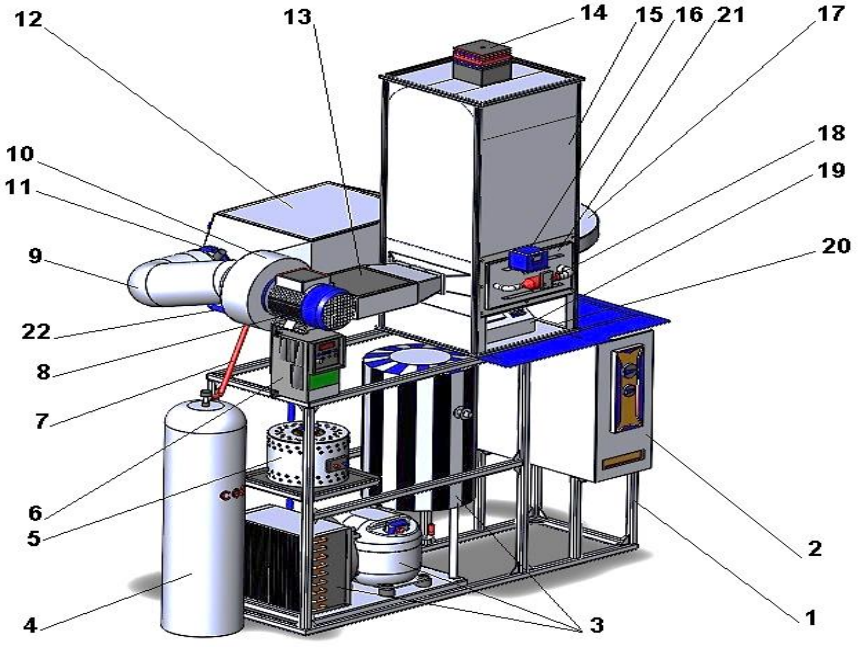

Figure 1. *Research facility:*
1 - metal housing, 2 - SHF processor, 3 - refrigeration plant, 4 - CO2 tank, 5 - resistor, 6 - inverter, 7 - hose, 8 - electric motor, 9 - intermediate channel, 10 - fan, 11 - nozzle, 12 - capacitor, 13 - heat generator, 14 - magnetron, 15 - drying chamber, 16 - CO2 indicator, 17 – recycling channel, 18 - the CO2 receptor, 19 - electronic weighing, 20 - intermediate chamber, 21 - cover, 22 - pipe.

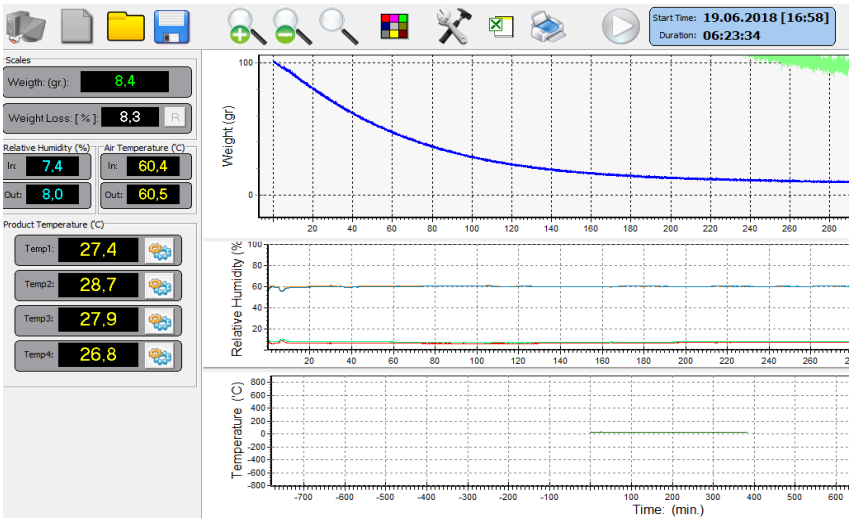

Figure 2. *Data electronic processing:*
1 – dial (indicates product's mass dropping curve), 2 – dial (indicates input and output drying agent temperature) 3 – dial (indicates input and output drying agent humidity)

Results and discussions

There are multiple, technological process (velocity, humidity, drying agent temperature, etc.) and drying product, the sugar sorghum properties (thermal conductivity, porosity, density, geometrical parameters, etc.) parameters that affect the drying process kinetics. [3, 4, 5]

Processed by convective method and different thermal agent temperatures, sugar sorghum drying curves shows a standard form, displaying stable moisture per time diminution Figure 3. From initial 76% to final 20% humidity drop duration depends on the drying agent temperature. Thus for the same 1.5 m/s drying agent velocity and initial humidity, but different temperatures, the drying period will be: for 50°C a 320 min length, 60°C a 250 min length, 70°C a 180 min length, 80°C a 110 min length and for 90°C a 80 min length.

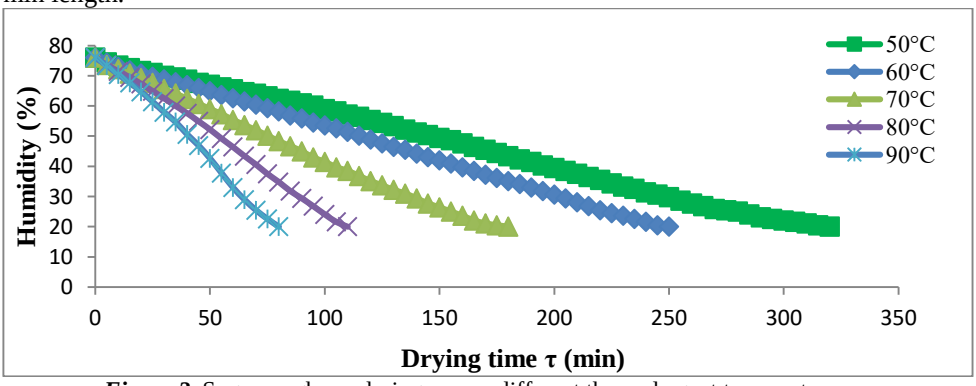

Figure 3. Sugar sorghum, drying curves different thermal agent temperatures
(Thermal agent velocity 1.5 m/s, and initial humidity 60.0%)

Figure 4 shows sugar sorghum's different thermal agent temperatures drying velocity curves. Their form also corresponds to the classic one, described in references [3, 4, 5]. There are as well presented the three drying periods, namely 1 – of product heating, 2 – of constant drying velocity and 3 – of decreasing drying velocity. For first period of product heating is characteristic decrease of humidity from 76% to 65%, for second period of constant drying velocity from 65% to 40% and for third period of decreasing drying velocity from 40% to 20% humidity. As shown in Figure 4 is observed the direct proportional dependence of the drying velocity on the working agent temperature for 50°C – 0.3 %/min; 60°C -0.4%/min; 70°C - 0.45%/min; 80°C – 0.55%/min; and for 90°C – 0.60%/min.

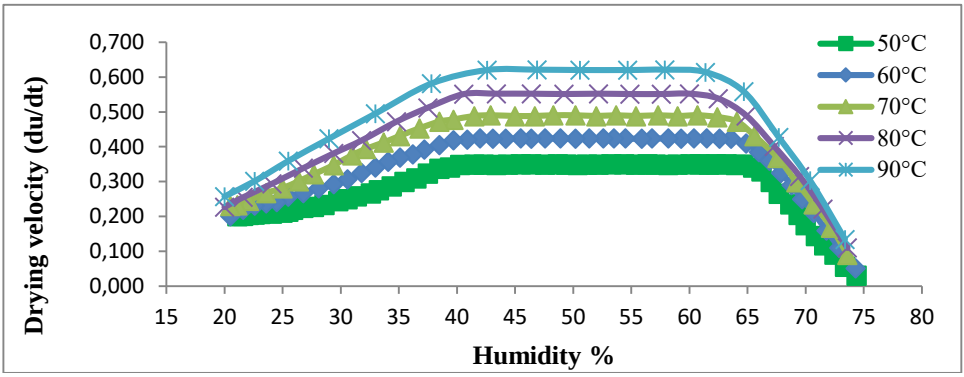

Figure 4. *Sugar sorghum different thermal agent temperatures drying velocity curves (Thermal agent velocity 1.5 m/s, thermal agent initial humidity 60.0%)*

The sorghum is famous for its high sugar content, so the purpose of drying the sorghum in such conditions is to get a maximum of sugar. For determining the sugar content the refractometry method was used and Bertrand method for comparison, the results are presented in Table 1, following the experiments it was found that at a temperature of 50 C persists a drying time too long 320 minutes which dispenses with an excessive energy consumption, Figure 5; at a temperature of 60°C total sugar content 52.04 g/100g, Figure 6; the total sugar content of 66.22 g/100g was obtained by thermal treatment of 70C, Figure 7; at 80°C and 90°C the caramelization phenomenon occurs, Figure 8 and 9; so the optimal drying temperature with a dry quality product is 60°C but with maximum contain of sugar at 70°C.

Table 1 *Determining the total sugar content*

Nr.	Fructose	Glucose	Sucrose	Total sugar content
1.	6.27	6.68	7.41	20.36
2.	12.87	17.42	21.75	52.04
3.	**15.74**	**21.29**	**29.19**	**66.22**

Where: 1 – fresh sugar sorghum, 2 – dry sugar sorghum at 60°C, 3 – sugar sorghum dried at 70°C.

Examples of dry sugar sorghum by convection method

Figure 5. *Temperature 50°C*

Figure 6. *Temperature 60°C*

Figure 7. *Temperature 70°C*

Figure 8. *Temperature 80°C*

Figure 9. *Temperature 90°C*

The kinetics of the drying of the sugar sorghum by application of the microwaves to different thermal regimes is shown in Figure 10. [9, 10, 11] Analyzing the drying curve with the use of microwaves we note that: at 550 W magnetron power, the product burns and an unpleasant odor occurs, Figure 16; at 480 W magnetron power, reaching 30 minutes. it smells burned and burns are present on the product, Figure 15; at the power of the magnetron of 360 W, reaching the time of 40 minutes, there is a smell of sugar and yellowish-orange colors appear on the surface of the product, Figure 14; at 240 W, the product humidity reaches 20% over 70 minutes, Figure 13; and in the final at 150 W magnetron power, product humidity reaches 20% over 95 min, Figure 12.

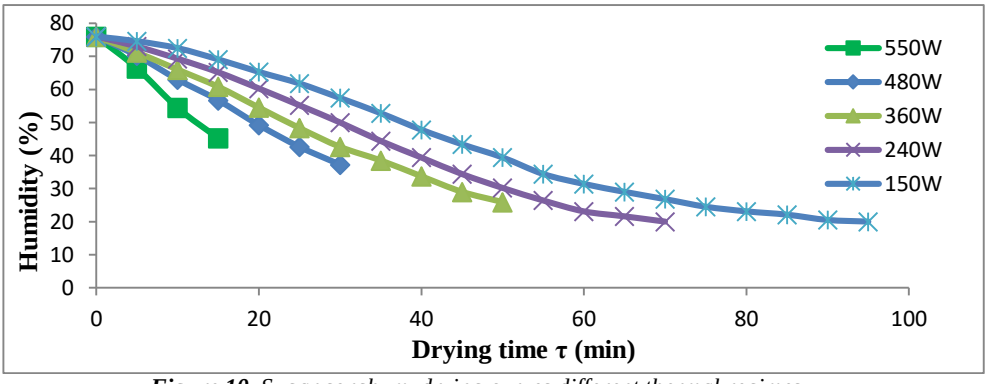

Figure 10. *Sugar sorghum, drying curves different thermal regimes*
(Thermal agent velocity 1.5 m/s, humidity 60.0% and microwave power 150W – 550W)

Figure 11 illustrates the curves of the drying velocity of sugar sorghum under the influence of three microwave regimes, or 150W, 240W, and 360W, because only these dry sorghum samples presents interest for research. Their form also corresponds to the classic one, described in references [9, 10, 11]. There are as well presented the three drying periods, namely 1 – of product heating, 2 – of constant drying velocity and 3 – of decreasing drying velocity.

For first period is characteristic decrease of humidity from 76% to 65%, for second period from 65% to 45% and for third period from 45% to 20% humidity. As shown in Figure 11 is observed the direct proportional dependence of the drying velocity on the working agent temperature for 150W – 0.9 %/min; 240W – 1.0 %/min; 360W – 1.1%/min., is observed compared to curve of convection drying curve the drying rate with SHF application is higher.

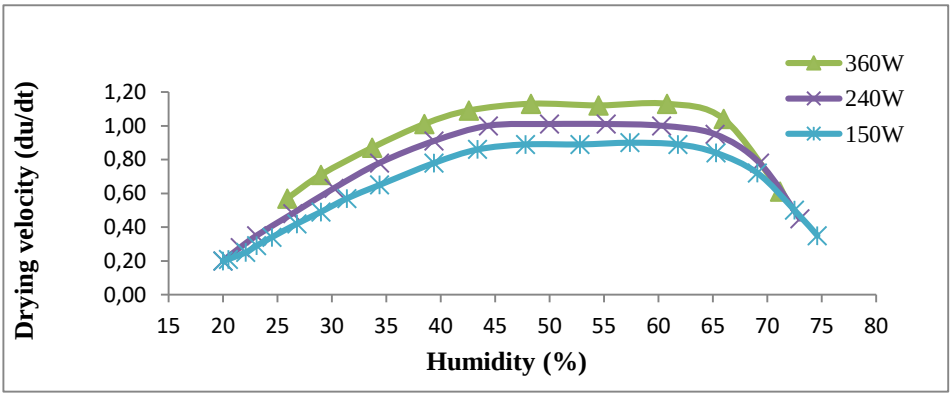

Figure 11. *Sugar sorghum different thermal regimes drying velocity curves (Thermal agent velocity 1.5 m/s, humidity 60.0% and microwave power 150W, 240W, 360W)*

The method of drying the sorghum in the electromagnetic field is optimal for 240W in terms of the obvious drying time and of the energy consumption and after the exquisite aspect of the dry samples Figure 12-16.

Figure 12. *150W*

Figure 13. *240W*

Figure 14. *360W*

Figure 15. *480W*

Figure 16. *550W*

Conclusion

The study of sugar sorghum convective and SHF drying kinetics at the temperature of the thermal agent in the range of 50÷90°C, and power in the range 150W – 550W, revealed that the increase thermal agent temperature end microwave power leads to an intensification of the process. However, convective temperatures above 70°C cause an acceleration of the undesirable sugar caramelization and browning phenomena. Therefore, for the convective drying of sugar sorghum, the temperature of 60°C - 70°C, and the speed of the heating agent is 1.5 m/s are recommended to get a quality product with a maximum quantity of sugar. The character of the draying curves is classic and does not differ from that of the fruits and vegetables described in the literature.

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