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RESEARCHES REGARDING THE OBTAINING OF JUICE FROM SUGAR SORGHUM STALK

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ABSTRACT

Sugar sorghum is a technical plant with high energy value due to the high productivity obtained per hectare. By pressing of sugar sorghum strains it can be obtained a juice that can be further used in various forms: alcohol, ethanol, etc.

INTRODUCTION

The main energy crops include maize, sugar cane, sweet sorghum, switchgrass, cassava, and other less known varieties. The maize has been traditionally used in the U.S for ethanol production; in Brazil, sugar cane is widely planted as raw material for ethanol production. A crop with enormous potential for ethanol production is sorghum, due to its high content of juice in the stalks (especially).

Also, sorghum is the second most important feed grain grown in the U.S. in terms of planting acreage, and is also planted on large surfaces in India and several countries in Africa. Grain sorghum is a high biomass which can produce not only grains but also bagasse, and both can serve as raw materials for juice production. Of all sorghum species, Sorghum bicolor has the highest potential for mass production of juice and ethanol. Sorghum bicolor, better known as sweet sorghum, has three different components which can be used for ethanol production: grain, bagasse, and the juice [1, 2]. The juice extracted from plant stalks contains plenty of sugars, such as sucrose, glucose, and fructose, which can be directly converted via biological fermentation process into ethanol [3, 4].

Sweet sorghum is an ideal energy crop because it possess the following properties that would enable it to accumulate biomass: high conversion efficiency of light into biomass energy, high water use efficiency and high leaf level nitrogen use efficiency [5], the ability to grow in marginal land areas [6], and a relatively high tolerance to soil constraints such as salinity and water concentration [7].

Sorghum is a very old crop, which is grown for grains, brooms manufacturing, juice, syrup rich in sugar, animal feed as silage or green fodder. Sorghum beans are used directly in the nutrition of people in the form of flour in some areas of Africa, India, China, the Middle East and Egypt.

In food industry, sorghum is used in the manufacture of starch, alcohol and beer, in combination with barley beans. Also, a sweet juice rich in sucrose is extracted from the sweet sorghum and it has many uses.

As animal feed, sorghum can be used either as fibrous feed, silage or grains, and it has a nutritional value similar to that of maize. As green fodder, sorghum is especially important in arid areas, because the plants are able to regenerate fast after harvesting, so it can be used as a pasture. For these purposes, varieties and hybrids without durin glycoside have been selected, which endanger the life of animals.

Sorghum is the crop to which more and more specialists turn their attention, especially that for the food of animals, because sorghum crop provides safety as it can grow even in the driest years. In Romania, the average production of grain sorghum ranged from 1.5 to 5.6 t/ha. Sorghum is successfully cultivated in the West and North West area, in the South and South East, in the South of Moldova and in some areas of Transylvania where the sum of degrees useful with base of 6 ^{o}C has values over 1700 degrees. It should be emphasized that the sugar sorghum for the green table can be grown on all corn growing areas.

In Romania, in 2014, 28.5 thousand ha were cultivated with sorghum, the average production being 3.8 t / ha, and the total production 108.3 thousand tones; and in 2015, the cultivated area was 29 thousand ha, according to "INFO AMSEM, Seeds and Material Saditor, year XVI, no. 7, August 2014" (www.amsem.ro).

Sweet juice has long been known as an excellent source of sugar (NAS, 1882), which can be easily fermented and distilled into fuel-grade ethanol. The main factor that keeps sweet sorghum from competing with corn as a fuel crop is the lack of an established method of production. Mechanical harvesting of sweet sorghum requires specialized harvesting equipment capable of extracting sugary juice from field stalks [8, 9, 10] or a modified sugar cane harvesting machine and a nearby pressing facility. The juice should be quickly moved to a fermenter to prevent sugars from degrading the juice.

Researches on the importance of sorghum cultivation for the biofuel industry to produce bioethanol [11] were conducted, and also on the constructive solutions for distillation installations for obtaining alcohol [12, 13], the technologies and equipment used for obtaining of alcohol from technical plants [14, 15], in different Romanian counties Romania [16, 17, 18].

Sorghum pressing equipment can be classified in: low capacity installations; fixed installations with drums, and mobile installations for sorghum cultivation and pressing.

1) Model of press installations with small capacity drums

These presses are generally manufactured with 2-4 rolls, are intended for household use and powered by a 1.5-2.2 kW electric motor (Fig. 1).

Fig.1. Instalation for obtaining juice from sugar sorghum stems [19]

2) Fixed drum installations

An important step in the process of exploiting the energy potential of sugar sorghum is the squeezing of raw juice. The technological line for extracting the raw juice from the fragmented stalks of sugar sorghum ensures the storage, dosing and supplying of raw material with the help of the conveyors, the squeezing of the juice in rolls with press blocks, the evacuation of juice and the draft in the means of transport.

• Mecagro company from the Republic of Moldavia has developed an high-performance equipment for the pressing of sorghum juice. The pressing block (Fig. 2) includes the container hopper 1, the block 2 with two feed rollers and the crushing of stalks, the conveyor 3, the press block 4 with three rollers, the drive gear 5, and the steering system 6. In the press block 4, the upper roller is placed on two bearings 7, each of them being installed on two vertical guide rods. On the upper side of bearings 7 are acting the arc-discs, and their tightening is adjusted by nuts 8. Each of the bottom rollers is installed on two bearings 9, mounted mobile on horizontal guide rods 10. The distance between the rollers is obtained by moving the lower rollers on guides using screw mechanisms 11. Adjusting the speeds of the press rollers is done by changing the transmission ratio and the frequency of the electric current with the help of the inverter. The squeezed juice accumulates in container 12, where it is discharged by pump 13 [20, 21].

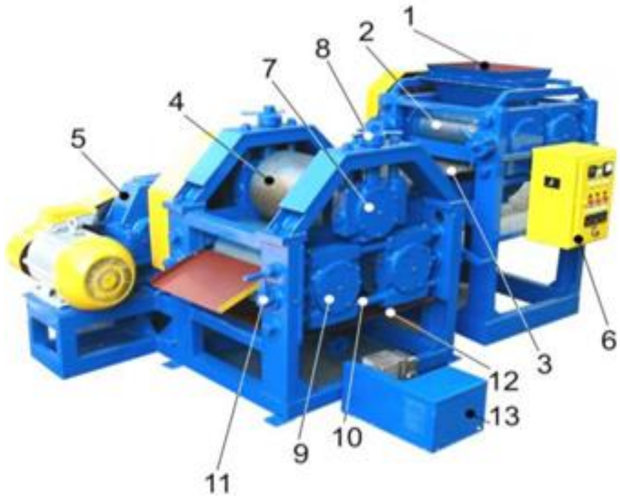

Fig. 2. Equipment for the processing of sorghum stalks [20, 21]

• KAMDHENU AGRO MACHINERY Wathoda, Nagpur, Maharashtra, India (Fig. 3), PATEL MANUFACTURING COMPANY, Gujarat, India (Fig. 4), TINYTECH PLANTS, Gujarat, India (Fig. 5) and PENAGOS HERMANOS, Columbia (Fig. 6), manufacture different variants of 3-drums Swwet Sorghum Crusher presses.

Fig.3. Sorghum press with three drums [22]

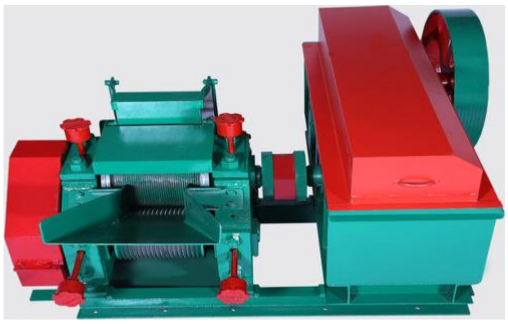

Fig. 4. Sorghum press with three drums [23]

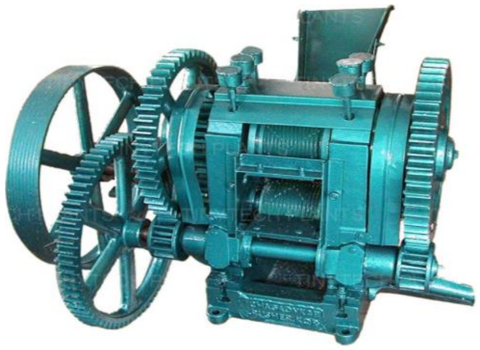

Fig. 5. Sorghum press with three drums [24]

Fig. 6. Sorghum press with three drums [25]

MATERIAL AND METHOD

In order to obtain the juice from the sugar sorghum stalks, an experimental 3-roll pressing model - IPST (Fig. 7) was used, comprising of the following main components (Fig. 8): 1. beat sorghum installation; 2. 3-wave pressing block; 2.1. press block housing; 2.2. module 3 waves; 2.2.1. upper valley; 2.2.2. valt mayor-material training; 2.2.3. valt for final pressing; 3. drum drive system; 4. electrical control and control panel.

Fig. 7. Press used in experiments to obtain juice

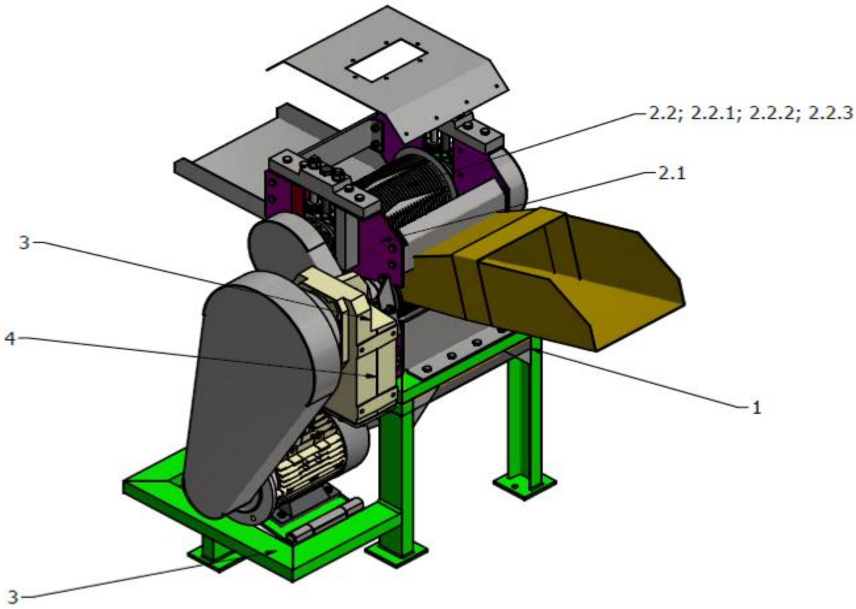

Fig. 8. Main components of the press used in the experiments

RESULTS AND DISCUSSIONS

In order to obtain juice, the sugar sorghum was manually harvested (Fig. 9) when it reached the maximum sugar concentration in the stalks (it was measured periodically using a digital refractometer). The sprouting stalks had heights between 3.8-4.5 m, which led to a very high productivity of this crop from the ASM variety (Republic of Moldavia).

Fig. 9. Sugar sorghum, before and at harvest time

Before harvesting, the number of plants/m^2 was determined, using 4 milestones and a roulette wheel (Fig. 10), and this operation was repeated 10 times, so that in the end an average very close to the reality was obtained.

Fig. 10. Determination of the number of plants / m^2

The plants framed by the 4 milestones (representing 1 m^2), were then manually cut with the sickle (Fig. 11), in the form of bundles, in order to be measured and to determine: the number of plants, the length and diameter of the stalks, the spike (Fig. 12), the average height, the weight of the plants (with and without leaves – Fig. 13), seed weight, based on which the average was determined for the 10 set surfaces. Using this average, it was possible to determine the average production per hectare and subsequently the quantity of juice obtained from a single plant (Fig. 14), then per m^2 and finally per hectare.

Fig. 11. Harvesting of sweet sorghum on about 1 m^2 to determine the average of plants

Fig. 12. Measuring of the length and diameter of the stalk, respectively of the spike

Fig. 13. Cleaning off the leafs from stalks for introduction into the press

Fig. 14. Pressing the sugar sorghum stalks and obtaining the juice

The sorghum stalks were cleaned by the top panicle of seeds and leaves, before being introduced into the press (Fig. 13) to extract the juice (Fig. 14).

In order to determine the density, *5 samples* from 6 rows were performed, proceeding as follows for each sample:

• randomly marked S = 1m², starting with row 2;
• all the plants inside this surface were harvested;
• the plants harvested were counted;
• the total mass for each sample (bundle) was determined, by weighing the plants harvested from S = 1m²;
• measurements were made at each harvested plant, as follows:

h = maximum height of the stalk, with leaves and panicles;
D_1 = diameter 1, base of the plant stalk;
D_2 = diameter 2, middle of the plant stalk;
D_3 = diameter 3, the tip of the plant stalk, before the panicle.

• the defoliation was carried out for each plant separately, manually removing the leaves and the panicle;
• after defoliation, the mass of the stalks was determined, again weighing each sample (sheaf) of plants harvested from a surface, S = 1m²;
• the *mass* resulting from the defoliation was determined, weighing the obtained residues (leaves, panicles), for each sample collected;
• sorghum juice was extracted separately from the defoliated stalks obtained for each sample, and the volume of juice obtained was determined, as well as its mass;
• the *mass of the bagasse* (vegetable residues resulting from the extraction of sorghum juice) was determined for each variety (sample collected).

For the ASM variety, for the 5 samples, the following results were obtained, after the juice extraction:

• Total number of plants harvested for the 5 samples: 67;
• Total plant mass: 48.38 kg;
• Mass of stalks after defoliation (without leaves and panicles): 39.40 kg;
• Vegetable mass resulting after defoliation of the stalks (residues): 8.98 kg (the difference between the total mass and the mass of the stalks after defoliation);
• Quantity of juice obtained: volume: 10.65 liters (mass: 11,579 kg);
• Vegetable mass obtained after juice extraction (berry): 27,821 kg.

In Table 1 are presented the results obtained for a sample (from 1 m²) of the 5 considered.

Table 1

The results obtained for a sample of the 5 considered from 1m²

Plant No.	*H = Height Stalks (cm)*	*D_1 = Base Stalk (cm)*	*D_2 = Medium Stalk (cm)*	*D_3 = Peak Stalk (cm)*	
1	394	20.45	13.42	6.95	
2	410	19.25	14.10	8.61	
3	365	19.03	11.63	7.26	
4	427	23.25	16.20	9.01	
5	422	22.14	15.82	9.14	
6	437	26.87	17.64	10.00	
7	376	16.74	11.93	6.18	
8	235	9.52	7.02	3.45	
9	383	24.20	17.81	8.60	
10	305	15.65	12.26	4.60	
11	396	19.85	13.37	7.03	
12	404	25.71	18.14	8.66	
• ***Total sample mass (leaf and panicle stalks), kg***				***14.04***	
• ***Sample mass (stalk cleaned, without leaves and panicle), kg***				***11.40***	
• ***Vegetable mass after defoliation (difference), kg***				***2.64***	
• ***Quantity of juice obtained***				***3.5 l***	***3.782 kg***
• ***Bagasse (vegetable mass after juice extraction), kg***				***7.618***	

CONCLUSIONS

The amount of juice obtained from the sugar sorghum (from the stalks) depends largely on the harvest period (it must be harvested when the Brix index has reached its maximum value) and on the quality respectively the quantity of the sorghum crop. In this case, the sorghum crop had an average height of over 4 m, which has led to the obtaining of a production per hectare of over 100 tons, which ultimately leads to obtaining an amount of juice of 33.18% from mass of stalk clean, without leaves and panicles, that is approximately 37.82 tons / hectare.

Since the average height of the sugar sorghum stems is normally between 3 and 4 m, the average sugar sorghum production is at 50-60 tons / ha, which corresponds to about 15 tons of juice obtained in following the pressure of the stalks.

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