CONSIDERATIONS CONCERNING THE VALORIZATION OF THE JUICE OBTAINED FROM SUGAR SORGHUM STALK FROM ALCOHOL

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ABSTRACT

With a high production per hectare, sugar sorghum is a high value technical plant for farmers because from an average production of 70-80 t/ha, a high quantity of juice can be obtained, which can be used as such in the food industry (natural sweetener) or processed for the purpose of obtaining alcohol. The alcohol has a higher value/liter, can be stored more easily and its uses are multiple: in the food, pharmaceutical, chemical industry, etc.

INTRODUCTION

To manage to take out the saccharate juice from the stalks, mechanical harvesting of sweet sorghum requires a specialized harvesting equipment or a modified machine for harvesting sugar cane and a pressing installation close to it. The juice should be rapidly moved into a fermentation installation for preventing its degradation. Sweet juice has been known as an excellent source for sugar, being easily fermented and distilled to fuel, i.e. high quality ethanol.

From the juice, alcohol and ethanol can be obtained with a smallest price when it is produced from sweet sorghum and sugar cane. Researchers from Romania (*Goian M., Antohe I*.), Italy, Republic of Moldavia (*Moraru Gh.)* have studied the possibility of cultivating and processing the sweet sorghum and the most suitable technologies for climate and soil conditions in Southern Europe. The preliminary results obtained have shown the efficiency of cultivating sweet sorghum for obtaining alcohols [1].

In the last year, researches were conducted on: the importance of cultivating sorghum to the biofuel industry for producing bioethanol [2], the equipments and technology for extraction of sugar sorghum juice [3, 4], current stage of technique in the field of sorghum pressing equipment designed to produce the raw juice necessary to obtain the bioethanol [1], the constructive solutions for distillation installations for obtaining alcohol [5, 6], the technologies and equipment used for obtaining of alcohol from technical plants [7], installation for obtaining raw alcohol by using plants with energetic/ food potential [8].

Because the sweet sorghum – an alternative for Dobrogea's agriculture [9] and Romanian farmers in the conditions of the current climate change [10], was necessary to know and chemical composition of some sorghum genotipes for grains cultivated in the center of Moldova [11].

Natural fermentation occurs when the microorganisms are allowed to react with susceptible organic substrates. Some of these fermentations made changes in food materials that were quickly recognized to be desirable. Thus, fruits and fruit juices left to the elements acquired an alcoholic flavor; milk on standing became mildly acidic [12].

The term "fermentation" was first applied to the production of wine more than a thousand years ago. The bubbling action was due to carbon dioxide gas released during the conversion of sugar. When the reaction was defined following the studies of Gay-Lussac, fermentation came to mean the breakdown of sugar into alcohol and carbon dioxide. Pasteur later demonstrated the relationship of yeast to this reaction, and the word fermentation became associated with microorganisms, and still later with enzymes [12].

The early research on fermentation dealt mostly with carbohydrates and reactions that liberated carbon dioxide. It was soon recognized, however, that microorganisms or enzymes acting on sugars did not always evolve gas. Further, many of the microorganisms and enzymes studied also had the ability to break down noncarbohydrate materials such as proteins and fats, which yielded carbon dioxide, other gases, and a wide range of additional materials [13].

Currently the term fermentation is used in various ways which require clarification. When chemical change is discussed at the molecular level, in the context of comparative physiology and biochemistry, the term fermentation is correctly employed to describe the breakdown of carbohydrate materials under anaerobic conditions. In a somewhat broader and less precise usage, where primary interest is in describing the end products rather than the mechanisms of biochemical reactions, the term fermentation refers to breakdown of carbohydrate and carbohydrate-like materials under either anaerobic or aerobic conditions. Conversion of lactose to lactic acid by *Streptococcus lactis* bacteria is favored by anaerobic conditions and is true fermentation [13].

Of the carbon sources preferentially used, ethyl alcohol is oxidized to acetic acid, and glucose to gluconic acid and 5-ketogluconic acid. Bacteria of the Gluconobacter genus use as main carbon sources: glucose and ethanol. Bacteria in the genus *Acetobacter* use as carbon sources: ethanol, lactate, hexoses and glycerol. Bacteria of the *Acetobacter* genus can also oxidize acetals to CO_2 and H_2O, when ethyl alcohol was consumed from the environment, because ethyl alcohol inhibits the activity of acetal oxidation enzymes [14].

In order to carry out the acetic fermentation in good conditions, the acetic bacteria need, in addition to ethyl alcohol and oxygen, secondary nutrients and growth factors [15, 16].

As a nitrogen source, acetic bacteria can use ammonium salts, amino acids (valine, alanine, isoleucine, cysteine, histidine, proline) and peptones, and as nutrients, which can be found more or less in some organic sources, uses yeast or corn extract [17, 18].

MATERIAL AND METHOD

In order to obtain alcohol from sugar sorghum, a crop of approx. 8,000 m^2 (Fig. 1), using seeds from the ASM variety (Republic of Modavia) was established. Harvesting of crop in order to obtain the juice was done when the maximum sugar amount was achieved in the stalks (accumulated by determining the Brix index), and juice was obtained by pressing the sorghum stalks (Fig. 2).

The juice was then characterized from a chemical point of view (refractive index -IR and pH) and then seeded with a specific yeast for obtaining alcohol. During fermentation (at approximately constant temperature), the evolution of IR was followed and when the IR reached a value around 6, the fermented juice was transferred to the distillation vessel (200 L) in order to start the process of obtaining of alcohol, not before adding about 15-20 kg shredded apples (so that the heated juice does not stick to the bottom of the boiler (distillation vessel).

Fig. 1. The culture of sugar sorghum

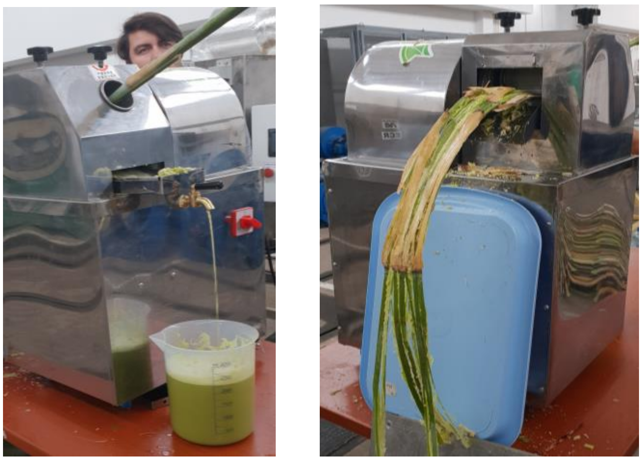

Fig. 2. Pressing of the sugar sorghum stalks and obtaining the juice

RESULTS AND DISCUSSIONS

The sugar sorghum was manually harvested in order to obtain juice 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 SASM (Republic of Moldavia) variety.

The distillation installation, IOAB (Fig. 3), used in the experiments to obtain alcohol from sugar sorghum, was designed to allow a high yield of raw alcohol from agricultural species used as a raw material for the distillation process. In order to ensure mixing times of the raw material subjected to the distillation operation, the equipment is fitted with a variable mixing system through a motor and frequency converter, the equipment allows to modify the working regime.

The main components of the distillation installation / obtaining raw alcohol (Fig. 4) are:

1. firebox (mantle);
2. technological vessel;
3. expansion vessel;
4. connection pipeline;
5. condensation vessel;
6. shaking system;
7. empty mouth lid.

The main technical characteristics of the installation are:

Boiler (technological and expansion vessel):

- volume: 200 liters
- height: 1750 mm

- width: 950 mm
- weight: 112 kg.

Cooler (Condensing vessel):

- volume: 450 liters
- height: 1660 mm
- width: 850 mm
- weight: 35 kg.

Connecting pipe (L): 2000 mm.

Fig. 3. Installation for distillation / obtaining raw alcohol (IOAB)

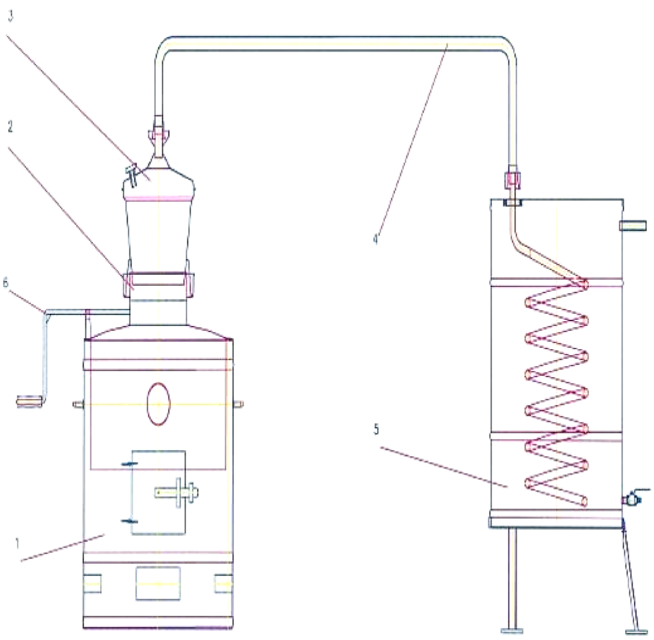

Fig. 4. The main components of the installation for distillation / obtaining raw alcohol

In order to ensure a good fermentation of the obtained marc, yeasts selected in proportion of 2-4% were used, thus inhibiting both the development of the bacteria and the yeasts with reduced alcoholic strength, which negatively influences the quality of the product. The fermentation with spontaneous yeasts was not used, as a slow fermentation takes place, always remaining unfermented sugar, which leads to a lower yield in alcohol (a lower quality and lower quality).

During fermentation, secondary products such as higher alcohols, glycerin, acetaldehyde, organic acids (acetic, formic, succinic, lactic, etc.) are produced alongside with ethyl alcohol and carbon dioxide.

The temperature for normal fermentation should be between 18 and 240°C. At higher temperatures, above 300°C, secondary fermentations take place and result in excess some acids that give the rachis an unpleasant taste. If the temperature drops below 150°C, the fermentation can stop before all the sugar is fermented.

The quantity of yeasts selected is closely related to the starting temperature of the fermentation; the lower the temperature, the more yeast is needed. After mixing the marc (in this case the juice) with the selected yeast maize, the fermentation vessels were closed, and to allow the carbon dioxide formed to be released, they were provided with the fermentation funnels. Because during the fermentation the volume of the mark / pore increases, only 2/3 of the capacity of the vessel was filled. During fermentation, due to the release of carbon dioxide, the solid parts of the marc rise to the surface in the form of a cap, the danger of acetic fermentation occurring, but in this case, it is just juice – so it is not the case. In order to prevent the development of acetic bacteria in the surface layer, the juice (juice) entered in the fermentation was mixed daily, mixing taking place when the air temperature is lower (morning / evening). Thus, the formation of the cap was prevented, the yeast development process was accelerated, and the uniform dissemination of the sugar in the juice was facilitated.

The beginning and the duration of fermentation depend on the temperature of the marc (juice) to be monitored throughout the fermentation, with the aim of keeping it within optimal limits and possibly being able to intervene; If the temperature is too low, a portion of the juice is heated, and if the temperature is too high it must cool down. Given that the fermented marc (juice) has no pips, the duration of fermentation is shorter, between 7 and 10 days, while in the others (with pips) it lasts for 10-14 days (if the marc is stored in pots and 12 - 18 days (if the marc is stored in basins).

During fermentation, the variation of sugar content was monitored; so, when it has dropped to near zero or for 2-3 days it has the same value, it means that the fermentation is finished and the pencil (juice) can be distilled.

Distillation of sugary sorghum juice (marc)

After the fermentation is completed, the juice - juice is subjected to the distillation process in the shortest possible time, because any delay will lead to losses in ethyl alcohol and the diminution of the quality of the alcohol.

The juice distillation was carried out in the specialized distillation plant (Fig. 3). For fermented peas without pips and with high fluidity, as is the case with the sugar sorghum juice, continuous columns of distillation can be used, on the heating of which the steam from a steam generator.

Determining of productivity (Table 1)

It was realized for the two varieties studied: BMR GOLD X and ASM, processing the data on an area of 21 m^2, taken into account as follows: 5m lenght and 4.2 m wide (6 rows), for which:

- the total mass was determined for each sample, by separately weighing the plants harvested from each variety;
- the defoliation of all the harvested plants was done, removing the leaves and the panicles, for each variety (sample) separately;
- the mass of the stalks after defoliation was determined, by weighing the plants harvested from each variety (sample);
- the vegetal mass resulted from the defoliation was determined, weighing the obtained residues (leaves, panicles), for each variety (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 (the vegetable residues resulting from the extraction of the sorghum juice) was determined, for each variety (sample collected).

Table 1

Determination of productivity / hectare for the two varieties of sorghum studied

Variety / Characteristics	ASM		BMR GOLD X	
	S = 21 m^2			
Total mass (stalks with leaves and panicles), kg	113.90		142.6	
Defoliated sample mass (leafless and panicle stalks), kg	89.14		119.75	
Vegetable mass after defoliation (difference), kg	24.76		22.85	
Quantity of juice obtained	24.00 l	26.46 kg	34.5 l	37.1 kg
Production obtained / hectare	11428.6 l	*12600 kg*	16428.6 l	*17666.7 kg*

Starch content. Starch is the main storing form of sugar and energy in plants existing with great amount in seeds, fruits, root and stalk tubers, and with small amount in leaves and stalks. This can not be fermented by saccharomycete directly, but it needs to be dextrinized and saccharified, turning into fermentable, and then it can be used to produce alcohol through fermentation.

Starch content was measured for 2 varieties, ASM and BMR GOLD X, at 6 growth stages, September 22, September 29, October 6, October 13, October 20, and October 27 (Table 2).

Table 2

Starch content of stalk juice (%) 2019

Time (D/M)	Variety	
	ASM	BMR GOLD X
22 /09	0.24	0.46
29 /09	0.32	0.35
6/10	0.17	0.20
13/10	0.12	0.09
20/10	0.06	0.13
27/10	0.03	0.02

The results of variance analysis have shown that varieties had little affect on starch content, among the 2 varieties.

It can be observed that the starch is very low in stalk juice, it contributes in alcohol production with small amount so the stem juice of sweet sorghum is a good saccharine source. Therefore, the alcohol production with sweet sorghum stem as raw material does not require complicated technology and expensive equipments, also the production period is short because of some procedures being left out. It is a low cost and easily operated alcohol producing method.

As for the starch content, early October is the best time for harvest when starch amount is high. starch can be utilized to produce alcohol through fermentation after saccharigation. Although starch content is not high, it is still important for a large production scale so the starch has also certain value in alcohol production.

Relation between total sugar and glucose, fructose and sucrose in stem juice

The total sugar in the juice includes some penthouse, hexose and polysaccharide, of these sugars, glucose, fructose and sucrose have been studied.

In Table 3 are presented the sugar contents of 5 varieties measured in 2019 (October 20). It is obvious that glucose, fructose and sucrose are the main parts of sugars in the juice, the sum of these 3 sugars is near to the total sugar amount but they are not the same thing, especially different sugars should not be simply summed up theoretically. So, the estimate of total sugar should be made by direct measurement or calculated according to the brix degree.

Table 3

Sugar Content in Stalk Juice (%) 2019

Variety	ASM	BMR GOLD X
Total sugar content	*15.26*	*17.50*
Glucose	4.2	3.2
Fructose	3.6	2.6
Sucrose	7.0	9.6

It is known that the transformation from glucose to sucrose under enzyme is a simple process. Furthermore, sugar and starch contents are different among varieties, so considerations should be made on choosing higher glucose and fructose or higher sucrose so it is better to select higher glucose and fructose sweet sorghum considering that the transformation from glucose to sucrose or starch, and then starch and sucrose turning into glucose in the process of fermentation all consume energy.

CONCLUSIONS

Since the juice obtained from pressing of the sugar sorghum stalks contains a high amount of sugar, its fermentation is carried out faster and the quantity of raw alcohol obtained will be higher than in the case of the classic fruits used to obtain the spirit (plums, apples and pears), relative to the same quantity of marc / juice subjected to distillation.

The alcohol obtained has a small distinct aroma (specific to sorghum), a pleasant taste and a high quality. Since the average production per hectare in the case of sugar sorghum is 60-80 tones, an amount of juice of about 13-18 tones is obtained, of which about 4.3-6 tones of alcohol are obtained by distillation.

As a result, in terms of yield per hectare, much more alcohol is obtained in the sugar sorghum cultures than in the classical crops used to obtain alcohol (plum, apple, pear, etc.), in addition, a very high amount remaining. Large size bagasse (pressed and squeezed stalks) can be chopped and used as animal feed, but it can alsi be used to obtain biogas or compost.

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