Maize/Sorghum as Raw Brewing Materials

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Brewing is among the oldest biotechnological processes, in which barley malt and—to a lesser extent—wheat malt are used as conventional raw materials. Other cereals as corn and sorghum could also be used in brewing.

beer sorghum maize

1. Introduction

Brewing is a food process that began in the Middle East 10,000 years ago [1]. Today, at almost 200 billion liters a year, beer is one of the most commonly consumed low-alcohol beverages in the world—and, in terms of volume, after water and tea, the third most prevalent beverage in general [2][3][4][5][6]. Barley is the most used cereal for brewing; however, unconventional malted grains have been used successfully. For instance: rice is used in Asia, maize is used in America, and millet and sorghum are used in Africa [7][8][9]. This process of replacing barley malt in beer production is increasing, and several factors shown in Figure 1 have contributed to this.

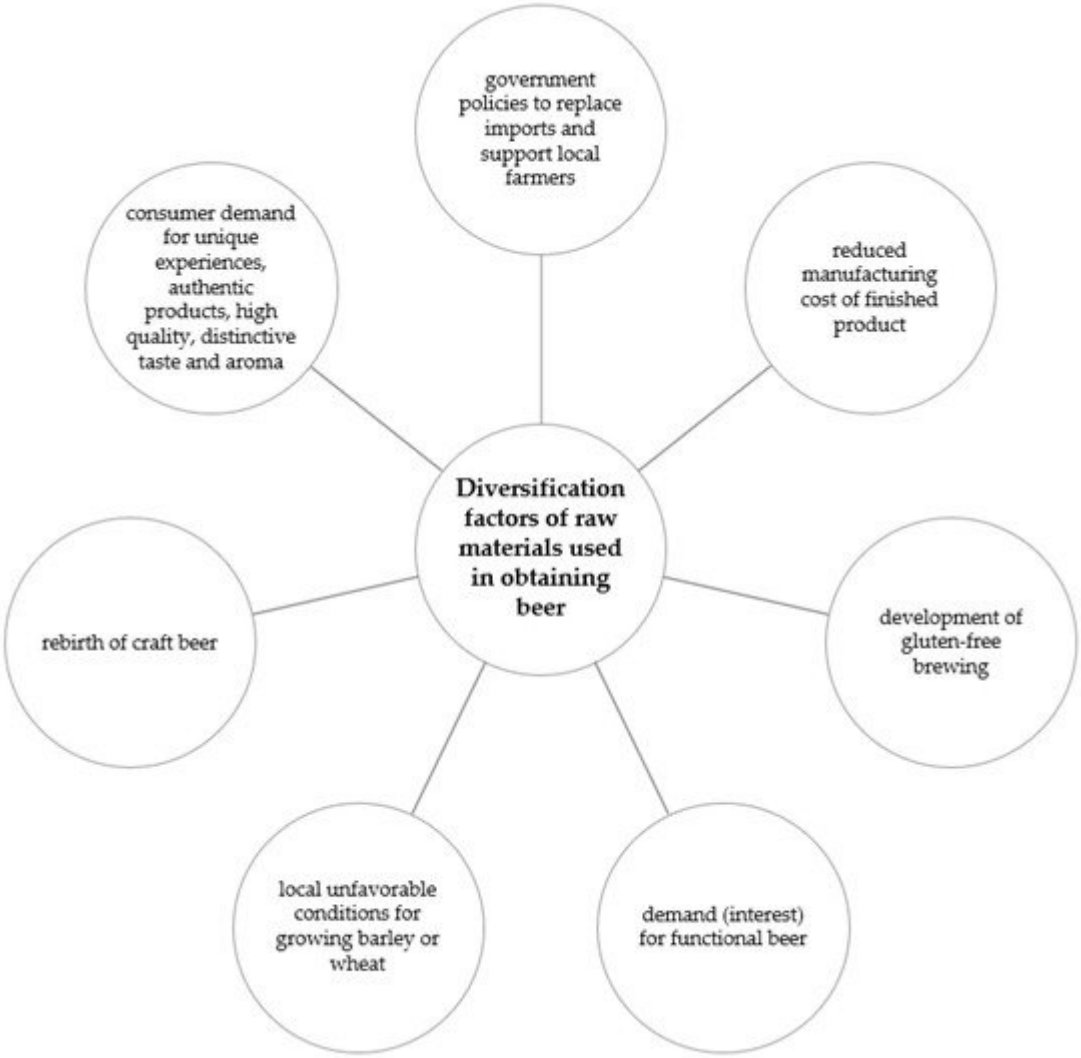

Figure 1. Diversification factors of raw materials for obtaining beer.

Barley and maize are the most commonly used adjuvants in Europe as partial substitutes for malt [10][11][12]. Adjuvants are widely used in the beer industry (in variable proportions ranging from 10–50%) to provide additional sources of fermentable yeast carbohydrates, to improve foam stability, to change the color of beer, or to adjust the flavor of the finished product [13].

2. Maize and Sorghum: Raw Materials for Brewing

2.1. Chemical Structure and Composition

The maize grain is 2.5–22 mm long and 3–8 mm wide. Depending on the variety and cultivation conditions, the weight of 1000 grains vary greatly (between 30 and 1200 g). Maize grains are constituted of endosperms (82–83%), germs (10–11%), pericarps (5–6%), and peaks (0.8–1.0%) [14]. Sorghum grains are rounded and sharp with a diameter of 4–8 mm. They vary in size, shape and color depending on the variety of sorghum. The weight of

1000 grains varies between 20 and 60 g. These grains are composed of endosperms (80–84.6%), embryos (7.8–12.1%), and shells (7.3–9.3%) [15].

For the beer industry, the chemical composition of raw materials is particularly important. Table 1 summarizes the physicochemical characteristics of the maize, sorghum, and barley.

Table 1. Physicochemical characteristics of maize, sorghum and barley.

Grain	Characteristic, [% DM *]					Moisture [%]	References
	Starch	Proteins	Lipid	Fiber	Ash		
Barley	60	8–13	-	2–10	-	-	[16]
	65–68	10–17	2–3	11–24	1.5–2.5	-	[17]
	63–65	8–11	2–3	-	2	14–15	[18]
	62–64	11.09–14.68	2.01–2.35	18.7–19.5	-	-	[19]
	66.97–69.08	10.35–12.38	1.58–1.71	3.57–5.12	1.94–2.39	-	[20]
	59.50–60.98	14.53–15.25	1.82–1.87	2.85–3.25	2.42–2.52	-	[21]
	65.45–69.08	10.37–11.93	1.09–2.00	3.07–5.10	1.94–2.40	-	[22]
	52.1–64.4	8.7–13.1	2.2–3.5	13.6–23.8	2.0–2.6		[23]
Maize	71.88	8.84	4.57	2.15	2.33	10.23	[24]
	74.4–76.8	8.05–11.03	5.91	-	-	15	[25]
	76–80	9–12	4–5	-	3.87	10–14	[26]
	-	8.92–10	-	1.3–6.26	1.20–2.38	-	[27]
	70.99	9.21	5.10	2.21	1.05	11.44	[28]
	62–78	10	4.4	-	-	-	[29]
Sorghum	71.7	9.5	4.3	2.6	1.4	-	[30]
	72–73	5.8–13.7	2.2–5.7	0.8–2.9	1.2–2.9	9.5–12.2	[31]
	-	9.4	2.8	-	2.1	-	[8]
	61.0–74.8	9.0–13.5	2.8–4.8	-	1.2–1.8	9–12	[32]
	55.6–75.2	4.4–21.1	2.1–7.6	1–3.4	1.3–3.3	-	[33]
	65.15–75.2	6.23–14.86	1.38–10.54	1.65–7.94	0.90–4.20	1.39–19.02	[34]

Grain	Characteristic, [% DM *]					Moisture [%]	References
	Starch	Proteins	Lipid	Fiber	Ash		
	70.65–76.20	8.90–11.02	2.30–2.80	1.40–2.70	0.92–1.75	8.10–9.99	[35]
	-	12.5	3.30	1.7	1.9	9.8	[36]
	71.95	11.36	4.70	2.76	3.17	6.07	[37]
	64.3–73.8	8.19–14.02	2.28–4.98	1.41–2.55	1.46–2.32		[38]

* DM—dry matter.

Starch is the main component of cereals, and is the main substance that is later converted to fermentable carbohydrates in beer wort. The highest amount of starch is found in maize (62–80%), followed by sorghum (55.60–76.20%), and then barley (52.10–69.08%). The protein content varies between 8–15.25% for barley, 5.8–13.7% for maize, and 4.4–14.86% for sorghum. The fat content is 1.09–3% for barley and 2.2–5.91% for maize. Sorghum varies greatly, with a lipid content between 1.38–10.54%.

2.2. The Use in Brewing

2.2.1. Maize

Maize starch is widely applied (due to its high fermentability) as an adjuvant in the production of high-gravity beer [39]. Corn flakes or pre-gelatinized maize can be used to significantly reduce mashing time. Corn kernels produce a somewhat lower extract compared to other raw adjuvants (such as rice) due to the lower amount of dextrin in the wort after mashing. They also contain higher levels of lipids and proteins. It should be noted that the addition of corn derivatives has an important impact on the organoleptic properties of beer. In the future, it may be recommended that brewers/manufacturers use exogenous enzymes together with corn in order to enhance saccharification and amylolytic activity. Table 2 summarizes data from the literature on the production of beer assortments based on maize or maize derivatives.

Table 2. Beer assortments in which maize is used as a raw material.

Beer Name (Origin Country)	Raw Materials	Tehnological Process	Finished Product Characteristics	References
Sendechó (Mexic)	Blue maize, chili Guajillo, pulque	Malting, grinding, mashing, brewing, fermentation	Fermented fruit flavor, smells of cooked vegetables, tortillas, bread, dried fruit and dried chili, amber-copper red color	[40][41]
Chicha de jora (Argentina, Euador, Peru)	Maize	Malting, grinding, brewing, lactic fermentation, alcoholic fermentation	Clear liquid, yellow color, effervescent drink, and a low alcohol content (1–3%)	[42][43]

Beer Name (Origin Country)	Raw Materials	Tehnological Process	Finished Product Characteristics	References
Umqombothi (Africa de Sud)	Maize flour, sorghum malt	Mashing, brewing, fermentation, filtration	Opaque, pink in color, rich in B vitamins, with a distinct aroma, acid and a creamy consistency, shelf life of 2–3 days	[44][45]
Sesotho (Lesotho)	Maize, sorghum and/or wheat flour	Grinding, mashing, lactic fermentation, cooling, alcoholic fermentation	Opaque liquid, thin consistency, distinct sour taste, 3–5% (v/v) alcohol content, rich in B vitamins	[46][47]
Chibuku (Zimbabwe, Tanzania, Zambia, Ghana, Nigeria)	Maize, sorghum, sorghum malt, barley malt	Malting, grinding, brewing, acidification, lactic fermentation, alcoholic fermentation	Opaque brown-pink liquid containing suspended and dissolved solids (3.6% w/v), alcohol content of 3–5%, pH of 3–4 and lactic acid levels of approx. 0.5 g/L	[48][49]
Tella (Etiopia)	Maize, barley, wheat, Rhamnus prinoides L.	Malting, grinding, brewing, alcoholic fermentation	pH 3.87–4.67 alcohol content (%v/v) 3.04–3.75 CO2 content (%) 0.24–0.034	[50][51]
Sekete (Nigeria)	Sprouted maize	Mashing, brewing, acidification, lactic fermentation, alcoholic fermentation	Dark brown color alcohol content of 1–3%	[9][52]

2.2.2. Sorghum

Outside of Mexico and Niger, sorghum has not been widely used as an adjuvant, although its potential has been promoted. Sorghum semolina offers several advantages in beer brewing, including short boiling time, easy filtration, high extract content and highly nutritious wort [53]. The use of sorghum malt in beer manufacture has led to some difficulties, largely due its low amylolytic activity (which is insufficient for complete saccharification), high gelatinization temperature, and low content of free amino nitrogen. The use of sorghum malt in beer manufacture has led to some difficulties, largely due its low amylolytic activity (which is insufficient for complete saccharification), high gelatinization temperature, and low content of free amino nitrogen.

Table 3 summarizes data from the literature on obtaining beer assortments that use sorghum as a basic raw material.

Table 3. Beer assortments in which sorghum is used as basic raw material.

Beer Name (Origin Country)	Raw Materials	Tehnological Process	Finished Product Characteristics	References
Burukutu/Otika (Nigeria, Niger, Ghana)	Sorghum	Malting (steeping, germination), milling, mashing, boiling, fermentation, maturation	Viscous, opaque, light brown liquid, alcohol content approx. 4% (v/v), sour taste, pH = 3.3–3.5	[33][52]
Pito (Ghana, Togo, Nigeria)	Sorghum	Malting, grinding, mashing, brewing, lactic fermentation, alcoholic fermentation	Sour taste, characteristic, alcohol content 3–5% (v/v)	[54][55][56][57]
Tchapalo (Coasta de Fildeș, Togo, Benin)	Sorghum	Lactic fermentation, alcoholic fermentation	Non-alcoholic beer, turbid, shelf life 3 days	[58][59][60][61][62]
Bantu (Africa de Sud)	Sorghum	Malting, grinding, mashing, lactic fermentation, alcoholic fermentation	Turbid liquid, alcohol content 3–4% (v/v), sour taste, brown-pink color, rich in B vitamins	[63][64][65][66]
Dolo (Burkina Faso, Benin, Rwanda)	Sorghum	Malting of red sorghum grains, crushing, mashing, cooking, lactic fermentation, filtration, boiling, alcoholic fermentation	Turbid liquid, alcohol content 1–5% (v/v), sweet-sour taste, fruit flavor	[67][68][69][70]
Bili bili (Ciad)	Sorghum	Malting, mashing, boiling, souring, and fermenting	Turbid liquid, brown-pink color, sour taste, fruity, alcohol content 1–8% (v/v), low in carbohydrates and high in protein	[71][72][73][74][75]
Omalovu (Namibia)	Sorghum, millet	Malting, drying, milling, souring, boiling, mashing, straining, alcoholic fermentation	Unpasteurized beer, opaque, red-brown or cream color, pH = 3.06–4.34, alcohol content 0.18–4.05% (v/v)	[71][76]

4. Conclusions

The studies undertaken demonstrated the real potential benefits of using maize and sorghum in the brewing process, whether as simple adjuvants or via the brewing of beers made from 100% sorghum or maize malt.

Maize is a versatile money crop and is adaptable to various climatic conditions; globally, it is known as the queen of cereals. Sorghum is genetically close to corn, and is also called the camel plant due to its resistance to extreme drought conditions. Sorghum is also a vital staple food in many semi-arid areas of the developing world.

There are some limitations in the use of these two cereals: maize has bare grains and lacks a husk (which would act as an adjuvant for filtration). It also has a low level of enzymatic activity. The structure of the sorghum grain is

similar to maize; it has no shell, and the aleurone layer inhibits the flow of enzymes. Moreover, the development of amylolytic enzymes during the germination of maize and sorghum is lower than in barley.

In countries around the world, craft and functional beer brewing has revived old varieties and created new ones. Specialist brewers have worked to advance novelty beers that exhibit a complete and rich taste through efficient processing. These new beverages are created using various ingredients, and often involve modifications of the brewing process.

In conclusion, industrial and scientific research can promote innovation by creating new assortments of beer using maize and sorghum. This, in turn, could have a significant impact on product quality improvements.

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