

NON-CONVENTIONAL RAW MATERIALS FOR BEER PRODUCTION

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Abstract

Beer is one of the oldest fermented drinks in the world. It is made from malted barley, hops, brewing water and yeast, and these ingredients were regulated in the well-known Beer Purity Law. Nevertheless, a number of other raw materials containing starch and fermentable sugars, i.e. cereal grains, pseudo-cereals, potatoes, glucose-fructose and maltose syrups, are used worldwide. Part of these raw materials can be malted, whereas others are used in their unmalted form. They change the conditions of the beer wort, the balance of the fermentable sugars, hence the organoleptic profile of the beverages obtained. In recent years, the focus has been placed on these raw materials, especially with the progress of craft brewing. Craft brewing has also introduced a new niche into beer production, namely, the change in the organoleptic profile of the beverages produced with the addition of cereals other than the traditional ones. Recently, there has been increasing use of different fruits, essential oil crops and other additives intended to appeal to new beer consumers. Special attention is being paid to new yeast cultures which can carry out the fermentation process. The aim of the present study was to make a brief review of the main characteristics and application of non-conventional raw materials to beer production.

Keywords: beer, non-conventional raw materials, adjuncts, fruit, essential oil crops, new yeast types

1. MALT SUBSTITUTES AS A NON-CONVENTIONAL RAW MATERIAL FOR BEER PRODUCTION

The brewing industry is relatively conservative with regard to the main raw and processed materials used. The main raw materials for beer production defined through the so-called Reinheitsgebot, also known as the Beer Purity Law, were malt, hops, water and yeast. The original document did not refer to yeast since fermentation was considered a kind of ‘a magical process’ in this phase of beer production [1, 2, 3].

The current stage of beer production development involves barley and wheat (for the making of the so-called wheat beers) as the main cereals for malting. Barley (*Hordeum vulgare*) and the malt obtained from it are used in brewing for the following reasons: high starch content, high hydrolytic enzyme content and grain structure and elements which have proved a good filtering agent in the wort separation from the malt grits [1, 2, 3].

Wheat (*Triticum aestivum* L.) is a hulless cereal. It was cultivated 8000 years ago and after 1940, it gradually replaced rye in bread making. In Germany and Belgium, it is used for the production of wheat beer and can be applied either malted or unmalted. Technologically, a combination of barley and wheat malt is usually used, with up to 50% share of the wheat [1, 2, 3].

The history of beer production is connected with the use of other cereal grains as well, which were gradually displaced by barley and wheat. Owing to the recent boom in the so-called craft brewing, there has been a comeback of these forgotten raw materials and they are often promoted as non-conventional [4]. In this part of the study, we will make a brief review of some of these raw materials and their technological characteristics. Their choice is made on the basis of three main requirements: raw material price, possibilities of supplying the raw material, and brewing characteristics [5, 6, 7].

A. Cereals as raw materials.

Oats (*Avena sativa* L.) are a cereal grain originating from its wild representative *Avena fatua* L. They date back to the Bronze Age, when they were grown in the regions of Central Europe. It is believed that in the Middle Ages they were the main raw material used in beer production, although they were referred to the weed species. Later, with the introduction of barley and barley malt, oats were used in the production of some lower grade beers. Oats can be applied to beer production in their malted or unmalted form. Owing to the specific structure of the grain, steeping is relatively fast since the grain takes up considerable water quantities. The germination conditions are similar to those of barley malt production; however, extract losses are higher because the hulls contain more sugars [4, 5, 6, 8, 9, 10].

Oats are rich in proteins, fats and β -glucans but barley malt has low hydrolase activity and is rarely applied to the brewing industry. The main advantage of oats is the relatively large hull which facilitates the process of mash filtration [4]. With regard to quality, the wort obtained from 100% oat malt does not differ much from that obtained from barley malt but there are increased quantities of zinc, β -glucans and tryptophan. The oat content improves the head retention of the beer and contributes to a stable haze [8, 11]. Oats are mainly used for beer from the Stout group, as well as for beer intended for people with gluten intolerance [5, 12, 13]. Data from various studies show that oat malt has relatively low diastatic power, hence the use of enzyme preparations is recommended with larger oat quantities (malted or unmalted) [4, 5, 6].

Over the past years, there has been an interest in the use of rye (*Secale cereale* L.) and rye malt in beer production. Rye was discovered as a crop around 7000 years ago but was gradually replaced by wheat and barley [4, 5, 14]. Rye is malted according to standard methods; however, the mash obtained has a higher viscosity, which is due to its pentosan content. This, in turn, extends the mash filtration time and increases the risk of its oxidation. Furthermore, as a result of the obstructed filtration, it is hard to obtain crystal types of beer. Beer wort made with the participation of rye malt is deep and dark in colour, with a rich aroma. Rye malt can also be used for correction of the beer colour [15, 16, 17]. From an organoleptic and biological point of view, rye imparts dry, spicy and astringent tones to beer, and enriches the wort with phenolic acids [4, 9, 14, 17].

Millet is botanically related to maize. Millet is mainly grown in India and Africa. In brewing, different millet varieties are used, i.e. pearl millet (*Pennisetum glaucum* (L.) R. Br.), foxtail millet (*Setaria italica* (L.) P. Beauv.), fonio (*Digitaria exilis*), tef (*Eragrostis tef* (Zucc.) Trotter), finger millet (*Eleusine coracana* (L.) Gaertn.), and proso millet (*Panicum miliaceum* L.). Millet malting is a difficult task and a product with low diastatic power is obtained, which leads to low extract yields. Beer made from 100% malted millet has an organoleptic profile different from traditional beers, as well as a good head formation and head retention capacity. Normally, millet is combined with other cereal grains for beer production. Millet contributes high biological value to beer due to its higher antioxidant and mineral content. In addition, it improves the digestibility, the sensory and nutritional quality of beer [4, 7, 17, 18].

A growing interest has also been observed in the use of sorghum. Its origin is related to Ethiopia, and it is currently grown in vast areas of Africa, Australia, Asia and the USA. It is usually cultivated in zones where the climate is not favourable for the growth of maize [4, 17].

In Africa, sorghum is used for the making of hazy and lager beer styles and can be applied as either malted or unmalted raw material. In the USA and Mexico, sorghum successfully replaces maize and rice in their role as adjuncts. Sorghum is malted at relatively high temperatures and the resultant malt is characterised by a high gelatinisation temperature and low diastatic power. The α -amylase activity of sorghum malt is almost equal to that of barley malt. Sorghum is lower in proteins, both as a raw material and as the wort obtained from it. The malting mode facilitates an increase in the mash viscosity due to larger pentosan quantities. Unmalted sorghum is the third main substitute for malt after maize and rice worldwide. The wort obtained with the addition of sorghum has higher tannin and polyphenol content. Sorghum can also be used for the production of low-alcohol beer since there are varieties rich in amylopectin and the wort they yield contains large amounts of non-fermentable dextrins. The beer made using sorghum is characterised by a slightly sour and bitter taste and astringent feeling. Some red-

coloured sorghum varieties have higher tannin content. Sorghum also provides bioaccessible proteins, B group vitamins, minerals, antioxidants and fibres [4, 5, 9, 17, 19-24].

Maize and rice are cereal grains that are common in the brewing industry. Recently, they have been used in considerable amounts, which makes them traditional raw materials for beer production [4, 5, 17].

A similar conclusion may be drawn about some types of wheat. Nevertheless, due to the wide range of wheat varieties, further information may be needed [4, 5]. Wheat includes the following main types: spelt wheat (*Triticum aestivum* ssp. *spelta* Thell. = *Triticum spelta* L.), einkorn wheat (*Triticum monococcum* L.), emmer wheat (*Triticum dicoccum* Sch ü bl.), Kamut (*Triticum durum* L., *Triticum turgidum* L., *Triticum polonicum* L.), etc. The majority of these types are related to beer production, spelt and einkorn wheat being currently of major importance to the brewing industry [4, 5, 17].

Spelt (*Triticum aestivum* ssp. *spelta* Thell. = *Triticum spelta* L.) is a wheat transferred to Switzerland from Asia in the Middle Ages. Then, it spread to Tirol, Baden-Württemberg and other parts of Europe, but most widely in Swabia, Germany. Spelt wheat can be malted and does not differ much from the classical wheat malt in terms of malt quality. The malt obtained can replace up to 70% of the barley malt, and the top-fermented beer has a pleasant organoleptic profile. Roasted spelt malt is made in Europe, with colour intensity of 450-650 EBC, and the resultant beer is intensive dark in colour [4, 5, 6, 7, 11, 24, 25].

Single-grain einkorn (*Triticum monococcum* L.) is one of the oldest plants grown in Europe. Within the past 10 years, this raw material has been rediscovered both for beer production [11, 25] and for the manufacture of different types of functional foods [4, 5, 6, 7] due to its nutritional properties. On the whole, einkorn is promoted as a promising raw material but it is difficult to obtain malt from it. Malted einkorn shows decreased protein and amino nitrogen content; hence, its use in an unmalted form is preferred. Besides, wort obtained using malted einkorn is characterised by a reduced fermentation degree [4].

A suitable variety for beer production is emmer wheat (*Triticum dicoccum* Sch ü bl.). Its grains are hullless, white, red or black in colour. The wort obtained from emmer malt has a relatively high extract yield and an average saccharification time but a low fermentation degree. The resultant beer is sourer, but this flaw can be remedied if top fermentation is applied [литературни източници]. Kamut (*Triticum durum* L., *Triticum turgidum* L., *Triticum polonicum* L.) has a relatively long grain which hinders the malting process. This leads to low extract yields and problems with the colour and amino nitrogen content. It is interesting to mention that the malt has a comparatively high diastatic power [4, 5, 6, 7, 11, 25]. In recent years, some breweries also use tritikale, a new cereal grain obtained through the hybridisation of wheat and rye ($\times T. riticosecale$ Wittmack). Owing to the fact that the hybrid is obtained on the basis of rye, the wort made from its malt resembles rye wort. This malt has high diastatic power but low α -amylase activity. The beer produced using tritikale is hazy [4, 5, 6, 7, 24, 25].

B. Pseudo-cereals.

Along with cereal grains, there has been a growing use of the so-called pseudo-cereals in craft brewing. These are cultures which do not belong to cereal grains botanically but are rich in starch. Currently, the crops used in beer production are amaranth, quinoa and chia [3, 4, 5].

Amaranth (*Amaranthus cruentus*, *Amaranthus hypochondriacus*, *Amaranthus caudatus*) is characterised by high starch content, 2-3 times as high as that of barley and wheat. The raw material can germinate (at 30 °C), and during germination, the amino acid content increases. The resultant malt is red in colour, which imparts a pink tint to the beer wort. Apart from the high amino acid content, the beer wort is rich in minerals and unsaturated fatty acids. The raw material itself is rich in calcium and magnesium ions, which enhances the enzyme activity during mashing and results in a higher extract yield and a higher fermentation degree of the wort. Special care needs to be taken throughout the malting process since the gelatinisation temperature of amaranth starch is high and complete saccharification may not be achieved. The data in literature show that 20% of the barley malt may be replaced by amaranth malt. Further studies explore the possibility of applying an unmalted raw material [4, 5, 6, 7, 26, 27, 28, 29].

Buckwheat (*Fagopyrum esculentum* Moench) is a plant that is not related to wheat. It has a hully fruit resembling that of beech nuts. The seeds can be milled into groats with a colour similar to that of wheat malt. Buckwheat can be malted, with fairly short steeping since the grain quickly absorbs a lot of water. The product has relatively high amylolytic activity, but some authors also report reduced activity and hence, a reduced extract yield. Buckwheat malt imparts a nut, pistachio-like flavour to the wort. This flavour is stable and is also present in the finished beer. The main advantage of buckwheat is the fact that it can be used for gluten-free diet beers. The beer produced using buckwheat has high antioxidant activity due to the rutin content. Data from various studies indicate that beer obtained using 20% to 40% of buckwheat malt is evaluated as similar to malt beer. The beer gives a less intensive bitterness feeling owing to the higher polyphenol content in buckwheat [4, 5, 6, 7, 18, 28, 30, 31, 32].

Quinoa (*Chenopodium quinoa* Moench) is a relatively new raw material in the brewing industry. It originated in Peru and was the staple diet of ancient Incas. It is considered a super food because of its high polyphenol, mineral and vitamin content. The raw material may be malted but the resultant malt has relatively low activity and yield values, whereas the saccharification time is longer. When applied in its unmalted form, again there are problems with the achievement of a significant extract yield. The data in literature demonstrate a controversial organoleptic profile of the beer made using quinoa [4, 5, 6, 7, 18, 29, 33, 34, 35].

C. Sweet potatoes.

Potatoes, sweet potatoes (*Ipomoea batatas*) in particular, are a potential starch source. They can be viewed as a potential raw material for beer production due to the high starch content and their higher amylase activity compared to malt. The interest in the use of potatoes also arises out of the fact that they contain certain amounts of β -carotene and anthocyanins, which significantly improve the biological value of beer [5, 36, 37].

2. NEW YEAST TYPES WITH APPLICATION TO THE BREWING INDUSTRY

The craft revolution in beer production has led to innovations in the wort fermentation process. The combination of non-conventional raw materials that provide the necessary starch quantities and the application of new yeast types results in the creation of beverages that are unique in terms of taste and aroma profile. Until several years ago, the brewing industry, including craft breweries, were oriented towards the use of yeasts of the *Saccharomyces* genus, whereas the application of non-*Saccharomyces* yeasts was quite limited (mainly to the Lambic-type beer). Recently, however, there has been an expanding interest in non-*Saccharomyces* yeasts since their enzyme profile contributes to a richer taste and aroma of beer. These non-conventional yeasts can be used both on their own and as mixed populations with a view to creating beverages with a unique organoleptic profile [38, 39].

Classical bottom-fermenting (lager) and top-fermenting (ale) beer production is associated with the application of yeasts of the *Saccharomyces pastorianus* and *Saccharomyces cerevisiae* species. Bottom-fermenting yeasts have a relatively conservative metabolic profile, whereas the application of top-fermenting strains enriches the beverages with aromatic components. This can be attributed to the differences in the genetic profile of both yeast types. The difference is also due to the fermentation temperatures: 5 – 15 °C temperatures are used with bottom-fermenting strains, while top-fermenting strains act within the 15 – 25 °C range [1, 2, 3, 38].

As has already been mentioned, craft breweries have also started using a number of non-*Saccharomyces* yeasts. In conventional industrial production, a lot of these yeasts are associated with their negative effect on the final product [38, 39]. With the development of the biotechnological industry, some of these yeast types have also found application in the brewing industry since they bring differences into their organoleptic profiles. Still, it has to be borne in mind that these yeasts are also applied to conventional production, such as the production of Lambic-type beers. Conventional production involves spontaneous fermentation using yeasts of the *Brettanomyces bruxellensis* species, later developed into targeted fermentation processes [38, 40, 41, 42].

It is important to note that non-*Saccharomyces* species have weaker primary metabolism, which affects the alcohol content of the beverage; nevertheless, their enzyme profile is richer. Thus, they can include sugar metabolism in different enzyme paths and thus lead to the production of more aromatic components [38, 39, 40].

The summary of the data in the sources shows that yeasts of the species below (an excerpt from the most widely used species has been presented) find their application in beer production [38]:

- *Brettanomyces/Dekkera* – they produce large quantities of ethyl acetate, ethyl caprate, ethyl caprylate and ethyl lactate [38, 43, 44, 45, 46, 47];
- *Saccharomycodes ludwigii* – they produce lower alcohol quantities, large quantities of ethyl acetate, isoamyl acetate and 4-vinylguaiacol, as well as increased quantities of amyl alcohol and higher alcohols [38, 39, 48, 49];
- *Torulaspora delbrueckii* – they produce large ethanol quantities, as well as β -phenylethanol, n-propanol, iso-butanol, amyl alcohol, and ethyl acetate [38, 39, 43, 50, 51, 52, 53].

Data are also available in literature on the production of beer using yeasts of the *Candida*, *Debaryomyces*, *Hanseniaspora*, *Kazachstania*, *Kluyveromyces*, *Pichia*, *Rhodotorula*, *Saccharomycodes*, *Saccharomycopsis*, *Zygosaccharomyces* and other species. Nevertheless, the use of these species is more often in combination with conventional yeast strains for the purpose of ensuring a new organoleptic profile of the beverages [38, 39].

An interesting object of research lately has been the use of yeasts having a certain activity for the release of monoterpene alcohols (linalool, α -terpineol, β -citronellol, geraniol, and nerol) from hops with a view to enhancing the organoleptic profile. In wort, these components are connected with glycoside bonds; therefore, yeast cells need to have a β -glucosidase activity. In this case, both the non-*Saccharomyces* species and the yeast strains that are typical of wine production can be applicable [50, 54, 55].

3. FRUIT IN BEER PRODUCTION.

The craft revolution in beer production has brought about the use of a number of fruits for enhancement of the organoleptic profile of beer and the development of a whole new beer category referred to as fruit beer. The industrial-scale use of fruits is comparatively low due to the additional costs involved in their processing [56]. When exactly fruit beer production started is not very clear historically but it is known that over the years, people have used different kinds of fruits for beer production. Thus, some types of fruit beer have become a tradition, while at other places they are now considered an innovation [56, 57].

The use of fruits in the production process meets certain needs but is also very important to the organoleptic profile of the final product. Firstly, fruits contribute a new taste and aroma, thereby enriching the typical beer profile. Therefore, fruit extracts and bases for the production of the respective fruit beer type are preferred for use in commercial beer production [58]. Perhaps the best known fruit beer types are the spontaneously fermented Lambic with cherries (Kriek) and raspberries (Framboise) [57, 59, 60, 61, 62, 63, 64, 65]. Nowadays, the craft revolution makes beer producers search for a serious variety of tastes and hence, use a number of fruits: blueberries, apples, strawberries, pineapple, kiwi, oranges, different grape varieties, etc. In recent years, the use of grapes has resulted in the formation of a new beer style, Italian Grape Ale (IGA). This style was introduced in 2015 and has sub-styles which are defined by terroir. It is Pilsner beer or another light malt type, where 40% of the malt has been substituted with grapes [66].

Fruit addition can be applied at different stages: during mashing, boiling, primary fermentation, secondary fermentation and conditioning, and deposit of the finished beer [67, 68]. The main challenge in the use of fresh fruits is the fact that they are microbiologically contaminated with typical microflora which contaminates the finished beer. Therefore, methods of microflora inactivation or fruit addition at the high-temperature stages of beer production have to be found. This, in turn, may lead to a number of problems, mainly related to chemical reactions that could change the desired beer character. In this sense, practice makes it necessary to use different types of fruit concentrates. These are intermediate

products that have undergone certain processing (skin and seed removal) and an element of pasteurisation/sterilisation. This facilitates the beer production process and reduces the risk of development of non-typical microflora and changes in the desired organoleptic beer profile [67].

The addition of different fruits to beer may have the respective functional effects on the beverage. The phenolic compounds in fruit are known to have functional benefits for human health. Hence, fruit addition may increase the functional effect of beer, especially if it is combined with a reduction of its alcohol content. Data may be found in literature that the consumption of beer made with the addition of grapes may reduce blood pressure to normal levels [65, 66, 67, 68].

4. HERBS AND ESSENTIAL OILS IN BEER PRODUCTION.

In recent years, there has been an increase not only in the scientific interest but also in beer consumption, which has certain functional characteristics. At different stages (mashing, boiling, primary fermentation, secondary fermentation and maturation), different plants or their extracts and oils are added to beer, including mugwort (*Artemisia vulgaris*), juniper (*Juniperus communis*), lemon balm (*Melissa officinalis*), spearmint (*Mentha spicata*), peppermint (*Mentha piperita*), oregano (*Origanum vulgare*), anise (*Pimpinella anisum*), etc. The spectrum of herbal plants used is very wide but their addition does not always produce the desired effect, especially in terms of the organoleptic qualities of beer [7, 69, 70, 71]. Historically, the use of medicinal and aromatic herbs in beer production has most often been related to ensuring its biological stability. Thus, it is a well-known fact that in Northern Europe, juniper successfully replaced hops in the beer production process, and it was exactly with a view to the preservation of the finished beer [70]. On the whole, the use of different types of herbs enhances the functional effect of beer by providing a higher antioxidant potential due to the increased polyphenol content. Still, the change in the organoleptic profile is a major consideration with regard to herb addition; therefore, the concentration of the raw materials added has to be subjected to careful studies [7, 70].

A relatively new trend in this respect is the production of functional beverages based on beer wort made with the addition of herbal raw materials. In this case, the beneficial effects of beer wort (phenolic capacity, antioxidant activity) are combined with the occurrence of lactic acid fermentation involving probiotic bacterial strains and herbal raw materials in the form of leaves or extracts. Some studies indicate that this combination makes it possible to produce a large variety of beverages which have an improved biological profile. In the specific studies, lactic acid beverages were made using *Lactobacillus casei* ssp. *rhamnosus* LBRC11 and *Lactobacillus casei* ssp. *paracasei* PX3 strains and peppermint leaves or extracts, on the basis of beer wort obtained from different malt types. The data demonstrated that the lactic acid beverages made were pleasant for consumption and had increased antioxidant activity [72, 73].

5. CONCLUSIONS

This paper examined some types of non-conventional raw materials which are increasingly applied to beer production. Different types of cereal grains and pseudo-cereals, yeasts, herbal and plant raw materials that are successfully used in craft brewing were also reviewed. Special attention was paid to the changes in the biological profile of the resultant beverages as a basis for the creation of new types of beer and wort-based beverages.

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