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Mini-Review

Cereal Safety and Quality in Malting and Brewing Industries

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Abstract

Cereals are mostly used as a raw material in the food industry, mostly for baking industry, but cereals are also a wanted commodity in the industry of alcoholic beverages and spirits. There are strict recommendations and legal limits regarding satisfactory quality of cereals intended for malting and brewing. When it comes to malting and brewing, the most important indicator of cereal quality is protein content. Most suitable protein content ranges between 11 - 12%. However, worldwide problem regarding cereal quality for malting and brewing industries are *Fusarium* infections. *Fusarium* infection causes not only economic losses, but directly influences malt and beer quality. The aim of this paper was to present some of the main and important quality indicators considered in malting and brewing industries.

General requirements regarding malting cereals

There are strict recommendations and legal limits regarding satisfactory barley quality intended for malting and brewing (protein content, β-glucan content, Kolbach index, malt extract, extract difference, saccharification time, wort colour, viscosity, FAN (free amino nitrogen) etc. However, protein content if far most important indicator of quality, deciding on the initial acceptance of cereals in the malt factory. Optimal protein content is below 12%. Higher amounts result in heighten soluble proteins content in wort which leads to off-flavours in beer. Protein content < 11% usually means lower extract values [1]. This reflects poorly to the fermentation process because of the poor amino acid content available for yeast nutrition. β-glucans can also act as a limiting factor in malting and brewing.

In recent research attention has been paid to β-glucans because of their beneficial effects on human health since they can be characterised as prebiotics [2]. However, brewers label β-glucans as not desirable in cereals intended for malting and brewing. Total β-glucan content in barley normally ranges from 2 to 8% [3], with the acceptable level for brewing being < 4% (MEBAK; EBC). Even though there are no recommendations for total β-glucan content in malt, according to Davis (2006) [9], β-glucan values in wort should be kept below 200 mg/L. β-glucans in cereals principally depend on genetic factors, but climatic conditions, agro technical measures, soil type also influence the total β-glucan content in barley [5-7]. Not to be all negative about β-glucans, in the right amount they are considered useful for brewing, because they do contribute to the beer foam stability and improve beer organoleptic properties (i.e. beer mouth feels) [8]. During malting, high β-glucan content can lead to unsatisfactory cell wall degradation, disrupting the germination and reducing malt extract which means less sugars for yeast during fermentation [9]. Other negative consequence of β-glucan residues in malt is poor mash conversion, highly viscous wort and difficulties during the filtration process [9,10]. All this conditions the acceptable low to moderate β-glucans content in cereals intended for malting [10]. Wheat is used in malting and brewing to a much lesser extent and the recommendations for malting wheat are not as strict as for barley. Only 0.5% of wheat ends up in beer, in oppose to barley where 16% of world's production is provided for malting [11,12]. Wheat is usually used in production of special beer and whiskey malts.

Fusarium infections and mycotoxins occurrence in malting and brewing industries

Good quality raw material is the most important factor in malting and brewing industry. Pathogenic fungi belonging to *Fusarium* spp. can cause great degradation of malt grain quality. Most important species causing FHB in Central and Northern Europe are *F. avanceum, F. graminearum, F. poae and F. culmorum* (WG Smith) Sacc. [13,14]. Because they thrive in malting process conditions (high moisture, low temperature, high nutritive values of grains), *Fusarium* fungi are considered one of the most important indicators of cereal quality. They are ability to degrade endosperm, as they integrate into the grain. *Fusarium* fungi reduce 1000 kernel weight, test weight, increase moisture content, prolong saccharification time and speed of filtration, increase total protein and total nitrogen content, increase soluble protein and soluble nitrogen content [11,15]. Congress wort colour, colour after cooking, viscosity, free amino nitrogen (FAN) and pH value are highly important indicators of malt quality. In case of *Fusarium* infection they are prone to deteriorate and as such influence beer quality [15].

Gushing is a phenomenon best described as sudden overfoaming of beer on opening the container (can, bottle). Gushing is in direct linkage with proteins called hydrophobins. Hydrophobins are a product of fungal metabolism, and are also found in *Fusarium* fungi [16]. Overfoaming serves as an indicator of malt quality and causes economic problems for breweries [17].

Mycotoxins are secondary metabolites of *Fusarium* fungi and are also considered quality indicators of cereals prior their entrance into the malting factory. *Fusarium* fungi produce these toxic compounds that represent health hazard not only for humans but for animals too. Several hundred mycotoxins [18], about 200 of which belong to trichothecenes group [19] have been classified so far. High temperatures applied during malting (drying phase) and cooking (beer) do not act degrading to mycotoxins and this is why they are such an important topic in brewing industry [20,21]. Today's brewing is a global industry, meaning that a few big breweries are taking the major piece of the market. However, small, home-brewers and craft breweries are very popular.

Mycotoxins levels should be monitored in order to avoid health safety issues. Even casual beer-drinkers (up to 2 beers per day, or up to 1 L of beer), according to Warth *et al.* (2012) [12] can exceed the PMTDI (provisional maximum tolerable daily intake) for DON (1 μg/kg bw/d), and similar can be expected for other mycotoxins found in beer. Filtration is by tradition, for some types of wheat beers, an omitted unit operation, meaning that yeast remains active during storage and changes beer profile (aroma, body and taste). Many studies dealt with mycotoxins in commercial and craft beers [22-25], and results showed that mycotoxins (deoxynivalenol (DON), nivalenol, T-2, HT-2, diacetoxyscirpenol, zearalenone, aflatoxins, ochratoxin A, and fumonisins) do occur in beers, but in very low concentrations (mostly <1 μg/L).

Malting and brewing by-products

Malting and brewing by-products represent a nutritious and valuable, low-cost source of feed for livestock and additives for food industry [26,27]. By-products derived from the malting and brewing processes, such as germ/rootlets, spent grains and spent yeast are rich in proteins, digestible fibre material, vitamins and minerals. However, the above-mentioned by-products can also be contaminated with mycotoxins [21,27]. Habschied *et al.* (2011) [28] and Krstanović *et al.* (2015) [21] conducted a research where the highest concentrations of DON and ZEA were found in germ/rootlets fraction.

Brewing and malting by-products can also be used directly (spent grains can be utilized in snacks production or bread) or as supplements in human nutrition [29]. Mussatto *et al.* (2006) [26] proposed the use of brewer's grain flour in manufacture of flakes, whole-wheat bread, biscuits and aperitif snacks. Zechner-Krpan *et al.* (2014) [30] investigated the use of β-glucan from spent yeast in food industry, and the positive biological effects of β-glucan in human body have been previously described [31].

Brewer's spent grains (BSG) are obtained after the filtration of mash and represent a moist brewing by-product that is used as animal feed in form of fresh (wet), ensiled or dehydrated (dried) grain, depending on the type of the animal. Spent grains are often mixed with hot trub, another by-product of brewing process. Hot trub is the result of precipitation of boiled wort after hopping. It is mostly formed of high molecular, insoluble proteins, which coagulate during cooking with hops, and, mixed with spent grains, adds nutritive value to animal food [32]. Implementation of spent yeast into the brewing process is also possible. According to Mussatto *et al.* (2006) [26], BSG extract can be utilized as an antifoaming agent in brewing process. Brányik *et al.*, (2001) [33] described the use of BSG's irregularly shaped particles and their active centers as a mean to immobilize yeast cells and to re-emerge them into the brewing process. There are many possibilities for use of BSG in different biotechnological processes, detailed in a review by Solange & Mussatto (2014) [34].

Spent yeast is a final by-product, taken after the fermentation and filtration of beer. Due to its high moisture content, spent yeast also has to be subjected to additional processes, i.e. drying, in order to inactivate the living yeast cells because ruminants have a complex mixture of micro flora to help breakdown the cellulose into simpler carbohydrates they can use for energy. Small amounts of live yeast can be safe for ruminants, but higher amounts can lead to a gas build up. This can block ruminants' air passage causing suffocation or even death [35]. Brewer's spent yeast (BSY) can be re-used several times (usually four - six generations), and its biomass represents the second major by-product in brewing industries [36]. The re-use of BSY in breweries is a very common practice since it is much faster than propagation.

Conclusion

Today's demands for safe and healthy food is increasing and the number of consumers who are willing to educate themselves on this subject set the bar high for good food on the market. Institutions monitor every aspect of food industry and every day new analytical techniques and methods are being developed in order to determine lower and lower levels of harmful and nutritive compounds that directly or indirectly - via animal products, effect human health in a positive or negative manner. Today's industries are prone to prevent every possibility of economic losses and health safety issues before the raw material acceptance into the malting or brewing factory.

Bibliography

1. Bishop, L. R. (1930). The nitrogen content and quality of barley. *Journal of the Institute of Brewing, 36*(4), 352-369.

2. Bamforth, C.W. & Gambill, S.C. (2007). Fiber and putative prebiotics in beer. *Journal of the American Society of Brewing Chemists, 65*(2), 67-69.

3. Marconi, O., Tomasi, I., Dionisio, L., Perretti, G. & Fantozzi, P. (2014). Effects of malting on molecular weight distribution and content of water-extractable β-glucans in barley. *Food Research Intrnational, 64,* 677-682.

4. Davis, N. (2006). Malt and malt products. In: Bamforth, C. W. Brewing – New technologies. Woodhead Publishing Ltd., Cambridge, UK. (pp. 68-101).

5. Aastrup, S. (1979). The effect of rain on β-glucan content in barley grains. *Carlsberg Research Communication, 44,* 381-393.

6. Narziss, L., Miedaner, H. & Koch, M. (1989). Examination of volatile substances during malting and originating from thermal loading of the products. Part 2. Influence of the malting and mashing parameters. *Monatsschrift fuer Brauwissenschaft, 42*, 232-242.

7. Zhang, G., Chen, J., Wang, J. & Ding, S. (2001). Cultivar and environmental effects on (1→3,1→4)-β-D-glucan and protein content in malting barley. *Journal of Cereal Science, 34*(3), 295-301.

8. Havlová, P., Lancova, K., Váňová, M., Havle, J. & Hajšlová, J. (2006). The effect of fungicidal treatment on selected quality parameters of barley and malt. *Journal Agricultural and Food Chemistry, 54*(4), 1353-1360.

9. Wang, J., Zhang, G., Chen, J. & Wu, F. (2004). The changes of β-glucan content and β-glucanase activity in barley before and after malting and their relationship to malt qualities. *Food Chemistry, 86*(2), 223-228.

10. Vis, R. B. & Lorenz, K. (1998). Malting and brewing with a high β-glucan barley. *Lebensmittel-Wissenschaft und Technolgie, 31*(1), 20-26.

11. Schwarz, P. B., Schwarz, J. G., Zhou, A., Prom, L. K. & Steffenson, B. J. (2001). Effect of *Fusarium* graminearum and *Fusarium* poae infection on barley and malt quality. *Monatsschrift für Brauwissenschaft, 54*(3-4), 55-63.

12. Mastanjević, K., Šarkanj, B., Krska, R., Sulyok, M., Warth, B., Mastanjević, K., Šantek, B. & Krstanović, V. (2018). From malt to wheat beer: A comprehensive multi-toxin screening, transfer assessment and its influence on basic fermentation parameters. *Food Chemistry, 254*, 115-121.

13. Krstanović, V., Klapec, T., Velić, N. & Milaković, Z. (2005). Infection of malt barley and wheat by *Fusarium* graminearum and *Fusarium* culmorum from the crop years 2001–2003 in Eastern Croatia. *Microbiological Research, 160*(4), 353-359.

14. Parikka, P., Hakala, K. & Tiilikkala, K. (2012). Expected shifts in *Fusarium* species' composition on cereal grain in Northern Europe due to climatic change. *Food Additives and Contaminants Part A, 29*(10), 15431555.

15. Sarlin, T., Laitila, A., Pekkarinen, A. & Haikara, A. (2005a). Effects of three *Fusarium* species on the quality of barley and malt. *Journal of the American Society of Brewing Chemists, 63*(2), 43-49.

16. Sarlin, T., Nakari-Setälä, T., Linder, M., Penttilä, M. & Haikara, A. (2005b). Fungal hydrophobins as predictors of the gushing activity of malt. *Journal of the Institute of Brewing, 111*(2), 105-111.

17. Mastanjević, K., Mastanjević, K. & Krstanović, V. (2017). The gushing experience—a quick overview. *Beverages, 3*(2), 25.

18. Berthiller, F., Sulyok, M., Krska, R. & Schuhmacher, R. (2007). Chromatographic methods for the simultaneous determination of mycotoxins and their conjugates in cereals. *International Journal of Food Microbiology, 119*(1-2), 33-37.

19. Varga, E., Wiesenberger, G., Hametner, C., Ward, T. J., Dong, Y., Schöfbeck, D., McCormick, S., Broz, K., Stückler, R., Schuhmacher, R., *et al.* (2015). New tricks of an old enemy: Isolates of *Fusarium* graminearum produce a type A trichothecene mycotoxin. *Environmental Microbiology, 17*(8), 2588-2600.

20. Bullerman, L. B. & Bianchini, A. (2007). Stability of mycotoxins during food processing. *International Journal of Food Microbiology, 119*(1-2), 140-146.

21. Krstanović, V., Mastanjević, K., Velić, N., Pleadin, J., Perši, N. & Španić, V. (2015). The influence of *Fusarium* culmorum contamination level on deoxynivalenol content in wheat, malt and beer. *Romanian Biotechnological Letters, 20*(5), 10901-10910.

22. Varga, E., Malachova, A., Schwartz, H., Krska, R. & Berthiller, F. (2013). Survey of deoxynivalenol and its conjugates deoxynivalenol-3-glucoside and 3-acetyl-deoxynivalenol in 374 beer samples. *Food Additives and Contaminants Part A, 30*(1), 137-146.

23. Benešová, K., Bêláková, S., Mikulíková, R. & Svoboda, Z. (2012). Monitoring of selected aflatoxins in brewing materials and beer by liquid chromatography/mass spectrometry. *Food Control, 25*(2), 626-630.

24. Piacentini, K. C., Dagostim Savi, G., Olivo, G. & Scussel, V. M. (2015). Quality and ccurrence of deoxynivalenol and fumonisins in craft beer. *Food Control, 50*, 925-929.

25. Peters, J., van Dam, R., van Doorn, R., Katerere, D., Berthiller, F., Haasnoot,W. & Nielen, M. W. F. (2017). Mycotoxin profiling of 1000 beer samples with special focus on craft beer. *PLoS ONE, 12*(10), e0185887.

26. Mussatto, S. I., Dragone, G. & Roberto, I. C. (2006). Brewers' spent grain: Generation, characteristics and potential applications. *Journal of Cereal Science, 43*(1), 1-14.

27. Cavaglieri, L. R., Keller, K. M., Pereya, C. M., Gonzalez Pereya, M., Alonso, V. A., Rojo, F. G., Dalcero, A. M. & Rosa, C. A. R. (2009). Fungi and natural incidence of selected mycotoxins in barley rootlets. *Journal of Stored Products Research, 45*(3), 147-150.

28. Habschied, K., Šarkanj, B., Klapec, T. & Krstanović, V. (2011). Distribution of zearalenone in malted barley fractions dependent on *Fusarium* graminearum growing conditions. *Food Chemistry, 129*(2), 329-332.

29. Ktenioudaki, A., Chaurin, V., Reis, S. F. & Gallagher, E. (2012). Brewer's spent grain as a functional ingredient for breadsticks. *International Journal of Food Science & Technology, 47*(8), 1765-1771.

30. Zechner-Krpan, V., Petrović-Tominac, V., Galović, P., Filipović-Grčić, J. & Srečec, S. (2014). Application of different drying methods on β-glucan isolated from spent brewer's yeast using alkaline procedure. *Agriculturae Conspectus Scientificus, 75*(1), 45-50.

31. Petravić-Tominac, V., Zechner-Krpan, V., Grba, S., Srečec, S., Panjkota-Krbavčić, I. & Vidović, L. (2010). Biological effects of yeast β-glucans. *Agriculturae Conspectus Scientificus, 75*(4), 149-158.

32. Thiago, R. dos, S. M., Pedro, P. M. de M. & Eliana, F. C. S. (2014). Solid wastes in brewing process: A review. *Journal of Brewing and Distilling, 5*(1), 1-9.

33. Brányik, T., Vicente, A. A., Machado Cruz, J. M. & Teixeira, J. A. (2001). Spent grains – a new support for brewing yeast immobilisation. *Biotechnology Letters, 23*(13), 1073-1078.

34. Mussatto, S. I. (2014). Brewer's spent grain: a valuable feedstock for industrial applications. *Journal of the Science of Food and Agriculture, 94*(7), 1264-1275.

35. Heuzé V., Sauvant D., Tran G. & Lebas F. (2014). *Brewer's grains*. Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO.

36. Ferreira, I. M. P. L. V. O., Pinho, O., Vieira, E. & Tavarela, J. G. (2010). Brewer's Saccharomyces yeast biomass: characteristics and potential applications. *Trends in Food Science & Technology, 21*(2), 77-84.