TASTE-ACTIVE COMPONENTS OF BEERS FROM EMMER WHEAT (*TRITICUM DICOCCUM*) MALT*

P. Benedetti[1], S. Salvi[1], A. Giomo[1], R. Van Deun[2], E. Boselli[1], N.G. Frega[1]

[1]*Marche Polytechnic University, Department of Agricultural, Food and Environmental Sciences, Ancona, Italy*
[2]*Thomas More University College, Faculty of Technology and Design, Geel, Belgium*

Emmer wheat (EW, *Triticum dicoccum*) grows under adverse climatic and soil conditions in the hilly areas of Italy and other temperate regions. So far, EW has been used for pasta or bakery products. The malt obtained from EW was used to produce a light beer, a double malt beer, and beers with 50% (B50) and 30% (B30) EW malt combined with barley malt. These top-fermented beers showed a sweet, fruity, citrus character. The different sensory impact and chemical composition (betaglucans and flavanoids) of the beers was related to the germinative energy of EW and the different proportions of malted EW and barley malt. The light beer combines the moderate alcohol (3% vol.) with a good intake of natural antioxidants (total phenolic content, TPC, 85 mg l^{-1}), whereas B50 showed a high TPC (109 mg l^{-1}) and the highest beta-glucan content (27 mg l^{-1}).

Artisanal beer; light beer; sensory analysis; beta-glucans; polyphenols; diastatic energy

DE GRUYTER OPEN

doi: 10.1515/sab-2016-0012
Received for publication on January 11, 2016
Accepted for publication on March 1, 2016

INTRODUCTION

Minor (but robust) cereals such as emmer wheat (EW, *Triticum dicoccum*) can be a good alternative for the economic development of many rural areas of the temperate regions of Europe and the world. EW has a low content of gluten with respect to common wheat; however, its yields were higher than those of barley, oats, and wheat in years that were characterized by less than favourable growing seasons (Stallknecht et al., 1996). EW can be easily cultivated with organic methods and shows rusticity characters, such as adaptation to poor land, resistance to cold climates, drought and diseases, which are the conditions found in many temperate areas of the world (such as the Apennines in Italy) (Pelillo et al., 2010). The aspects lined up above have suggested extending the use of EW also to the beer production (Marconi et al., 2013). However, a wide scientific literature on the use of EW for beer production is missing, unlike for bread or other food products. In Italy, the actual trend of craft breweries is still positive (increasing in the period 2012–2014), meaning that the consumer's interest towards non-mainstream products is still alive, despite of the international crisis that heavily affected consumption and trades of beverages (Assobirra, 2014).

The aim of this work is to contribute to filling the gap of scientific and technological knowledge for an innovative application in the beer industry. The chemical and sensory quality of four different beer styles obtained with EW malt and the evolution of the chemical components during the brewing process are described as well as the critical points of the process. The artisanal top-fermented beers were produced at a small industrial scale (a craft brewery) with EW malted in a small-scale local malt house. The beers were brewed using 100% (two types), 50%, and 30% of organic malted EW. The remaining part was malt obtained from barley organically grown in the region of Marche (Italy).

MATERIAL AND METHODS

Four different types of beer were obtained from EW (*Triticum dicoccum* L.) malt on a small scale, as reported in Fig. 1. These were: a light beer (Lt) from 100% hulled EW malt; a double malt (DM) beer

---

*Supported by Regione Marche L.R. 37/99 – D.G.R. 1234/05 Beer from Emmer wheat.

Table 1. Ingredients of the beer types made from EW malt

Beer type	EW malt	EW malt (kg hl^{-1})	Barley malt (kg hl^{-1})	Hop pellets (*Hallertau Perle*) (g l^{-1})	Hop pellets (*Hallertau Hersbrucker)* (g l^{-1})
Light	100% H	23	0	0.46	0.53
Double malt	blend (70% D + 30% H)	33	0	0.63	0.63
Blend with 30% EW malt	100% D	9.9	23.1	0.63	0.63
Blend with 50% EW malt	100% D	16.5	16.5	0.63	0.63

EW = emmer wheat, D = dehulled grains, H = hulled grains

obtained from a blend of 70% dehulled EW malt and 30% hulled EW malt; a blend beer (B30) obtained from a blend with 30% EW malt (100% dehulled), and a beer (B50) obtained from a blend with 50% EW malt (100% dehulled). EW was grown in the region of Marche (Italy) according to the EU official rules for organic farming (E C, 2007). Organic two-row summer barley (*Hordeum vulgare* L.) grown in the Marche region was used for the production of the B30 and B50 beers according to the scheme reported in Fig. 1.

Other raw materials common to all the beer types were decarbonated tap water and hops. The hop pellets were Hallertau Hersbrucker and Hallertau Perle (Mr. Malt, Udine, Italy) with a declared content of 2.7 and 7.2% alpha-acids, respectively. The fermentation with *Saccharomyces cerevisiae* was conducted by using selected dry ale yeast (Fermentis Safale S. 04; Lesaffre, Marcq-en-Barœul, France).

EW malt

Malting of organic EW was performed in a small malting house (COBI, Ancona, Italy) by using a vertical malting tank (Sfoggiatech, Montebelluna, Italy) designed to process up to 2000 kg of dry grains and equipped with a stirrer, a perforated false bottom and an automated hygrothermal and air conditioning system.

Aliquots of 35 kg EW (hulled or dehulled, as described in Table 1) were singularly packed in closed sewn synthetic perforated bags. The synthetic fabric allowed for the free access of air and water used for wetting. The EW bags were added to 2000 kg of barley into the malting tank. The malting process was conducted simultaneously, however the physical separation of the two cereals was ensured.

The induction of germination of caryopses lasted 24 h. During this time, periods of steeping were alternated to periods of rest. The kernels were immersed in water for 210 min and then left to dry for 16 h, and once more immersed for 4 h (Fig. 1). The germination (vegetative period) in the malt house lasted for 5 days, during which the cereal was subjected to a temperature gradient from 18 to 12°C. The kilning was conducted with a temperature program from 45 to 84 °C for 20 h. After cooling, the malted EW bags were removed from the batch. Conditioning of the EW malt lasted for other 20 days at room temperature.

Beer production

The beers were produced in a local microbrewery (Il Boccale d'Oro, Cingoli, Italy) equipped with 300-litre tanks. After dry-grinding into a roller mill, the malted cereals (EW malt or barley malt) were used to prepare the mash as reported in Table 1 for each type of beer.

An amount of 300 l of each type of beer was obtained, with the exception of the light (Lt) beer (150 l). The initial infusion was conducted at 40°C. The temperature of the mash was raised from 40 to 52°C with a rate of 0.4°C/min and then held at 52°C for 10 min (protein rest). Successively, the mash was heated from 52 to 62°C at 1°C/min. The final temperature was held for 10 min (beta-amylase rest). Afterwards, the temperature was raised from 62 to 72°C and the mash was held at 72°C for 10 min (alpha-amylase rest). The temperature was then raised from 72 to 78°C at the rate of 1°C/min. This final temperature was held for 10 min.

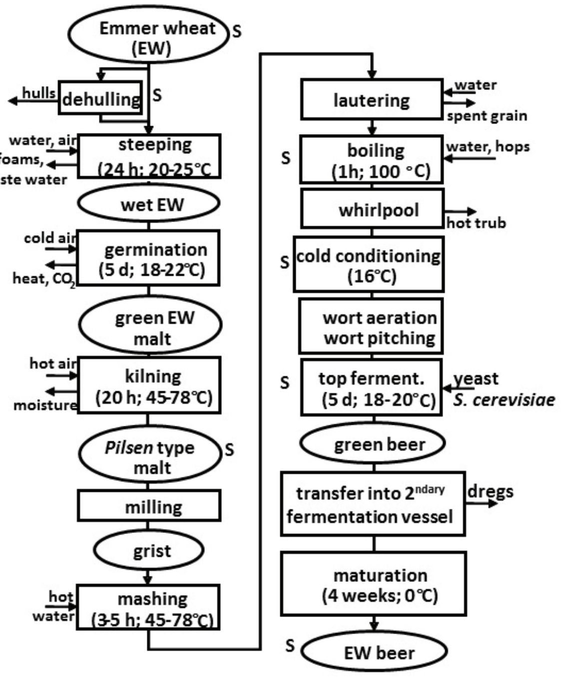

Figure 1. Flow chart of the emer wheat (EW) beer production
S = sample collection

Table 2. Quality parameters of EW grains, EW malt, and barley malt

	EW grains		Malted EW		Barley
	H	D	H	D	
Moisture (%)	8 ± 2.6	10.7 ± 0.9	8 ± 2.6	9.2 ± 1.1	10
Protein (DM base) (Nx5.7) %	12.7 ± 1.7	16.0 ± 0.3[a]	11.7 ± 2.1	14.4 ± 0.6[b]	8.3
Germinative energy (% at 5 days)	93 ± 1.0[a]	86 ± 1.0[b]			
Husks (w/w %)	22.3 ± 0.6				
Diastatic Power (°WK)	n/a	n/a	277 ± 153	83 ± 27[a]	322 ± 0[b]

DM = dry matter, H = hulled, D = dehulled, EW = Emmer wheat, WK = Windisch–Kolbach units.

[a,b]values in the same row followed by different letters in apex are statistically different ($P < 0.05$); number of repetitions: 3

After mashing, the wort was cooled down and the spent grains were separated by filtration and then washed with hot water. The total lautering time was 3 h. After lautering, the wort was transferred into a stainless steel tank (kettle) and was boiled for 60 min. A half of the amount of hop pellets was added before boiling and the remaining dose was added at the end of boiling according to the dosage reported in Table 1. After boiling, the wort was cooled down and subjected to the procedure reported in Fig. 1. The active dry yeast (1 g l^{-1}) was rehydrated and inoculated in the wort for the top fermentation. The green beer was transferred into the maturation tanks and kept at a constant temperature of 0°C.

Sampling and chemical characterization

The samples were collected throughout the process as shown in Fig. 1. All the analytical determinations were performed according to the European Brewery Convention (EBC, 2008). The moisture content, germinative energy, and total nitrogen were determined on EW. The moisture content, diastatic power, and the total nitrogen were determined on the EW malt and barley malt. The samples of wort were collected immediately after boiling (boil) and before the inoculation with the yeast (cold conditioning, CC) in order to determine the colour, bitterness, free amino nitrogen, total polyphenols, flavanoids, total carbohydrates, beta-glucans, and pH. The beer was sampled on the first (1F), third (3F), and on the fifth day of fermentation (5F), two weeks after the end of fermentation (EF), at the end of a 4-week maturation (M). The beer was analyzed for the alcohol content, colour, bitterness, free amino nitrogen, flavonoids, total carbohydrates, beta-glucans, and pH.

Sensory analysis

The beer samples at the end of a 4-week maturation (M) were evaluated by a trained panel of 10 judges selected among the students of the Food Science programme at the sensory analysis laboratory of the University. Beer was cooled down to 12°C and served (Rudnitskaya et al., 2009). ISO type tasting glasses (height 155 mm, glass diameter 65mm, capacity, 215 ml) from Bormioli (Parma, Italy) were filled with 50 ml beer. The main olfactory, gustatory, and tactile (astringency) descriptors of the beers were identified during the first session with the procedure of the round table: fruity (Fr), malty (M), honey (H), yeasty (Y), sweet (S), acidity (Ac), bitter taste (B), astringent taste (As), foam (Fm). Each sample was evaluated by using a scale of ten points (0 = no perception, 10 = highest intensity). In addition to the chosen descriptors, the panelists could indicate two additional descriptors in their scoreboards and evaluated the overall harmonic character of the beers in a range of 1 to 3 (1 = bad balance, 3 = good balance).

A consumer panel of 30 untrained assessors was recruited during a public meeting organized to disseminate the results of the project. They were asked to evaluate the overall taste of the beers in a range of 1 to 3 (1 = bad balance, 3 = good balance).

Statistical analysis

The data were processed using the GraphPad Instat statistical software,Version 3.05 (2003, San Diego, USA). Comparisons of the different samples were made by using one-way ANOVA, and the results were further analyzed using the Tukey's test. The unpaired *t* test was used at $P < 0.05$ to determine a statistically significant difference between the samples.

RESULTS

EW and EW malt

The quality parameters of EW (hulled and dehulled) are reported in Table 2 and were compared in order to assess the potential use in brewing. EW can be considered suitable for malt production since it shows a germinative energy and protein content similar to barley as confirmed by previous literature (Mayer, 2011). The process of grain dehulling has only slightly

Table 3. Chemical parameters of the beers from malted EW

Parameters	EW malt light beer	EW double malt beer	Blend 30% EW malt beer	Blend 50% EW malt beer
Alcohol content (% vol/vol)	3.1 ± 0.5^{a}	6.0 ± 0.5^{b}	5.5 ± 0.02^{b}	6.9 ± 0.1^{c}
pH	4.0 ± 0.2^{a}	5.0 ± 0.2^{c}	4.8 ± 0.08^{c}	4.4 ± 0.01$^{a.b.c}$
Acidity (ml NaOH per 100 ml)	30.4 ± 0.5^{c}	33.8 ± 0.5^{d}	25.6 ± 1.7^{b}	30.2 ± 1.5^{c}
Colour (EBC unit)	8.2 ± 0.5^{a}	18.5 ± 0.01^{b}	15.7 ± 0.01^{c}	11.5 ± 0.02^{d}
Turbidity	267 ± 0.5^{a}	609 ± 5.5^{b}	80.4 ± 4.7^{c}	92.4 ± 0.1^{d}
Bitterness (BU)	6.7 ± 0.5^{a}	8.1 ± 0.5^{b}	13.5 ± 0.33^{c}	5.5 ± 0.01^{d}
Flavonoids (mg l^{-1} (+)-catechin eq.)	10.4 ± 0.5^{a}	45.1 ± 0.3^{b}	39.7 ± 3.5^{c}	56.5 ± 0.9^{d}
Total phenolic content (mg gallic acid per l) FAN (mg l^{-1})	85 ± 15^{a} 20.1 ± 0.5$^{a.b}$	68 ± 16^{b} 166 ± 30.5^{c}	196 ± 6.6^{c} 33.7 ± 10.1^{b}	141 ± 0.2^{d} 4.5 ± 0.1^{a}
Carbohydrates (g 100 ml^{-1})	2.2 ± 0.5^{a}	2.3 ± 0.5^{a}	4.5 ± 0.19^{a}	4.1 ± 0.01^{a}
Beta-glucans (mg l^{-1})	2.7 ± 0^{b}	9.8 ± 0^{b}	6.1 ± 1.7^{b}	26.8 ± 5.7^{a}

EW = emmer wheat, BU = bitterness units, FAN = free amino nitrogen

data are expressed as mean (three replicates) ± SD

$^{a-d}$values in the same row followed by different letters are statistically different ($P < 0.05$); number of repetitions: 3

decreased the germination energy (from 93 to 86%), meaning that the embryo was not damaged by the mechanical process. The germination energy did not increase when the husks were removed although the husks can contain germination inhibitors. The good germination energy shown by the samples of EW was crucial for a successful malting process and to obtain an enzymatic profile suitable for an efficient saccharification.

In hulled grains, husks represented about 22–23% (Table 2) of the total weight of the caryopsis. Therefore, when processing the hulled grains of EW, the amount of grains should be increased by about 20–25% in order to get a mash with a specific gravity (extract) similar to the dehulled EW. As reported in Table 2, dehulled EW showed a low diastatic power. For this reason, the EW malt (both hulled and dehulled) was combined with barley malt in the formulation of blend beers.

Beers from EW malt

In Table 3, the comparison between the chemical-analytical parameters of beers obtained by using different percentages of EW malt is reported. The data regarding the chemical parameters of the light EW beer (Lt) and the double EW malt beer (DM), and their development during processing are analytically discussed below. The ingredient composition of the beers is reported in Table 1.

Light EW beer (Lt)

The Italian legislation (GURI, 1962) prescribes an alcoholic content ranging 1.2–3.5% vol. and a Plato degree (°P) ranging 5–10.5 g per 100 g for the Lt beer style. The Lt obtained from 100% malted EW (Table 1) had an alcoholic content of 3% vol. and a Plato degree of 6.3°P.

The observed levels of flavonoids and total phenols in EW beer were comparable to those generally found in high quality white wines (Boselli, 2006). However, the alcohol content of the light beer was about 1/4 compared to that of wine. Therefore, this beer style can be interesting in the daily diet as a key source of antioxidants combined with a low alcohol intake.

The bitterness (BU) was slightly lower in Lt than DM; thus, the bitterness felt by the sensory panel was significantly lower in Lt compared to DM (Fig. 2). According to this result, the amount of hops was in-

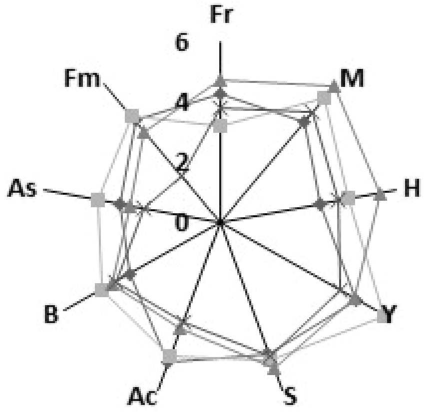

Figure 2. Radar plot of the sensory attributes of emmer wheat beers

Lt = light emmer wheat beer, DM = double malt emmer wheat beer, B30 = blend with 30% emmer wheat malt, B50 = blend with 50% emmer wheat malt, Fr = fruity, M = malt, H = honey, Y = yeast, S = sweet, Ac = acidity, B = bitterness, As = astringency, Fm = foam

—◆— Lt, —■— DM, —▲— B30, —✕— B50

creased up to the conventional dose for the production of the other types of beers (Table 1).

Despite of the low alcohol content, the Lt beer was appreciated by the consumer panel during a public meeting because it was characterized by a high fruity flavour, a low bitter taste, and a pronounced acidity (Fig. 2). Although the colour showed a low value, its perception was enhanced by a characteristic significantly higher turbidity than B30 and B50, presumably due to the high colloid content (total phenols) (Table 3). The beta-glucans have prebiotic properties (Vis, Lorenz, 1997; Izydorczyk, Dexter, 2008) and can contribute to the viscosity of this beverage and to the perception of the 'body' of the beer. The high total acidity of Lt was accompanied by a citrus note, according to the additional notes given by the sensory panel. Lt beer has the advantage of being suitable for a responsible consumption according to the guidelines on a moderate alcohol assumption (ICAP, 2005) combined with a high intake of natural antioxidants (total phenols).

Evolution of chemical variables of Lt beer during the production process

Total phenols (Fig. 3) and flavonoids (Fig. 4) followed a wave trend during beer processing. The EW malt was richer in proteins than barley malt (Table 2); thus, the protein complexation with polyphenols during the boiling of the wort presumably led to a moderate astringent taste of the finished Lt (Fig. 2). As a result, a sweet, fruity character was the peculiar sensory attribute of the EW beers. All the beers were not very bitter, but the difference between Lt and DM was statistically significant ($P < 0.05$) (Table 3). The panel noticed this difference, probably because DM beer contained more hops and thus more isohumulones.

The catechins and proanthocyanidins derived from the cereals used for beer production are the main source of total phenols. The total phenols decreased during the first steps of brewing and then slightly increased after the fermentation ended. This trend can be due to the formation of a tannin–protein complex in the first steps of brewing followed by the hydrolysis or depolymerization of complex polyphenols leading to the release of low molecular weight phenols during beer maturation.

The carbohydrates present in higher concentration were fermentable sugars. Thus, there was a sharp decrease of total carbohydrates at the beginning of alcoholic fermentation (Fig. 5).

Beta-glucans showed a fluctuating trend. After cooling the mash, beta-glucans decreased due to precipitation; however the early steps of the fermentation process led to their increase; they were produced by the yeast biomass. Successively, beta-glucans decreased for their low solubility in ethanol. The cooling process after the primary fermentation accelerated this decline (Fig. 6).

The low pH of Lt beer led to a high perceived acidity of the product during tasting. The total acidity (Table 3) confirmed acidification occurring during the

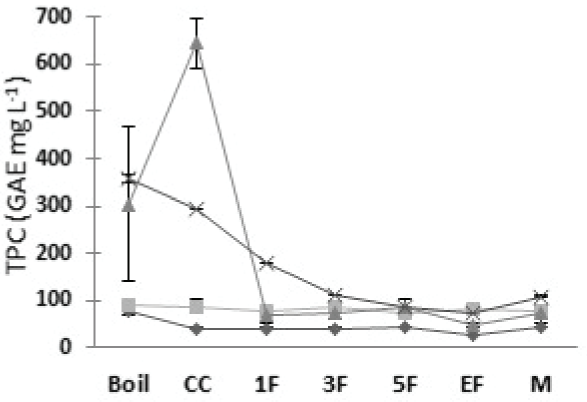

Fig. 3. Evolution of polyphenols (total phenolic content) during the brewing process of Lt, DM, B30, and B50. Data shown as mean (three replicates) ± SD

Lt = light emmer wheat beer, DM = double malt emmer wheat beer, B30 = blend with 30% emmer wheat malt, B50 = blend with 50% emmer wheat malt, boil = after boiling, CC = after cold conditioning, 1F, 3F, 5F = days of fermentation, EF = two weeks after the end of fermentation, M = after maturation (four weeks after the end of fermentation)

—◆— Lt, —■— DM, —▲— B30, —✕— B50

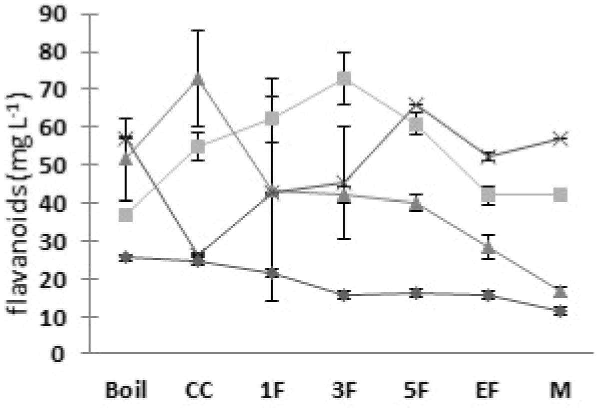

Fig. 4. Evolution of flavonoids during the brewing process of Lt, DM, B30, and B50. Data shown as mean (three replicates) ± SD

Lt = light emmer wheat beer, DM = double malt emmer wheat beer, B30 = blend with 30% emmer wheat malt, B50 = blend with 50% emmer wheat malt, boil = after boiling, CC = after cold conditioning, 1F, 3F, 5F = days of fermentation, EF = two weeks after the end of fermentation, M = after maturation (four weeks after the end of fermentation)

—◆— Lt, —■— DM, —▲— B30, —✕— B50

production process. The acidity characterized the EW beer, giving it a pronounced freshness that resulted in the perception of citrus highlighted during the tasting. Acidification is therefore a critical point in the production of beer from EW malt and is presumably related to the extent of alcoholic fermentation and the development of undesired fermentations.

From the technological point of view the grinding of the EW malt was a critical point too, because the presence of the husks made it difficult to grind it properly. However, the husks facilitated the draining during lautering. In order to maximize the positive aspects related to the presence of the husks, and at the same time minimizing the disadvantages, it was decided to use only a portion of hulled grains in the subsequent production experiments.

Furthermore, in order to achieve a greater control of the temperature inside the tanks during the production process, higher amounts of grains were processed to fill the 300-l tanks in the craft brewery.

Double EW malt beer (DM)

The DM beer was obtained from 100% EW malt and reached an alcohol content of 6.0% vol and an original wort extract of 15.9°P. An aliquot of 100 kg of EW malt was mixed with 300 l of water to obtain the mash. The main part of the malt (70%) came from EW, which was dehulled before malting, while the remaining part was hulled. The germinative energy of the dehulled EW grains was comparable to that of the whole caryopsis (including its hulls) (Table 2). The high percentage of dehulled grains was chosen in order to obtain a more concentrated extract still keeping a good draining efficiency in the lauter tun. In fact, the presence of the husks created a filtering bed and speeded up the drainage during the filtration.

The fermentation and maturation conditions were the same as described for the other types of beer.

The DM showed a high flavonoid content (45 mg l^{-1} (+)-catechin equivalents) and a moderate beta-glucan content (10 mg l^{-1}at the end of maturation) (Table 3).

The beer had a deep amber colour characterized by high turbidity which is typical of unfiltered beers. The trained panel found a strong attribute of yeast, honey, and malt together with notes of citrus in the DM beers. The DM was also felt as slightly bitter, especially in comparison with the Lt beer ($P = 0.03$) and sour, perhaps due to the high flavonoid and total phenolic content (Figs. 3, 4). The sensation of malt, yeast, bitter, and astringent taste was perceived higher than Lt by the panel (Fig. 2), although the data did not show significant differences (data unpublished), apart from the malt and bitter descriptors (both for $P = 0.03$). This can be attributed to the higher extract and to the increased amount of hops added during boiling (BU were 8.1 and 6.7 for DM and Lt, respectively). Therefore, the perception of fresh fruits and citrus was lower in the DM beers than in the Lt beer. The DM beer received a very good score by consumers who tasted the beers during an informative meeting (2.4 in a 1–3 scale).

Evolution of chemical variables of DM beer during the production process

The total phenolic content (TPC) and flavonoids showed a fluctuating trend ($P > 0.05$) all through the

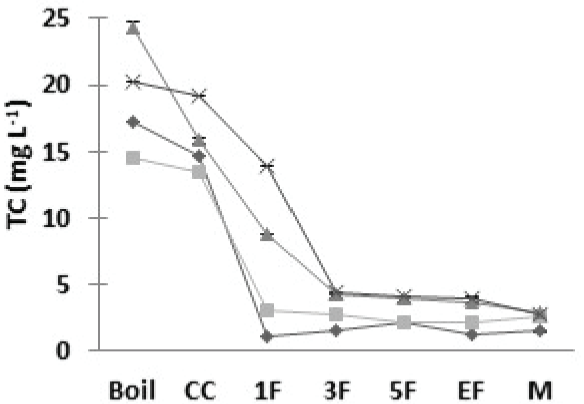

Fig. 5. Evolution of total carbohydrates (TC) during the brewing process of Lt and DM. Data shown as mean (three replicates) ± SD

Lt = light emmer wheat beer, DM = double malt emmer wheat beer, boil = after boiling, CC = after cold conditioning, 1F, 3F, 5F = days of fermentation, EF = two weeks after the end of fermentation, M = after maturation (four weeks after the end of fermentation)
—◆— Lt, —■— DM, —▲— B30, —✕— B50

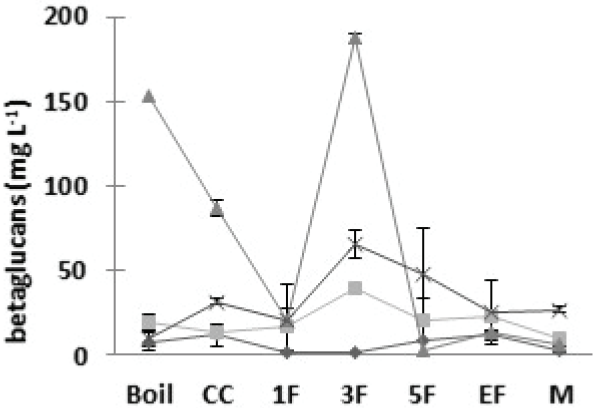

Fig. 6. Evolution of beta-glucans during the brewing process of Lt and DM. Data shown as mean (three replicates) ± SD

Lt = light emmer wheat beer, DM = double malt emmer wheat beer, boil = after boiling, CC = after cold conditioning, 1F, 3F, 5F = days of fermentation, EF = two weeks after the end of fermentation, M = after maturation (four weeks after the end of fermentation)
—◆— Lt, —■— DM, —▲— B30, —✕— B50

process (Figs. 3, 4). The TPC tended to increase during the primary fermentation and finally decreased at the 5th day of fermentation. After a short increase, the TPC fluctuated during the storage.

Total carbohydrates followed the same trend as for Lt (Fig. 5). The difference in the beta-glucan content between Lt and DM decreased at the end of storage (Fig. 6).

Blend beers obtained with EW malt

Alternative types of beer based on the blend of EW malt and barley malt in various proportions were formulated after collecting the results from the previous beer styles.

Two special beers were produced, both from dehulled EW malt (30% and 50%) mixed with malted organic barley grown in the Marche region (Table 1).

The alcohol content in blend beers was 5.5% and 6.9% by volume, respectively for blend of 30% and 50% of EW malt, while the Plato degree was 12.7°P and 14.4°P, respectively.

At the time of commercial maturity, both beers contained higher concentrations of total phenolic compounds (196 and 141 mg l^{-1} for beer B30 and B50) with respect to the other beers (Table 3). Flavanoids were 40 and 57 mg l^{-1} for beer B30 and B50, respectively, which was not too far from DM (45 mg l^{-1}).

The B50 showed the highest content of beta-glucans (27 mg l^{-1}) among all the beers.

The sensory analysis carried out on blend beers showed a general appreciation, as these kinds of beers had a strong body and flavour, in addition to a particularly pleasing flavour profile of honey, malt, and yeast (Fig. 2).

The B30 was evaluated less astringent and acidic but more fruity and with a strong honey flavour, compared to the other types of EW beer (Fig. 2). However, the difference was not statistically significant. Thus, the presence of EW malt was balanced by the presence of barley malt resulting in an equilibrated sensory profile (Liu et al., 2012).

The B50 was cloudy, amber, and did not develop a persistent foam. B50 was considered balanced in taste, especially for sour and bitter sensations. In general, blend beers were evaluated very balanced, with a persistent taste and fresh fruit aroma. B30 showed a less persistent foam than B50 even if this difference was not statistically different. This result was presumably related to the lower content of EW malt, which was richer in proteins than barley malt.

The malt perception in B30 was similar to DM beers. Yeast perception in B30 was comparable with that in Lt and (not statistically) lower than in DM. The intensity of sweet taste was similar in all beers.

The B50 was characterized by a lower perception of malt, yeast, astringency, and acidity, but with a sweet taste similar to the other beers ($P > 0.05$). The fruity taste was similar to B30 and Lt ($P > 0.05$). In B50, the perception of honey was slightly lower than in B30 but slightly higher than in the other two beers, while the bitter taste was comparable to DM. The only significant difference in B50 was the ‘foam’ descriptor, which was lower in B50 compared to DM and Lt ($P < 0.05$). As mentioned above, the foam of B50 was not very consistent and tended to disappear very quickly.

DISCUSSION

Previous scientific literature regarding Emmer wheat malting and brewing is mostly related to the archaeological and historical aspects (Sicard, Legras, 2011), not to the technological approach. In fact, Emmer was slowly displaced by the naked wheats, primarily the tetraploid species over the centuries (Stallknecht et al., 1996).

So far, the natural outcome of EW revaluation has been the milling industry. Bread, pasta, biscuits, snacks, both sweet and savory, and soups made from EW are quite popular in Italy (Mayer et al., 2011). Moreover, in recent years, EW has been in considerable expansion in Italy, especially in inland and hilly areas, with good results in economic terms. The production of beers from EW malt was popular only in ancient times (Samuel, 1996) and now it has recently become a promising and innovative alternative use of EW.

Recent experiments on the brewing suitability of EW malt were only conducted by Marconi et al. (2013) on a laboratory scale (max 20 l). They produced different batches of top fermented beer by using different ratios of hulled/dehulled EW malt and did not take in consideration the possibility of producing DM or light beers with EW malt on a microbrewery scale. In the present work, we established that the production of EW beers on an artisanal scale represents a good source of natural antioxidants (68–196 mg l^{-1} of total phenolic content). A significant content of flavonoids (up to 56 mg l^{-1}) can be expected in these types of beers (not determined by Mayer et al., 2011; Marconi et al., 2013). Therefore, EW beer can fulfill the expectations of consumers who pay an increasing attention to the dietary aspects, and to organic and local food products with a high sensory impact.

CONCLUSION

The EW beer is simultaneously an innovative product of good nutritional quality, and can be highly identified with the territory of origin. The ‘harmony’character of beer reflects the overall taste of the beer and is related to a balanced taste of sour, sweet, bitter, acerbity, and other tastes (Liu et al., 2012). This experimentation showed that it is possible for a microbrewery to obtain a good quality light beer by using 100% EW malt in the mash. It is also possible to obtain blend beers with different sensory impact according to the different proportions of malted EW and malted barley on a small artisanal scale, as it resulted by the characterization of all the four types of beers, not present in previous literature (Marconi et al., 2013).

However, a careful characterization of the malting attitude of EW is crucial in order to achieve the objectives of quality and to ensure the best technological performance. In fact, in the case of EW malt with a low diastatic energy, it is possible to achieve good results by applying the most appropriate ingredient formulation (e.g. mixing EW malt with barley malt showing a high diastatic power). Also monitoring the entire processing line through the analysis of the intermediates is a key point to ensure an efficient production.

ACKNOWLEDGEMENT

Monterosso (S. Lorenzo in Campo, Italy) and Prometeo (Urbino, Italy) are kindly acknowledged for supplying the emmer wheat.

REFERENCES

Assobirra (2014): Annual Report for the year 2014. http://www.assobirra.it/press/wp-content/annualreport2014data.pdf.

Boselli E, Minardi M, Giomo A, Frega NG (2006): Phenolic composition and quality of white d.o.c. wines from Marche (Italy). Analytica Chimica Acta, 563, 93–100. doi: 10.1016/j.aca.2005.10.024.

EBC (2008): European brewery convention. Analytica EBC, Fachverlag Hans Carl, Nürnberg, Ed. December 2008.

EC (2007): Council Regulation (EC) No. 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. Official Journal of the European Union L 189, 1-23. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF.

GURI (1962): Gazzetta Ufficiale No. 234 of 17th September 1962 containing the Law No. 1354 of 16th August 1962 – Hygienic discipline of the production and commerce of beer, amended by the Laws No. 329/74 and 141/89, D.L. 109/92 and DPR 272/98.

ICAP (2005): International Center for Alcohol Policies (ICAP). International Drinking Guidelines. http://www.icap.org/PolicyIssues/DrinkingGuidelines.

Izydorczyk MS, Dexter JE (2008): Barley beta-glucans and arabinoxylans: molecular structure, physicochemical properties, and uses in food products – a review. Food Research International, 41, 850–868. doi:10.1016/j.foodres.2008.04.001.

Liu C, Dong J, Wang J, Yin X, Li Q (2012): A comprehensive sensory evaluation of beers from the Chinese market. Journal of the Institute of Brewing, 118, 325–333. doi: 10.1002/jib.43.

Marconi O, Meyer H, Chiacchieroni F, Ricci E, Perretti G, Fantozzi P (2013): The influence of glumes on malting and brewing of hulled wheats. Journal of the American Society of Brewing Chemists, 71, 41–48. doi: 0.1094/ASBCJ-2013-0124-01.

Mayer H, Marconi O, Perretti G, Sensidoni M, Fantozzi P (2011): Investigation of the suitability of hulled wheats for malting and brewing. Journal of the American Society of Brewing Chemists, 69, 116–120. doi: 10.1094/ASBCJ-2011-0418-01.

Pelillo M, Ferioli F, Iafelice G, Marconi E, Caboni MF (2010): Characterisation of the phospholipid fraction of hulled and naked tetraploid and hexaploid wheats. Journal of Cereal Science, 51, 120–126. doi: 10.1016/j.jcs.2009.11.002.

Rudnitskaya A, Polshin E, Kirsanov D, Lammertyn J, Nicolai B, Saison D, Delvaux FR, Delvaux F, Legin A (2009): Instrumental measurement of beer taste attributes using an electronic tongue. Analytica Chimica Acta, 646, 111–118. doi: 10.1016/j.aca.2009.05.008.

Samuel D (1996): Investigation of ancient Egyptian baking and brewing methods by correlative microscopy. Science, 273, 488–490. doi: 10.1126/science.273.5274.488.

Sicard D, Legras JL (2011): Bread, beer and wine: yeast domestication in the Saccharomyces sensu stricto complex. Comptes Rendus Biologies, 334, 229–236. doi: 10.1016/j.crvi.2010.12.016.

Stallknecht GF, Gilbertson KM, Ranney JE (1996): Alternative wheat cereals as food grains: einkorn, emmer, spelt, kamut, and triticale. In: Janick J (ed.): Progress in new crops. ASHS Press, Alexandria, 156–170.

Vis RB, Lorenz K (1997): Beta-glucans: importance in brewing and methods of analysis – review article. Lebensmittel Wissenschaft und Technologie, 30, 331–336. doi: 10.1006/fstl.1996.0196.

Corresponding Author:

Prof. Emanuele Boselli, Marche Polytechnic University, Department of Agricultural, Food and Environmental Sciences, via Brecce Bianche 10, 60131 Ancona, Italy, phone: +390712204923, e-mail: e.boselli@univpm.it