to dimethyl sulfoxide (DMSO). When hold time or vigor of wort boiling is inadequate to convert residual SMM, DMS may continue to form as the wort cools – with subsequent transfer into the beer.

Technological methods for reducing the level of DMS in beer have been developed. Thus, AU 38578/93 described a method of reducing DMS levels in malt, comprising steam treatment of said malt. In patent application US 2006/0057684 to Bisgaard-Frantzen, H. et al. was described brewing methods comprising heat treatment of mash at temperatures of 70°C and above. And in U.S. Patent No. 5,242,694 to Reuther, H. was described methods for preparing low carbohydrate beer, wherein the methods comprise extensive boiling of wort followed by carbon dioxide washing of said wort. However, all of the aforementioned treatments consume high levels of energy, and further they may alter the characteristics of malt or wort.

SUMMARY OF THE INVENTION

In one aspect, there is provided a beverage prepared from a barley plant, or a part thereof, wherein said beverages contains a level of dimethyl sulfide (DMS) below 20 ppb and a level of S-methyl-l-methionine (SMM) of less than 20 ppb, and wherein said barley plant, or part thereof, carries a mutation in the gene encoding methionine S-methyltransferase (MMT), causing a total loss of functional MMT.

Disclosed are~~The present invention discloses~~ beverages prepared from barley, or parts thereof, in particular beer with improved flavor. The beverages disclosed herein exhibit very low levels of DMS, or even no DMS at all – particulaly beverages with DMS levels below taste threshold, and thus characterized by the absence of DMS taste.

Moreover, the beverages of the present disclosure~~invention~~ have superior taste properties. Accordingly, the beverages of the present disclosure~~invention~~ are characterized as particularly balanced and drinkable, with a high degree of freshness, aromatic and floral flavor.

Thus, the present disclosure~~invention~~ provides beverages with remarkable flavor properties based on the absence of DMS or low DMS levels. It is herein found that DMS strikingly influences the human perception of estery compounds in beer (cf. FIG. 1B), consistent with a model provided by the inventors in which DMS masks the taste of said compounds.

It is considered of profound importance that the present disclosure~~invention~~ provides barley or malt kernels with defects that specifically block formation of the DMS precursor. In this way, the above-described masking of estery taste by DMS may be avoided, which enables new opportunities in the industrial utilization of barley and malt. In addition,

barley or malt kernels with defects that specifically block formation of the DMS precursor also have taste properties caused by the absence of DMS per se. Notably, said barley or malt type might be exploited as a raw material in effective industrial applications to help establish tailored production settings far beyond contemporary capabilities. In particular, improvements relate to issues of beer quality and environmental sustainability in beer production, specifically for:

(i) Beer having a low level of DMS-specific taste;
(ii) Beer having an improved estery taste profile;
(iii) Reduced energy input for beer production; and
(iv) Reduced energy consumption in wort production.

Barley plants and kernels fulfilling said improvements are provided by the instant disclosure~~invention~~.

So, without being bound by theoretical considerations on how the metabolism of SMM could be interwined with other biological processes, the instant application offers not-yet provided opportunities to exploit and explore the breeding and industrial use of barley plants defective in SMM synthesis.

The present disclosure~~invention~~ disclosed that beverages characterized by low levels of DMS-specific taste and an improved estery taste profile, and/or beverages that are particularly balanced and drinkable – i.e. with high degrees of freshness, aromatic, and floral flavor – may be prepared from barley plants, or parts thereof, carrying a mutation in the gene encoding MMT, which causes a total loss of MMT activity. Such plants are herein denoted "null-MMT" barley.

Thus, the present disclosure~~invention~~ relates ~~in one aspect~~ to beverages prepared from a barley plant, or a part thereof, wherein said beverage contains a level of DMS below 30 bbp (such as less than 30 ppb DMS), and wherein said barley plant carries a mutation in the gene encoding MMT, causing a total loss of MMT activity.

In another aspect, the present disclosure~~invention~~ offers barley plants useful for preparing said beverages. Accordingly, also disclosed is~~it is also an object of the invention to provide~~ a barley plant, or

part thereof, wherein the barley plant carries a mutation in the gene encoding MMT that causes a total loss of functional MMT enzyme.

In another aspect, there is provided a barley plant, or part thereof, wherein the barley plant carries a mutation in the gene encoding methionine-S-methyltransferase (MMT) that causes a total loss of MMT function.

In yet another aspect, there is provided a barley plant or part thereof, wherein the barley plant carries: (i) a mutation in the gene encoding MMT, causing total loss of MMT activity; and (ii) a mutation in the gene encoding lipoxygenase 1, causing a total loss of lipoxygenase 1 activity.

In addition, the present disclosure~~invention~~ relates to plant products produced from said null-MMT barley plant, including, for example, malt and wort compositions, or barley-based syrups or extracts, or malt-based syrups or extracts, or adjuncts. Adjuncts in the present context may be unmalted barley, which may be used either alone or in combination with malted barley for preparing wort. Also, methods of preparing said barley plants, as well as methods of preparing the beverages and other plant products, are provided by the present disclosure~~invention~~.

In another aspect, there is provided a composition comprising the barley plant, or part thereof, as defined herein.

In yet another aspect, there is provided a malt composition comprising a processed barley plant, or part thereof, wherein said barley plant is the barley plant as defined herein.

In yet another aspect, there is provided a wort composition prepared using the barley plant, or part thereof, as defined herein, or using a malt composition prepared from said barley plant or part thereof, or mixtures thereof, wherein the wort composition comprises less than 20 ppb SMM.

In yet another aspect, there is provided a composition prepared from a mixture of: (i) a composition comprising a barley plant, or a part thereof, as defined herein; and (ii) a malt composition as defined herein.

Further, in a world with climate disruption on the international agenda, society and industry should contribute to global greenhouse-gas emission reductions and environmental benefits. An objective of the present disclosure~~invention~~ is therefore to provide barley plants useful for production of beer using low-energy consuming methods. Accordingly, barley plants of the present disclosure~~invention~~ are useful for production of beer using methods wherein time spans of heating steps are reduced, or the temperature in heating steps are reduced, compared to standard brewing methods. Of fundamental importance are benefits in the steps of kiln drying and wort boiling procedures, which may be significantly shortened or performed at lower temperatures compared to standard brewing and beer production regimes, reducing energy consumption to provide a more sustainable method for beer production.

Thus, in one aspect, there is provided a method of producing a beverage containing less than 20 ppb DMS and less than 20 ppb SMM, said method comprising the steps of: (i) preparing a composition comprising a barley plant, or parts thereof, as defined herein; (ii) processing the composition of (i) into a beverage; thereby obtaining a beverage containing less than 20 ppb DMS and less than 20 ppb SMM.

In yet another aspect, there is provided a method of producing a malt composition comprising at the most 200 ppb free DMS, said method comprising the steps of: (i) providing kernels as defined herein; (ii) steeping said kernels; (iii) germinating the steeped kernels under predetermined conditions; (iv) treating germinated kernels with heat; thereby producing a malt composition comprising at the most 200 ppb free DMS.

In yet another aspect, there is provided a method of preparing a barley plant carrying a mutation in the gene encoding MMT, causing total loss of MMT activity, comprising the steps of: (i) mutagenizing barley plants and/or barley kernels and/or barley embryos and/or barley cells and/or barley tissue thereby obtaining generation MO barley; and (ii) propagating said mutagenized barley plants, kernels, cells, tissue and/or embryos for at least 2 generations, thereby obtaining generation Mx barley plants, wherein x is an integer ≥ 2; and (iii) obtaining a sample of said Mx barley plants; and (iv) determining the level of SMM in said sample; and (v) selecting plants with no detectable SMM activity; and (vi) sequencing at least part of the MMT gene; and (vii) selecting plants carrying a mutation in the MMT gene; thereby obtaining a barley plant carrying a mutation in the gene encoding MMT, causing total loss of MMT activity.

SEQUENCE LISTING

The invention can be more fully understood from the following detailed description and the accompanying sequence listing (summarized in Table **10**), which forms a part of this application. Said table lists the nucleic acids and polypeptides that are described herein, the designation of the oligonucleotide primers as well as the cDNA and gDNA clones that comprise the nucleic acid fragments encoding polypeptides representing all or a substantial portion of these polypeptides, and the corresponding identifier (SEQ ID NO:). The sequence descriptions and sequence listing attached hereto comply with the rules governing nucleotide and/or amino acid sequence disclosures in patent applications.