

Identification, Cause, and Prevention of Musty Off-Flavors in Beer

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ABSTRACT

Musty off-flavors in beer can result from contamination with geosmin, 2-methylisoborneol, 2-isopropyl-methoxypyrazine, 2-isobutyl-methoxypyrazine, 2,3,6-trichloroanisole, and 2,4,6-trichloroanisole, alone or in combination. Musty compounds can be introduced via source water or raw materials or, alternatively, may be produced within the brewery. In response to a brewery's chronic, sporadic musty problems, a study was undertaken to identify and eliminate the source or sources of the musty off-flavors. To assess the plausibility of various vectors, sensory thresholds for the musty compounds were determined in beer. Remediation measures included improved practices pertaining to carbon filtration of the source water, cleaning-in-place procedures, packaging conditions, and raw material storage, as well as physical upgrades to the brewery's ventilation and pasteurization systems. A monitoring program involving sensory and instrumental analyses via a recently described ASBC method was implemented for the brewery. A literature review of musty off-flavors beyond the context of beer and water was also undertaken. As a result of these efforts, the problem appears to have been corrected. The resulting literature review and practical knowledge acquired, as well as the threshold values, will be discussed.

Keywords: beer, geosmin, methylisoborneol, musty, 2,4,6-trichloroanisole, water

SÍNTESIS

Un sabor o aroma a moho en una cerveza puede resultar de una contaminación con geosmina, 2-metilisoborneol, 2-isopropil-metoxipirazina, 2-isobutil-metoxipirazina, 2,3,6-tricloroanisol y 2,4,6-tricloroanisol, solos o en combinación. Estos compuestos pueden ser introducidos con el agua de proceso o las materias primas, como también podrían ser producidos dentro de la cervecería. A raíz de un problema crónico de problemas esporádicos con este tipo de sabor/aroma, se inició un estudio para identificar y eliminar la fuente o las fuentes de este problema. Antes de evaluar los posibles factores involucrados, se preparó un panel sensorial para determinar en cerveza los umbrales de los diferentes compuestos que pueden originar estos sabores. Algunas de las medidas correctivas tomadas tenían que ver con la manera que se filtraba el agua por carbón, los procedimientos CIP, condiciones del envasado y almacenaje de materias primas, así como el mejoramiento de los sistemas de la ventilación y de la pasteurización. Se implantó un sistema de supervisión que incluye chequeos sensoriales y un método analítico instrumental de la ASBC descrito recientemente. Se hizo una revisión de la literatura en cuanto a la presencia de sabores de moho en medios diferentes a cerveza o agua. Pareciera que el problema se resolvió satisfactoriamente. Se discute en este papel los resultados de la revisión de literatura, los umbrales encontrados y los conocimientos prácticos adquiridos en este estudio.

Palabras claves: cerveza, geosmina, metilisoborneol, mohoso, 2,4,6-tricloroanisol, agua

Introduction

Musty-earthly malodorants can be introduced into beer via source water or raw materials or, alternatively, may be generated within the brewery. Sensory panelists were sporadically detecting musty taints in finished beer from a Labatt brewery throughout 1999–2000. This paper will describe the background causes, remediation steps, and preventative measures for eliminating musty off-flavors.

The six most common musty causative agents are listed in Table 1.

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Musty compounds are microbial metabolites that can be divided into three categories, listed below, based on origin.

Water Sources

- geosmin (GSM) and 2-methylisoborneol (MIB)
- are produced by blue-green algae/cyanobacteria (6) and others
- are often seasonal, depending on water temperature and clarity
- can also be produced by bacteria living in biofilms (non-seasonal)

Chlorophenols

- 2,4,6-trichloroanisole (2,4,6-TCA) and 2,3,6-trichloroanisole (2,3,6-TCA)
- originate from municipal water treatment, decomposition of wood preservatives, chlorine bleaching of recycled fiberboard, chlorinated cleaners, and sanitizers
- subsequent fungal/bacterial methylation of chlorophenols (7)

Other Sources

- 2-isopropyl-3-methoxypyrazine (IPMP) and 2-isobutyl-3-methoxypyrazine (IBMP)
- are metabolites of Actinomycetes and soil bacteria (10)
- are the least common and least understood

Identification of musty analytes is most conveniently done by gas chromatography-olfactometry (GC-O). This technique uses conventional gas chromatography with the human nose as a detector. An organic solvent extract of beer or water is injected onto the GC-O; when a musty odor is detected, the retention time is noted. This time is then compared with the retention times of the six common musty analytes from standard injections. A matching retention time gives a positive identification.

Background

Musty Sources in the Brewery

Raw source water is a common musty vector; however, some experiences with other breweries have shown that mustiness can be attributed to less obvious vectors. Vector information from Australia (3), America (2), and Mexico (E. Zabawa [1998], unpublished data) is listed below.

Table 1. Musty sensory thresholds in water

Analyte	Odor quality	Thresholds in water ^a
Geosmin (GSM)	Soil, earthy	4 ^b – 10 ^c
2-Methylisoborneol (MIB)	Soil, camphoraceous	9 ^b – 29 ^c
2-Isopropyl-3-methoxypyrazine (IPMP)	Green peppers	2 ^b
2-Isobutyl-3-methoxypyrazine (IBMP)	Green peppers	2 ^b
2,3,6-Trichloroanisole (2,3,6-TCA)	Damp basement	7 ^b
2,4,6-Trichloroanisole (2,4,6-TCA)	Damp basement	0.03 ^b

^a In parts per trillion.
^b Data from Malleret et al. (8).
^c Data from Krasner et al. (5).

Australia

- a musty taint was observed in bottled beer after overseas shipment
- mold growth was observed on fiberboard within shipping containers
- identified as 2,4,6-TCA by GC-mass spectroscopy (GCMS)
- 2,4,6-TCA ingress through the bottle closure from a musty environment

America

- a musty taint was observed in canned beer only
- identified as MIB and 2,4,6-TCA by GCMS
- empty can line conveyor passed directly over the pasteurizer
- MIB and 2,4,6-TCA was adsorbed into can liners from a musty pasteurizer

Mexico

- bottled beer became musty during storage after being palletized and shrink-wrapped
- mold growth was observed on shrink-wrapped pallets
- mold produced mustiness directly or via chlorophenols
- musty analytes was presumed to be 2,3,6-TCA and 2,4,6-TCA, alone or together

Figure 1 illustrates some of the routes by which beer can become contaminated with musty off-flavors.

Sensory Threshold Determinations in Beer

Although MIB, 2,4,6-TCA, and 2,3,6-TCA have been detected in beer, no published threshold values exist (2,3,11,12). The thresholds for the six common musty analytes were determined by the ASTM method of ascending concentration in Labatt Blue Lager (1).

The threshold determinations, shown in Table 2, yielded concentrations similar to those published for aqueous samples. GSM and 2,3,6-TCA sensory thresholds were verified by a GCMS analytical method (9). The threshold concentrations for MIB, 2,4,6-TCA, IPMP, and IBMP were not verified analytically and, as such, are differential thresholds (4).

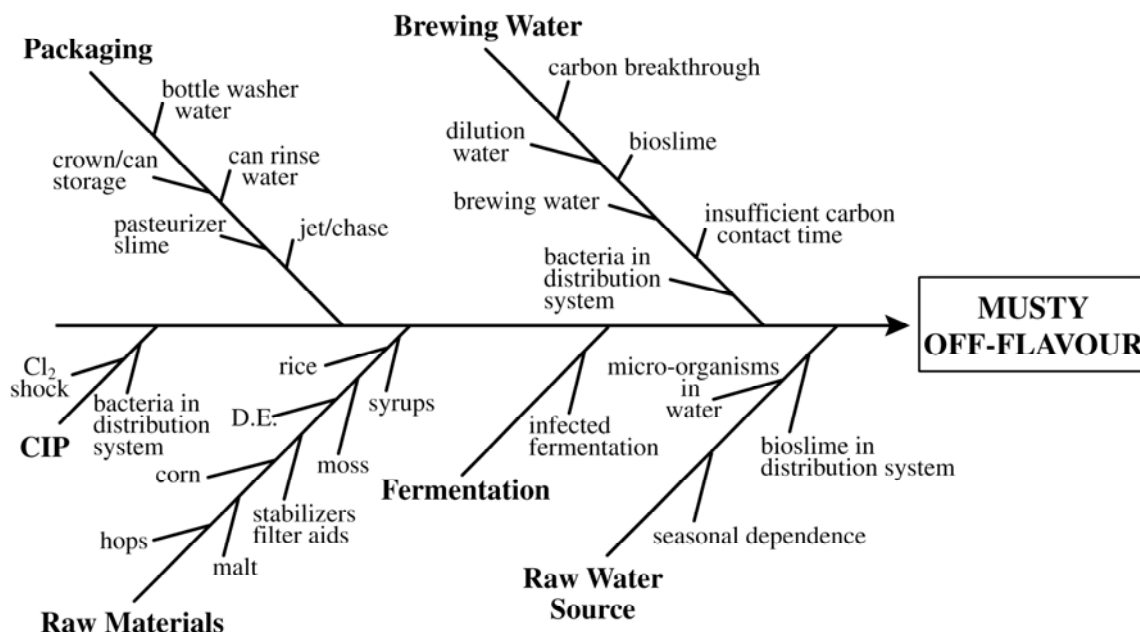


Figure 1. Potential musty sources. Cl₂ = chlorine, and D.E. = diatomaceous earth.

Probable Musty Vectors Within the Brewery

Assume you have a musty analyte with a 10-parts per trillion (ppt) threshold. With a total brew volume of 1,170 hL, approximately 1.2 mg of this analyte would be necessary to cause a musty taint in the finished product. Assuming the musty analyte is attributable to a single source, where could it come from? Calculations follow from a typical 18°Plato/14-bitterness units (BU) brew (Table 3). Note that many of the raw materials would require a musty compound concentration in extreme excess of the sensory threshold. As a result, the materials would be overtly musty and would never be included in a brew, thus making them improbable vectors.

Remediation

The actions taken at the brewery to combat mustiness are listed below.

1. Ventilation Improvements

- There was mold growth in the ductwork as a result of the damp environment, coupled with an exposed open-porous type of insulation
- This ductwork was replaced with a type featuring a sealed insulation layer
- A separate ventilation system was installed in the sensory panel room

2. Pasteurizer Upgrades

- Slimicide was added to the pasteurizers
- More fresh water was introduced into the pasteurizer and can rinser, reducing nutrient levels and inhibiting microbial growth
- The spray heads within the pasteurizer were thoroughly cleaned
- Carbon-filtered water was used for the final rinse in the pasteurizer
- A knife-air spray was added to dry the can rims, since cans stacked with wet rims were found to develop musty taints on the rims

3. Water Distribution System

- Dead-ends in the water distribution system were eliminated to inhibit biofilm development
- The water distribution system was manually shock-chlorinated every 6 weeks with 200 parts per million (ppm) of chlorine (Cl₂) introduced via the chilled water tanks

4. Carbon Filtration

- Initial observations suggested that trihalomethanes (THMs) break through carbon filters before musty substances do
- Carbon filters were changed prior to THM breakthrough
- Switched from municipal water to carbon-filtered water in packaging for can rinser, jettets, chase, and final bottle rinse

5. Fermentation and Aging Tank Cleanup

- Aging tanks and fermenters contained deposits of protein and oxalate that could harbor microbes or microbial nutrients
- The cleaning-in-place program was enhanced with a commercial cleaner combining ethylenediaminetetraacetic acid (EDTA) and chlorinated caustic to remove beerstone deposits

6. Sensory Panel Room Desensitization

- The ventilation system in the sensory panel room was improved to reduced musty saturation
- Water and beer samples were sent to a remote national weekly panel for further sensory analysis

7. Raw Materials

- Musty flavors in malt were traced to moisture in leaking rail hopper cars
- Mold growth was sometimes visible in the bottom of the hopper cars
- Hopper cars were lined in plastic to prevent mold growth
- Shipments were rejected when mold was visible

8. Monitoring Program

- Analytical monitoring of water and beer was instituted
- 2,4,6-TCA was observed in the municipal source water
- Downstream samples indicated that carbon filtration removed the musty compound
- These results support the observation that THM breakthrough occurs before TCA

Table 2. Musty sensory thresholds in beer

Analyte	Musty thresholds in beer ^a	
	Detection	Recognition
Geosmin (GSM)	10	18
2-Methylisoborneol (MIB)	6	8
2-Isopropyl-3-methoxypyrazine (IPMP)	1.5	2.9
2-Isobutyl-3-methoxypyrazine (IBMP)	1.8	2.3
2,3,6-Trichloroanisole (2,3,6-TCA)	7	9
2,4,6-Trichloroanisole (2,4,6-TCA)	0.094	0.180

^a In parts per trillion.

Table 3. Probable raw material vectors

Compound	Amount of musty compound required to contaminate entire brew ^a	Probable vector?
Corn	240	No
Malt	98	Yes
Moss	240,000	No
Hops	39,000	No
Chilled dilution water	27	Yes
Brew water	15	Yes
Jetter/rinse water	220,000	No

^a In parts per trillion.

Prevention

The remediation steps were successful in eradicating musty problems in the finished beer at this particular brewery. This experience and the resultant findings can be applicable for any brewery facing musty problems.

Cleaning Protocols

- The water distribution system must be free of bioslime — bioslime may lead to TCAs, MIB, and GSM — shock chlorination to remove/prevent bioslime
- Pasteurizer must be clean to prevent mold growth — may require biocide addition
- Tank linings must be cleanable and uncompromised — pockets in tank linings may harbor bacteria or organic deposits
- Tank deposits must be removed — deposits (beerstone) may trap bacteria or organic matter
- Cleaning or sanitizing tanks with chlorine products may lead to TCAs

Storage and Warehousing

- Ventilation and dampness must be controlled to eliminate mold growth
 - a musty environment can contaminate beer via ingress through the bottle closure
 - unused liners and empty cans can absorb mustiness from air

Packaging

- Fiberboard, pallets, and cartons all have potential for mold growth
 - mold growth can lead to TCAs
- Avoid shrink wrapping in humid conditions to reduce mold growth
- Pallet liners may prevent mustiness from leeching into the bottom of cartons

Water

- Ensure that a chlorine residual is present to prevent bioslime
 - carbon filtration should remove GSM and MIB
- Monitor the THM breakthrough data for carbon replacement

Conclusions

Musty thresholds range in beer from parts per quadrillion to parts per trillion levels. 2,4,6-TCA has the lowest threshold at 180 parts per quadrillion. Very low amounts of this compound are able to taint your finished product, emphasizing the need to control the vectors leading to its creation.

Raw water is not the only source of musty analytes in finished beer products. Many other sources, including generation of mustiness within the brewery, must be considered when attempting to combat a problem of this nature.

The staff of this Labatt location successfully addressed complaints of a musty finished product with diligent brewery hy-

giene, THM breakthrough monitoring, and routine shock chlorination.

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