Health-Promoting Ingredients in Beer

By Caroline Walker and E. D. Baxter

Brewing Research International, Lyttel hall, Nutfield, Surrey, United Kingdom.
This paper was originally presented at the MBAA 112th Anniversary Convention, Keystone, Colorado, 1999.

ABSTRACT

It has been recognized for many years that beer is a good source of several micro-nutrients, including a number of vitamins, especially the B-vitamins, and essential minerals, such as potassium, magnesium and silicon. More recently, a substantial body of clinical studies has shown that moderate consumption of alcoholic beverages is associated with a reduced risk of coronary heart disease. This protective effect is generally ascribed to ethanol itself. However, a number of studies suggest that some plant phytochemicals, including many that occur in hops and malt, can also provide additional health benefits, for example, via anti-mutagenic effects. This paper will review our current understanding of potentially health-promoting ingredients in beer.

Keywords: beer, malt, hops, health benefits

INTRODUCTION

Beer is an ancient beverage that has been consumed as an integral part of the diet in many cultures. The wholesomeness of beer seems obvious - the goodness of sprouted grain is extracted into a rich liquid and fermented to produce a nutritional ‘liquid cereal’ beverage. However, in recent years researchers have been looking for hard scientific facts to back up the conventional wisdom that moderate beer consumption is beneficial to health.

The purpose of this paper is to summarize the outcomes of epidemiological studies, clinical trials and basic research where the health benefits of beer drinking have been addressed. Although there are positive health benefits associated with alcohol, these will not be discussed since this will be covered by Mike Babb’s accompanying paper. Instead, this paper will focus on potential health-promoting ingredients that tend to be more characteristic of beer.

SILICIC ACID AND ALUMINIUM TOXICITY

Aluminium (Al) is abundant in the environment and our daily exposure to dust, foodstuffs, fluids, medicines (antacids) and antiperspirants results in the average person consuming up to 20 mg Al per day.\(^\text{[1]}\) Although our gut is relatively impermeable to Al, approximately 1% of the Al we consume is accumulated in tissues such as the liver, muscles, bone, brain and spleen.\(^\text{[1]}\) The long term effects of this Al burden are not certain, but there is abundant evidence that its accumulation in body tissue is harmful.\(^\text{[1]}\) One possible mechanism for reducing the amount of Al in the body is the consumption of silicic acid. In theory, silicic acid

SINTESIS

Se ha reconocido por muchos años que la cerveza es una buena fuente de varios micro nutrientes, incluyendo un número de vitaminas, especialmente vitaminas del grupo B y minerales esenciales, tales como potasio, magnesio y silicio. Recientemente, un substan­cial cuerpo de estudios clínicos han demostrado que el consumo moderado de bebidas alcohólicas está asociado con un riesgo reduci­do de enfermedades cardiacas. Este efecto protector se debe al efec­to del alcohol por sí mismo. Sin embargo, un número de estudios sugieren que algunos fitoquímicos de las plantas, incluyendo muchos contenedores en el lúpulo y la malta, también pueden proveer benefi­cios a la salud adicionales, por ejemplo, por medio de efectos anti­mutagénicos. Este documento revisará nuestro conocimiento actual de los ingredientes de la cerveza que pueden ser promotores de la salud.
and Al can form an excretable hydroxyaluminosilicate that would be more readily eliminated by the kidneys; therefore, a diet rich in silicic acid should protect Al toxicity.111

Cereals such as barley are rich in Si. However, the Si is present as insoluble polymeric silicates in the barley husk which are not very bioavailable. But when malted barley is processed to make beer, in the mashing and sparging stages the hot water brings the Si into solution as silicic acid which is more bioavailable. In fact, levels of silicic acid in beer are up to five times that found in water! If the above model for the action of silicic acid is correct, it follows that beer consumption should promote the depletion of Al from body tissues. This idea has in fact been tested in a small clinical study. Male volunteers drank two pints of beer and their urine was monitored for both Al and Si. During the 8-hour period immediately following consumption, a peak of Si in the urine was observed which coincided with a peak of Al excretion. A key finding was that the Al in the urine was from body stores, suggesting that the Al burden of these volunteers had been decreased. Controls showed that Al excretion was not promoted due to the alcoholic content of the beer and was not due to a simple diuretic effect. This study suggests, therefore, that a significant health benefit of beer drinking is to reduce the amount of Al accumulated in the body and thus reduce the risks of long-term effects of Al toxicity.111

**FOLIATE AND OTHER VITAMINS IN MALT**

Seed germination is an ancient and widespread method used to increase the nutritive value of seeds and it is likely that malted barley was originally used in brewing for this very reason. We now know that this is due to synthesis of vitamins by the germinated grain. It has been reported that germination promotes a 3-6 fold increase in the level of riboflavin, a doubling of the levels of niacin and almost a doubling of the amount of folate.161

Although green malt is a rich source of vitamins, only some persist through kilning and brewing, e.g. niacin, riboflavin and folate are present in significant amounts. We have measured the levels of these vitamins in malt, and also in the beer brewed from that malt on a pilot scale (Table 1). By allowing for dilutions of malt extract in the brewing process, it was clear that the niacin and riboflavin in malt persist into the beer without significant losses; for the folates, approximately 60% did not survive processing. However, it should be noted that even though there is a loss of folate, the levels present in the final product are still high enough to make beer a significant source of folate.

Why do we need folate? Folate are one of the B group of vitamins which are required for the metabolism of single carbon units. As such, they participate in the very basic processes of DNA and protein synthesis and hence cell division. Not surprisingly, when folate intake is insufficient there are wide ranging health problems that can arise. Epidemiological studies have suggested that folate intake can protect against neural tube defects, cardiovascular disease (CVD), colon cancer and may have a role in protecting against Alzheimer’s disease and cervical cancer.12,3,141 It has been estimated that in countries such as the UK, on average 10% of the daily folate intake (which averages about 220 μg/day) could come from beer. The implication is then that if beer drinking were given up it would not be beneficial in terms of the public health!171

Perhaps the most important role of folates is in preventing CVD, since this causes about 40% of all deaths in the developed world. It’s been calculated that in the US, increasing folate consumption by 100 μg/day might prevent 2-4% of deaths from CVD in the over 45s - this would correspond to 27,500 lives saved annually.12 In dietary terms, this would correspond to three additional daily servings of fruit or vegetables. Current literature values range from 50-120 μg folate/litre16,17 so around 1 litre of beer could provide a significant amount of the additional folate.

One of the indicators of risk for CVD is high levels of plasma homocysteine; higher folate intake is thought to lower homocysteine levels. But does beer drinking lower homocysteine levels? Two epidemiological studies have suggested a link between beer consumption and lower homocysteine levels. A study of men aged 50-64 years in Caerphilly (Wales) found that alcohol intake was a significant negative determinant of serum homocysteine levels.121 In this population, beer was the preferred alcoholic beverage and the authors suggested that the folate content of the beer was responsible for the lowered homocysteine concentrations. A second smaller study in Spain found that beer drinkers had significantly lower concentrations of homocysteine than drinkers of wine or spirits.141 Since wine and spirits have negligible levels of folate, one possible explanation is that lower homocysteine concentrations in the beer drinkers was due to folates in the beer.

These (and all) epidemiological studies on the effect of beer consumption on health have two limitations. Firstly, people are understandably inaccurate in their keeping of food diaries. This is a particular problem with alcoholic beverages since recollection of consumption can be colored by social factors! Secondly, surveys can ask about alcohol intake without requiring respondents to specify whether intake was wine, spirits or beer. Clearly, any effects on health due to beer cannot be distinguished from those of alcohol. Nevertheless, epidemiological studies are very useful for identifying potential links between health benefits and diet for further investigation in focused clinical trials. For this reason, at BRI we are collaborating in Europe-wide clinical trials on folate bioavailability and will address any direct links between beer consumption and serum folate and homocysteine levels.

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Malt (μg/brew)</th>
<th>Potential</th>
<th>Beer (μg/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niacin</td>
<td>884,000</td>
<td>8,500</td>
<td>7,000</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>24,300</td>
<td>240</td>
<td>300</td>
</tr>
<tr>
<td>Folate</td>
<td>13,100</td>
<td>129</td>
<td>54</td>
</tr>
</tbody>
</table>

Niacin, riboflavin and folate were determined in malt and in the beer made from that malt with 1 hectolitre brew length (columns 1 and 3). The vitamin levels in the malt were used to calculate the maximum levels in beer ('Potential') assuming 100% recovery.
HOP COMPOUNDS

Hops have been targeted by pharmaceutical researchers as a potential source of anticarcinogens and other phytoceuticals. As such, there is a substantial body of literature on therapeutic uses for hop-derived compounds such as prenyllavonoids. Most of this work has been in vitro with cell cultures and although such systems can highlight the potential health benefits of components in beer, they have the disadvantage that it is difficult to extrapolate results to in vivo effects. For example, factors such as relative absorption in the gut cannot be predicted. However, higher plants making prenyllavonoids are rare, and it is probable that beer is one of the most important foodstuffs containing prenyllavonoids in terms of quantity.[118] Xanthohumol, related prenyllavonoids and α-acids, such as humulone, are present in beer (α-acids at 0-10 μM) and so it is worthwhile considering reported health-promoting ingredients in hops.

Both xanthohumol and α-acids have shown anticarcinogenic activity.[10,18,22] Xanthohumol inhibited cytochrome P450 systems responsible for the formation of carcinogens and also stimulated the detoxifying enzyme quinone reductase. α-Acids enhanced cell differentiation (which is an anticarcinogenic activity) also inhibited tumor formation. Both of these substances were active at micromolar levels at which they show no generally toxic effects and, therefore, show promise as pharmaceuticals. Other in vitro studies have shown that xanthohumol and α-acids have also shown biological activity as inhibitors of bone resorption, a process which causes osteoporosis and loss of bone density.[20] α-Acids were the most inhibitory, effective in the nanomolar range and have good therapeutic potential. It should be emphasized that the effect of these compounds in the context of beer consumption has not been established, but their activity is clearly likely to be beneficial.

Hops are also a source of phytoestrogens – plant-derived compounds that have oestrogenic or anti-oestrogenic activity. Phytoestrogens are present in many foods including vegetables, cereal grains and especially soy beans. They are thought to protect against several chronic diseases and conditions such as CVD and breast and prostate cancer.[12] Indeed, one possible explanation of the ‘French Paradox,’ (i.e. the apparent imbalance between deaths from CVD and saturated fat consumption in France is due to red wine consumption) is that red wine contains the phytoestrogen reversatrol. In hops, four compounds have been identified as potential phytoestrogens: daidzein, genistein, 6-prenylnaringenin and 8-prenylnaringenin.[13,15] The question of how much benefit we can gain from these phytoestrogens is more difficult to assess. For example, Mandl[13] has estimated that for daidzein and genistein in beer to have a significant oestrogenic effect, consumers would have to drink approximately 175 litres of beer per day! It is possible that 8-prenylnaringenin is a better candidate for positive health effects since this compound is more potent than all the others and is present in larger amounts than daidzein and genistein. But to date, 8-prenylnaringenin has only been tested in vitro.[15] Typically, when phytoestrogens are tested in vivo, their potency falls several hundred fold due to the body’s system for rapidly deactivating and eliminating foreign substances.[111] 8-Prenylnaringenin may, therefore, still be only weakly oestrogenic to humans. In Western societies such as the UK, the average daily consumption of phytoestrogens is approximately 1 mg/day; one litre of beer will provide about 0.1 mg of 8-prenylnaringenin and beer could, therefore, contribute about 10% of our daily intake of phytoestrogens.[15] In other parts of the world, such as Asia, daily consumption of phytoestrogens through the diet is much higher, of the order of 50-100 mg/day, and there is no data to suggest that consumption of phytoestrogens is harmful to adults.[111]

ANTIOXIDANTS

Antioxidant is a term that covers a wide range of compounds, all capable of quenching oxygen radicals. Beer is rich in antioxidants, derived from both malt and hops, consisting of mostly flavonoids and phenolic secondary plant metabolites. The total antioxidant activity of beer ranges from about 1 - 2.3 mM (rela­ tive to Trolox®, a water-soluble vitamin E analogue), which is approximately in the same range as orange juice but lower than some red wines (>20 mM). However, given that a typical serving size for beer is larger than for orange juice, it can be argued that the beer is a better source of antioxidants!

What are the health benefits of consuming antioxidants? It’s been suggested that cellular damage from oxygen radicals is one of the processes leading to CVD and cancer. Since antioxidants quench oxygen radicals, they should protect against these diseases. In fact, the high antioxidant activity of red wine is thought to account for some of the protective effects of this beverage against CVD.

Although beer is a rich source of antioxidants, the implications in terms of health cannot be determined until more is known about their bioavailability, i.e. how readily these compounds can be absorbed in the body and how quickly they are eliminated from the body. Many of the polyphenolic antioxidants in plant materials (for example, the anthocyanins associated with plant pigments) are bulky molecules and are not readily bioavailable. We have conducted a small-scale clinical trial to determine the bioavailability of antioxidants in beer. Five healthy male volunteers on a low flavonoid diet were asked to drink 7 pints of a low alcohol (1% ABV) beer over 4 hours. The beer was designed to maximize the levels of antioxidants by using a 100% malt grist and a high hopping rate (2.84 g/L Fuggles hops). Urine samples were collected for the following 24 hours which were subsequently analyzed for polyphenols by HPLC. Due to the lack of commercially available polyphenol standards, peaks on HPLC traces were assigned letters rather than names but patterns of excretion of compounds were still readily apparent. Some of these polyphenols were present in the urine at high levels before beer consumption, indicating that they were in the ‘low polyphenol’ diet. Others, however, were low before beer consumption but increased markedly around 5 or more hours later suggesting that they were derived from beer. For example, the polyphenol peak H (also peaks A and B, data not shown) was not excreted until after about 5 hours, after which there was a sharp increase in excretion reaching a maximum in the urine after 12 hours (figure 1). This suggested that the polyphenols were bioavailable and were retained in the body for several hours before excretion. A similar pattern was found for the monophenolic, ferulic acid, in both conjugated and free form (Rice-Evans, personal communication).

In summary, this clinical trial demonstrated that the antioxidants in beer are readily absorbed and remain for a significant length of time in the body. It might, therefore, be expected that
beer antioxidants could give significant health benefit to the consumer – but is there any physiological evidence for this? The physiological consequences of beer consumption have been studied in rats where the animals had either wine or beer solids incorporated into their feed.\textsuperscript{19} A number of risk indicators for CVD were followed in the rat serum, all of which were reduced to an equal extent by both wine and beer. The authors suggested that it was the antioxidants in the solids that were responsible for these effects, although effects from non-antioxidants could not be ruled out. A second study in rats also showed that beer components (which were again assumed to be antioxidants) were able to prevent oxidative damage to livers.\textsuperscript{19} Perhaps the evidence that beer antioxidants have a significant health benefit is now strong enough to justify a human trial to address this issue.

**YOU ARE WHAT YOU EAT (OR DRINK)**

The goodness of beer is probably apparent from its ingredients – sprouted grains, hops and yeast. Recently, medical research has allowed us to understand in greater detail how the health promoting ingredients in beer could produce positive physiological effects. However, there is a final point which is worth considering when interpreting reports from epidemiological studies on foodstuffs and disease prevention – the beverage itself may be associated with food choice! For example, a recent study in Copenhagen found that wine drinking was associated with a higher intake of vegetables, fruit, salad and the use of olive oil in cooking; whereas beer drinking was associated with a higher consumption of saturated fats.\textsuperscript{19} In other words, beer drinkers had a less healthy diet. So fans of beer need to fix in their minds the image of a pint next to a green leafy salad...cheers!

**FIGURE 1**

The figure shows the pattern of the accumulation of the polyphenol designated ‘peak H’ in the urine of five volunteers. Time 0 is the point at which the volunteers consumed the beer. Details of the protocol are in the text.

**REFERENCES**