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Suitability of Beer as an Alternative to Classical Fitness Drinks

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ABSTRACT

During longer physical strains, our body loses water and salts through sweating. This deprivation leads to states of exhaustion and convulsions. A fitness drink should replenish both, water and mineral nutrients (mainly sodium). Different beers, alcoholic, alcohol-free and yeast-clouded, alcohol-free beer were analyzed by HPLC and Ion chromatography to determine the content of mineral salts and carbohydrates. Osmolality as a degree of tonicity was calculated based on the dissolved components. Data was compared to fitness drinks declared as mineral nutrient containing and isotonic. Subsequently, different sodium salts were added to alcohol-free, yeast-clouded beer to reach the EU recommended sodium concentrations of 500 mg L^{-1}. These spiked beers were blind tested for flavor impairments. This study shows that the fitness drinks came close to fulfill the EU direction. Generally, almost all beers are mineral nutrient containing, as defined by Austrian law. Due to the alcohol concentration, none of alcoholic beers are isotonic, as they are hypertonic. Most of the alcohol free beers are within the isotonic range, especially considering dissolved carbon dioxide. After ingestion, it is degassed by the acidic conditions in the stomach, changing many beers to hypotonic in the end. Each beer fulfills the EU recommended carbohydrate content but none comes even close to reaching the required sodium content. The blind tasting of the spiked beers showed minor flavor impairment with sodium carbonate causing the least negative effects on taste and odor. In conclusion, yeast clouded, alcohol-free beer might be labeled as mineral nutrient containing and isotonic, implying to be an ideal sport drink. Due to the lack of sodium, the real benefit of such a beverage could diminish unless mixed with beverages containing high levels of sodium or sodium carbonate.

Keywords: Beer, fitness drink, sodium, osmotic pressure, isotonic, sport, minerals.

INTRODUCTION

Beer, in particularly non-alcoholic beer, recently came in the focus of interest as a fitness drink to be consumed after sports[1]. Some breweries even promote their beers as the ideal beverage after physical activity.

During longer physical strains, like endurance sports, our body loses vast amounts of water and salts by sweating. Up to two liters of water having a sodium chloride concentration of 2.5 g L^{-1} may be lost in one hour. The mineral and water deprivation leads to states of exhaustion and convulsions[2]. A fitness drink should replenish both (water and sodium chloride) and is usually labeled mineral nutrient containing ("*mineralstoffhaltiges Getränk*" as defined by Austrian law) and isotonic[3]. The chemical/physical characteristics of such beverages are regulated in food codices[4]. According to this, beverages need to fulfill two requirements in order to be labeled as a "mineral nutrient containing, isotonic beverage": a minimal combined mineral content of 500 mg L^{-1} cations and a limited osmotic pressure, expressed as osmolality of 290 mOsmol kg^{-1}. Additionally, the European Commission considers a sodium range of 500–1200 mg L^{-1} and a carbohydrate concentration of 20–80 g L^{-1} as recommendable for fitness drinks[5].

The aim of this study was to compare the chemical and physical properties of different beers, alcoholic (A), alcohol-free (F) and yeast-clouded alcohol-free beer (Y) with commercially available fitness drinks (I) labelled isotonic and mineral nutrient containing to show the suitability of beer as a fitness drink.

All samples were screened for their carbohydrate content per HPLC and the mineral nutrient content was determined on an ion chromatograph. The osmolality, as an expression of the tonicity, was calculated from the solved carbohydrates and salts determined earlier. Additionally, the beverages not containing the recommended amounts of sodium were spiked with several food quality sodium salts to reach the minimum sodium level for fitness drinks. A sensory analysis based on a simplified double blinded procedure described by Piggott[6] was conducted to determine the sensory suitability of the salts as a food additive.

MATERIAL AND METHODS

Different analyses were performed to obtain the characteristics of the beverages and subsequently to calculate the osmolality for comparison of the results with the EC recommendations and Austrian declaration laws.

CHEMICALS AND SAMPLES

All chemicals, if not mentioned otherwise, were purchased from Carl Roth GmbH (Karlsruhe, Germany) and Sigma Aldrich (Vienna, Austria). The following, international beer samples were analyzed. Alcoholic beers: Heineken, Budweiser , Erdinger Kristall, Stiegl Weiße, Erdinger Weißbier and Schneider Weiße; non alcoholic beers: Clausthaler Classic, Becks alcohol free, Erdinger alcohol free, Weihenstephaner Hefeweißbier alcohol free, Schneider Weiße alcohol free, Paulaner Hefeweißbier alcohol free. For comparison, the following popular fitness drinks have been analyzed: Isostar® and Powerbar ®.

Mineral Content

Mineral content was determined by a Dionex ICS 1000 ion chromatography system, equipped with an AS40 auto sampler. For anion analysis, the chromatographic setup was an IonPac AS14A (4x250 mm) separation column, guarded by an IonPac AG14A (4x50 mm) and the suppressor ASRS Ultra II, 4mm from Thermo Fisher. For cation analysis, the chromatographic setup was an IonPac CS12A (4x250 mm) separation column, guarded by an IonPac CG12A (4x50mm) and the suppressor CSRS Ultra II 4 mm from Thermo Fisher.

The chromatographic conditions were chosen according the columns reference method.

Carbohydrate and Ethanol Content

Analysis was carried out on an Agilent HPLC System 1200 series equipped with a refractive index detector for signal detection. Samples were measured on an Aminex HPX 42C column with the reference method.

Calculation of Osmolality

The osmotic pressure was expressed as osmolality and calculated by the molar concentrations of the main, dissolved contents according equation 1.

$$\text{Osmolality } (b_{osm}) \text{ in mol kg}^{-1} = \frac{\text{amount of substanc of solute } (n_{solute}) \text{ in mol}}{\text{mass of solvent } (m_{solvent}) \text{ in kg}} \quad ...(1)$$

To take the osmolality of dissolved carbon dioxide into account an overall concentration of 5 g L^{-1} was assumed resulting in additional 113 mosmol kg^{-1} respectively for each beer.

Sensory Analysis

A double-blind sensory analysis (affective testing) was applied to determine the effect on texture, taste and olfactory components of sodium spiked alcohol-free, yeast clouded beers. Clausthaler Classic as an alcohol-free clear beer and Paulaner Hefeweißbier alcohol free as alcohol-free yeast-clouded beer were spiked with the different sodium salts carbonate, lactate, citrate, chloride and sulfate (each Ph. Eur. quality, VWR Vienna, Austria). The beverages were spiked to the minimum recommended sodium content of 500 mg L^{-1} by slowly adding the respective salts at 4 °C while gently stirring until the salts completely dissolved. Three categories were applied for each sample: 1 for inconspicuous, 2 for minor and 3 for major sensory distractions (undrinkable). The test group consisted of 24 students and staff from the University of Applied Sciences Upper Austria. The mean value was calculated to show the overall result.

RESULTS

To evaluate different beer samples and declared fitness drinks in their eligibility as supplemental sports drink, the carbohydrate content was determined by HPLC analysis, the mineral content by IC analysis and tonicity was calculated by the solved components. The results were compared to the recommendations for sport supplement drinks. Beverages with low sodium level were spiked with different salts to reach a minimum sodium content and were evaluated by a sensory analysis for drinkability.

Carbohydrate Analysis

The carbohydrate content was analyzed by HPLC RI detection in different beverages and the results are shown as total sugar content, the concentrations of the monomers fructose and glucose as well as the concentrations of disaccharides sucrose, maltose and higher order polysaccharides (Table 1).

The A samples had the lowest total carbohydrate content; especially mono and disaccharides were significantly low, as they were metabolized during ethanol fermentation. Higher polysaccharides (poly) were present in the same concentration range as in the F and Y samples because they cannot be metabolized by fermenting yeasts. F and Y showed very much the same distribution of carbohydrates and had about double the total content than fermented beer.

Isostar^{R} showed high concentrations of di- and poly-saccharides and practically no monosaccharides, while Powerbar^{R} showed high poly and monosaccharide content and practically no disaccharides.

Table 1: Distribution of carbohydrates in beverages given as trisaccharides and higher polysaccharides (poly), disaccharides (di), glucose, fructose and total sugar content in g L^{-1}

Product	poly	di	glucose	fructose	total
A (alcoholic)					
Heineken	14.3	1.6			15.9
Budweiser	14.2	3.6			17.8
Erdinger Kristall	34.9	3.3		0.7	38.9
Stiegl Weiße	30.2	3.0		0.2	33.3
Erdinger Weißbier	32.5	2.7		0.3	35.4
Schneider Weiße	28.6	1.8		0.7	31.1
F (alcohol free)					
Clausthaler classic	31.7	22.4	3.9	2.6	60.6
Becks	16.9	23.6	3.1	1.5	45.1
Y (yeast-clouded, alcohol free)					
Erdinger Weißbier	26.6	30.4	3.2	1.7	61.9
Weihenstephaner	25.5	19.0			44.5
Schneider Weiße	37.6	19.3	2.0	1.2	60.1
Paulaner	22.0	18.8	2.6	0.6	44.0
I (fitness drinks)					
Isostar^{R}	23.6	58.6	0.4	0,2	82.8
Powerbar^{R}	24.0	1.0	15.5	27.8	68.3

The ethanol concentrations of the samples were within the limits of 0.2 to 0.5 vol. % in alcohol free beer and 4.6 to 5.4 vol. % in alcohol containing beer (data not shown) significantly influencing the tonicity as shown in 3.2.

Mineral Content, Osmolality and Tonicity; an Overview

The mineral content acquired by ion chromatography, the osmolality calculated from the carbohydrate content and the mineral content – obtained from the main solutes – together with the declaration as mineral containing and the tonicity are shown in Table 2.

Every samples, except the two Fs had a mineral content above 500 mg L^{-1}. According to the Austrian Codex Alimentarius, these samples can be labeled as mineral nutrient containing. None of the samples tested reached the EC recommendation of 500 mg L^{-1} sodium, only Isostar^R and Powerbar^R came close. Due to the ethanol content of all A samples the osmolality is around 1000 mosmol kg^{-1}, as an average ethanol concentration of 5 vol.% calculates for an osmolality of 890 mosmol kg^{-1}, so these samples clearly are hypertonic. Nearly every F and Y samples were in the range of isotonicity as well as Isostar^R and Powerbar^R.

Sensory analysis

As none of the beers reached the minimum recommended sodium level, F and Y samples were spiked with different sodium salts to reach a sodium concentration of 500 mg L^{-1} sodium. Afterwards, a sensory analysis was applied to analyze the new mixtures for drinkability. In Fig. 1, the drinkability of representative F (Clausthaler Classic) and Y (Paulaner Hefeweißbier alcohol free) samples spiked with the different salts is shown as an arithmetic mean value. Categories varied from 1 (no flavor impairment) over 2 (minor flavor deprivations) to 3 (undrinkable).

After spiking with different salts, every beer showed minor to major flavor impairments. In general, F is influenced more negatively than Y.

Table 2: Mineral content, sodium content, each in mg L^{-1}, osmolality in mosmol kg $^{-1}$, mineral nutrient content (yes = > 500 mg L^{-1}, no = < 500 mg L^{-1}) and tonicity (hypo = < 250 mosmol kg^{-1}, iso = 250-340 mosmol kg^{-1}, hyper = > 250 mosmol kg^{-1})

Product	Mineral content	sodium content	osmolality	mineral containing	tonicity
A (alcoholic)					
Heineken	597	24	980	yes	hyper
Budweiser	565	10	1045	yes	hyper
Erdinger Kristall	648	7	928	yes	hyper
Stiegl Weiße	679	7	943	yes	hyper
Erdinger Weißbier	700	5	941	yes	hyper
Schneider Weiße	645	7	1027	yes	hyper
F (alcohol free)					
Clausthaler Classic	363	1	340	no	iso
Becks	480	20	307	no	iso
Y(yeast-clouded, alcohol free)					
Erdinger	500	4	340	yes	iso
Weihenstephaner	700	9	324	yes	iso
Schneider Weiße	673	11	444	yes	hyper
Paulaner	674	5	329	yes	iso
I (fitness drink)					
Isostar^R	806	356	260	yes	iso
Powerbar^R	681	425	327	yes	iso

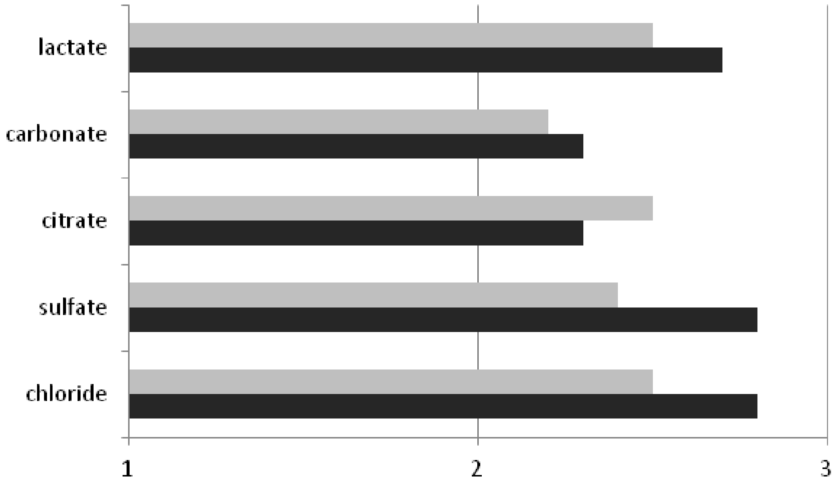

Fig.1: Drinkability of the sodium salt spiked clear and cloudy beer samples as mean value. Black: clear beer (F); grey: yeast clouded beer (Y)

The salt with the least negative interference for both beverages is sodium carbonate, just giving the beer a slight metallic taste, as the test group reported.

DISCUSSION

The proposition that beer in general is an appropriate fitness drink could not be confirmed. None of the beverages, even the labeled fitness drinks, matches the E.C. recommendation for sodium content. Alcoholic beer, besides the negative effects of the alcohol, is highly hypertonic. Clear alcohol-free beer has a lack of mineral nutrients. According to Austrian law, most yeast clouded alcohol-free beer might be declared and promoted as isotonic, mineral nutrient containing, as it matches the Codex Alimentarius threshold values. However, a significant part of a beer's osmolality is contributed by dissolved carbon dioxide, which is finally degassed from the beverage after ingestion due to the acidic conditions. A newly calculated osmolality, without carbon dioxide, results mostly in a declaration as hypotonic for all alcohol free beers. In the end, both facts, the lack of sodium and the bioavailable, hypotonic condition of alcohol free beer prohibits a recommendation as a sports drink. The labeled fitness drinks are declared correctly and even nearly match the suggested sodium concentration. For possible new beverage mixtures, alcohol-free clear and yeast clouded beer could be spiked with sodium salts to reach the recommended concentrations and osmolality. From our research, sodium carbonate seems to be the most promising additive, as it impairs the beers flavor the least of all tested sodium salts. Continuing developments could be to enrich the alcohol-free beers with sodium salts during the brewing process or, more challenging, to test alternative, sodium containing raw materials. The goal should be to create a natural beverage with appropriate sodium content and without any flavor impairment.

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