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How to quench your thirst. The effect of water-based products varying in temperature and texture, flavour, and sugar content on thirst

L. van Belzen[a], E.M. Postma[a,b,c], S. Boesveldt[a,*]

[a] Division of Human Nutrition, Wageningen University & Research, Wageningen, The Netherlands
[b] Hospital Gelderse Vallei, Ede, The Netherlands
[c] Nutrition & Healthcare Alliance, Ede, The Netherlands

A R T I C L E I N F O

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A B S T R A C T

The sensation of thirst plays an important role in the consumption of water or other fluids to rehydrate the body in order to keep bodily functions working properly. An increase in saliva secretion, wetting the mouth by ingestion of liquids, and cooling and sour components in products can alleviate this sensation already before absorption of fluids by the body. This study aimed to investigate the thirst-quenching ability of water-based products differing in temperature and texture (cold solids and cool liquids), flavour (flavoured and non-flavoured) and sugar content in two consecutive experiments. The first experiment tested four products of 10 ml each (flavoured popsicles, flavoured beverages, ice cubes, and water). 45 healthy, thirsty participants (8 men and 37 women, mean age 25.7 years SD ± 6.6) were randomly assigned to a flavour group representing the flavour of the popsicles and beverages: mint, lemon, raspberry. Each flavour group tasted all four products (popsicles, beverages, water, ice cubes) in four sessions on consecutive days. Participants rated their *thirst* and four attributes (*flavour intensity*, *thirst-quenching*, *refreshing*, *saliva stimulating*) during 3 min of consumption on a 100 mm VAS scale and ranked all four products on thirst-quenching ability at the end of the last session. The second experiment was performed similarly (n = 61, 6 men and 55 women, mean age 23.5 years SD ± 2.87), but used sugar-reduced popsicles to compare to the regular popsicles from the first experiment. In addition, saliva was collected before and after consumption. In the first experiment, cold solid (55.8 ± 0.99) and flavoured (55.9 ± 0.95) products were found to be more *thirst-quenching* than cool liquid (52.8 ± 0.96) and non-flavoured products (52.8 ± 0.96). The second experiment confirmed that saliva production increased upon consumption of these popsicles, with an increase of saliva weight from 1.7 g SD ± 0.15 before consumption to 2.0 SD ± 0.22 after consumption. Sugar-reduced popsicles were similar in thirst-quenching ability compared to regular popsicles. Overall, cold, solid, flavoured products (such as popsicles) performed best in quenching thirst, and it appeared that sugar-reduction in these products to create healthier alternatives can be achieved without compromising on thirst-quenching abilities. These results can be useful for optimisation of products to alleviate thirst in daily life, as well as in clinical settings for patients where fluid restriction is needed.

1. Introduction

The sensation of thirst is an important trigger for the consumption of water or other fluids, which is essential to keep all bodily functions working properly [1–5]. The sensation of thirst can also be seen as a warning signal from the body, indicating that rehydration is needed [6]. Ingestion and absorption of fluids decreases the sensation of thirst by restoring the body's fluid balance. However, quenching the sensation of thirst already begins before the absorption of fluids by the body. Already during drinking, it is assumed that the thirst-quenching ability of products is sensed by osmoreceptors and volume receptors in the mouth and throat, which trigger the signal to stop drinking [7]. Also the wetting of the mouth by drinking and an increase of saliva secretion play a role in quenching thirst [6,8]. However, it is yet unclear which (combination of) sensory characteristics of a product play a role in this process.

Research has shown that sensory properties can play a role in the thirst-quenching effect of foods and drinks. One of the factors that plays a role in the thirst-quenching effect of drinks is carbonation. A study investigating thirst-quenching properties of different beverages, found that a carbonated lemon drink was perceived as most thirst-quenching [9]. More recently, Peyrot des Gachons et al. confirmed that the feeling

* Corresponding author at: Division of Human Nutrition, Wageningen University & Research, PO Box 17, 6700 AA Wageningen, The Netherlands.
E-mail address: sanne.boesveldt@wur.nl (S. Boesveldt).

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of oral carbonation enhanced the thirst-quenching effect of beverages [6]. This effect of carbonation might be related to stimulation of the TRP (transient receptor potential) channels in taste buds and the trigeminal nerve, like TRPM8, TRPV1, TRPA1 and TRPC5 [6]. Next to this, trigeminal stimulation of oral cold receptors in the mouth (TRPM8) can also lead to an increase in saliva secretion [4]. This stimulation can be achieved physically by a cold source or chemically by menthol or cooling compounds. Studies investigating the effect of temperature of liquids on saliva flow showed that cold water (0–6 °C) is more salivating than water of higher temperatures (20–33 °C) [6,10]. Stimulation of oral cold receptors also plays a role in the hedonic evaluation of food products, in which the perception of cold is perceived as pleasant [8,11–14].

McEwan and Colwill point out that the combination of different properties of a product, such as astringency (trigeminal) and sourness (taste) in a lemon drink, may be more important in the perception of the thirst-quenching properties of a product than individual attributes, which was recently confirmed by Peyrot des Gachons et al. [6,9]. In the current study, we combine product properties related to temperature (cool and cold) and texture (liquid and solid) to investigate their joint effect on thirst-quenchingness.

Different taste qualities may have different thirst-quenching properties, although there is little literature available on this topic. Acids may alleviate thirst, as they are responsible for sour taste and can stimulate salivary glands, thereby increasing saliva secretion [4,12]. Moreover, McEwan and Colwill demonstrated that sweetness perception was negatively associated with thirst-quenchingness [9]. This implies that, in addition to being healthier, sugar-reduced products might be interesting in terms of quenching thirst.

Previous studies on thirst mainly focused on the effect of beverages on thirst, rather than on solid products that could be suitable for quenching thirst, such as popsicles. Also the effect of flavour in different products on thirst-quenching ability, or the role of sugar content in quenching thirst has not yet been explored. These factors are of interest to better understand of how to reduce the sensation of thirst. Such knowledge might be used to optimise products used to alleviate thirst, including beverages or popsicles. Moreover, research has shown that thirst is a common complaint in dialysis and heart failure patients. These patients often have to restrict their fluid intake, resulting in the sensation of thirst [3,15,16]. It is therefore imperative to investigate ways to reduce thirst, without using large volumes.

The current study aimed to investigate the thirst-quenching ability of products differing in temperature and texture (i.e. cold solids vs. cool liquids) and flavour (mint, lemon, raspberry) in healthy adults. We used small volumes so that results are potentially applicable in patients with fluid restrictions as well. We hypothesized that the liquid products would be more thirst-quenching than solids, as these products actually wet the mouth when drinking. We also expect that flavoured products would be more thirst-quenching than non-flavoured products, as they may contain sour and cooling components. In a second experiment, we investigated whether sugar-reduction in popsicles is possible without affecting the thirst-quenching abilities of the products. We hypothesized that sugar-reduced popsicles would be more thirst-quenching.

2. Experiment 1: thirst-quenching ability of products differing in temperature and texture, and flavour

The aim of this study was to investigate the thirst-quenching ability of water-based products differing in temperature and texture (cool liquids and cold solids) and flavour (no flavour, different flavours) in healthy adults.

2.1. Materials and methods

2.1.1. Study design

This study used a counterbalanced incomplete block design (Fig. 1). The design consisted of three blocks, each representing a flavour group: mint, lemon or raspberry. Participants were randomly assigned to a block, which consisted of four sessions each, testing two flavoured and two non-flavoured products. Flavoured products were given to the participants according to the flavour group they were assigned to. All participants received the same non-flavoured products, regardless of flavour group.

Test sessions took place on four consecutive mornings. All participants attended the test sessions at the same time every day and evaluated a different product in each session. Presentation orders of the products were counterbalanced over the participants.

2.1.2. Participants

45 participants (8 men and 37 women, mean age 25.7 years SD ± 6.6) were recruited from the surroundings of Wageningen, the Netherlands. All participants provided written informed consent form before start of the study, and filled in a questionnaire about their health. Participants were included in the study if they were aged between 18 and 55 year, were in good general health, had a normal smell and taste function and were not pregnant or lactating (all self-reported). The protocol was approved by the Medical Ethical Committee of Wageningen University (NL46034.081.13).

2.1.3. Stimuli

All participants tested four products: a flavoured popsicle, an ice cube, a beverage (in the same flavour as the popsicle), and water. Syrups in mint flavour (Plein Sud Mint), lemon flavour (Karvan Cévitam Lemon) and raspberry flavour (Karvan Cévitam Raspberry) were used for preparing popsicles and beverages. Popsicles and beverages were prepared in a ratio of 1:6 syrup to water.

Popsicles and ice cubes were prepared three days before the start of the test sessions and stored at a temperature of − 18 °C. Beverage and water samples were prepared one day in advance for each test session, and stored at 1 °C. All products were made in volumes of 10 ml. For beverage and water samples, the 10 ml was divided over five small cups (2 ml each) in order to keep consumption time similar for all products, as explained in Section 2.1.4. Study procedure. Popsicles and ice cubes were presented on a stick and were identical in shape. They were taken from the freezer and immediately served to prevent melting.

2.1.4. Study procedure

Participants were restricted from drinking 3 h prior to the test sessions to evoke thirst. At the start of each test session, participants rated their initial level of hunger and thirst (100 mm VAS, weak–strong). After this, participants consumed one of the products for 3 min. Consumption time was set on 3 min for all products, based on a pilot study on the average consumption time of the popsicle/ice cube to dissolve completely in the mouth. Ratings were given at the start of consumption ($t = 0$), and at $t = 45$, 90, 135 and 180 s. For the water and the beverage, one cup of 2 ml was consumed at each of these time points. For the popsicle and ice cube, participants were instructed to keep the popsicle or ice cube in the mouth for 3 min without biting it. Participants rated their *thirst*, and *flavour intensity*, *thirst-quenching*, *refreshing*, *saliva stimulating* of the product on a computerized 100 mm VAS scale. Scales were anchored at 10 mm from both sides of the line. Anchors were labelled as follows: weak–strong (sensation of hunger, sensation of thirst and *flavour intensity* of the product), weakly – very *thirst-quenching*, weakly – very *refreshing* and weakly – very *saliva stimulating*. After consumption, participants rated the product on liking (9-point hedonic scale). On the final test day, after consumption, they ranked the four products in order of perceived thirst-quenchingness, from least to most *thirst-quenching* (1–4). The program EyeQuestion (Version 3.16.14, Logic8 B.V.) was used for instructions and ratings.

2.1.5. Data analysis

IBM SPSS Statistics version 22 was used for data analyses. A p-value