Food Chemistry 187 (2015) 398–406

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Consumer acceptance and stability of spray dried betanin in model juices

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ARTICLE INFO

Article history:
Received 27 October 2014
Received in revised form 13 April 2015
Accepted 16 April 2015
Available online 22 April 2015

Keywords:
Betanin
Beetroot
Beta vulgaris
Colour
Consumer test
Stability

ABSTRACT

Spray dried beetroot powder was used to colour model juices, and the consumer acceptance of the juices and stability of the colour during storage at 60 °C, 20 °C, 4 °C, and −20 °C were studied. The majority of the consumers preferred the model juices coloured with anthocyanins or beetroot extract over model juices coloured with spray dried beetroot powder. The consumers preferred more intensely coloured samples over lighter samples. Spray dried betanin samples were described as 'unnatural' and 'artificial' whereas the colour of beetroot extract was described more 'natural' and 'real juice'. No beetroot-derived off-odours or off-flavours were perceived in the model juices coloured with beetroot powder. Colour stability in model juices was greatly dependent on storage temperature with better stability at lower temperatures. Colour stability in the spray dried powder was very good at 20 °C. Betacyanins from beetroot could be a potential colourant for food products that are stored cold.

1. Introduction

Visual appearance is usually the first attribute that consumers can use to evaluate quality of food, and as colour is a major part of visual appearance, colour of food is a very important factor for consumers (van der Laan, de Ridder, Viergever, & Smeets, 2011; van der Laan, Hooge, de Ridder, Viergever, & Smeets, 2015). Even in packaged foods, the colour of the food itself is important, as it may affect future choices and purchase decisions. Colours may also significantly affect the perceptions of foods and form expectations how they would smell or taste (Spence, Levitan, Shankar, & Zampini, 2010). Another factor that consumers can usually evaluate before making a purchase decision is the image of the product, for example ethical (fair trade), environmental (organic) and health issues. One image consideration that has become more important to consumers in recent years is the naturalness of the food. Usually this means that no additives, or especially no artificial additives should be used, which derives from the reported correlation between artificial additives and hyperactivity in children (McCann et al., 2007; Nigg, Lewis, Edinger, & Falk, 2012). In this regard, natural food colourants could be more acceptable to consumers, and many natural food colourants also have potential health benefits, mostly related to their antioxidative properties, which makes them a more favourable choice to consumers who are aware of health issues.

Fruit and vegetable processing produces large amounts of by-product or waste material in the form of for example peels. As there is a growing concern of environmental protection, there is a continuous effort to reduce the amount of solid agro-food waste (Papaioannou & Liakopoulou-Kyriakides, 2012). The waste material can be used as animal feed, or it can be turned into usable products, possibly with high value (Papaioannou & Liakopoulou-Kyriakides, 2012). Red beetroot (*Beta vulgaris*) is a rich source of betalain pigments, of which the main pigment in beetroot is the violet-red betacyanin pigment betanin with smaller amounts of its C-15 isomer isobetanin and yellow vulgaxanthin I (Cordeiro de Azeredo, Pereira, Rodrigues de Souza, Gouveia, & Mendes, 2009; Herbach, Stintzing, & Carle, 2004). Betalains are immonium conjugates of betalamic acid with either *cyclo*-dopa, producing violet-red betacyanins, or amino acids and amines, producing yellow betaxanthins (Herbach et al., 2004). Of the major betalains in beetroot, betanin and isobetanin (5-O-β-glucosides of betanidin and isobetanidin, respectively) are betacyanins, whereas vulgaxanthin

Abbreviations: ANOVA, analysis of variance; DE, dextrose equivalent; HPLC, high performance liquid chromatograph(y); PCA, principal component analysis; PCR, principal component regression; PLS, partial least squares (regression); PP, polypropylene; PTFE, polytetrafluoroethylene.

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http://dx.doi.org/10.1016/j.foodchem.2015.04.064
0308-8146/

I is a betaxanthin (Herbach et al., 2004). Several factors affect the stability of betalains with for example high water activity, high temperature, light, oxygen and pH above 7 or below 3 promoting betalain degradation (Herbach, Stintzing, & Carle, 2006). In addition to the use as a food colourant, betalains of beetroot have been shown to have antioxidative and anticarcinogenic properties (Esatbeyouglu et al., 2014; Kazimierczak et al., 2014; Suganyadevi et al., 2010; Vulic et al., 2014; Wroblewska, Juskiewicz, & Wiczkowski, 2011). The beetroot industry produces large quantities of beetroot peel by-product or waste material, which is rich in betalains and thus could be used to produce food colourants with health benefits. However, a volatile terpenoid, geosmin with an 'earthy' aroma is an important factor to the beetroot aroma and the compound has a very low detection threshold (Tyler, Acree, & Smith, 1979). Thus, the compound may be regarded as an unwanted off-flavour in many foods.

In this study, betalains were extracted from industrial beetroot processing side-stream and spray dried to produce a powder which can be used as a food colourant. Simple model juices were prepared and coloured with this betalain powder and the stability of betalains in model juices and in the dry powder was studied during storage at different temperature conditions. Consumer acceptance of betalain colour in model juices was studied and compared with similar model juices coloured with anthocyanins. The main focus in the consumer test was to study the hedonic responses to the appearance of the model juices, but additionally to investigate possible perceived odours or flavours released from the beetroot raw material.

2. Materials and methods

2.1. Materials

Two kinds of red beetroot (*B. vulgaris*) material were used: whole beetroots were bought from a local grocery store and industrial beetroot canning process side-stream (peeling fraction) was received from Orkla Foods Finland Oy (Turku, Finland). The whole beetroots were cut to approximately 1 cm^3 pieces and the industrial peeling fraction was used as such. Maltodextrin (from corn starch, dextrose equivalent (DE) 6, Func Food Finland Oy, Tampere, Finland) and steviol glycosides (stevia, liquid product containing 9.1% steviol glycosides, Merisant, Neuchâtel, Switzerland) were commercial products bought at a grocery store. Two betanin standards were used for identification of the HPLC peaks, one from Sigma–Aldrich (Milwaukee, WI, United States) and one from Adooq BioScience (Irwine, CA, United States). Water used for storage test study was purified reverse osmosis water (Milli-Q Plus ultra-pure water system, Millipore, Molsheim, France) and for sensory analyses activated carbon-filtered tap water was used. Other reagents were of analytical grade and solvents were of HPLC grade.

2.2. Extraction and spray drying of betanin

Betanin was extracted from cut whole beetroots or industrial peeling fraction with water (mass proportion beetroot:water 1:2) for 40 min at 40 °C with magnetic stirring and covered in aluminium foil. The extraction conditions are a little different than optimum conditions (mass proportion beetroot:water 1:5, solvent temperature 70 °C, grinding time 2 min) reported by (Cordeiro de Azeredo et al., 2009), but these were based on our own preliminary tests for optimum extraction conditions (unpublished data). After extraction, the suspension was filtered through a cloth and filter paper under vacuum to remove solid plant material. The extract from cut whole beets was stored at −20 °C until used. The extract from industrial peeling fraction was concentrated with rotary evaporator from 2 °Brix to 10 °Brix to increase solids content for spray drying. Before spray drying, 0.1 g/g of maltodextrin (DE 6) was added to the extract as wall material, and the extract was filtered through a milk filter bag and pasteurised for 10 min at 65 °C. The mixture was spray dried with a Mini Spray Dryer B290 (Büchi, Flavil, Switzerland) using the following conditions: inlet air temperature 170 °C, outlet temperature 67 °C, air flow 450 L/h, feed flow 6 mL/min, aspirator 35 m^3/h and nozzle orifice 1.50 mm. The spray dried powder was stored in a hot-seamed opaque plastic bag at room temperature.

2.3. Preparation of model juices

Model juices were prepared to mimic real juices but with a very simple composition. A total of six model juices for consumer acceptance and four model juices for storage test were prepared, and these are summarised in Table 1. The base mixture of each juice was a solution of 9 g/L citric acid and 0.3 g/L ascorbic acid in water with pH adjusted to either 3.4 or 5.0 with 1 mol/L NaOH solution. The pH 3.4 represents typical commercial juices, whereas pH 5.0 is the optimum condition for betanin stability (Herbach et al., 2004, 2006). For consumer acceptance, the base mixture was sweetened with 100 g/L sucrose and colourants were added to produce either a 'Weak' or a 'Strong' colour. Three different colourants were used in the study: spray dried beetroot powder (0.7 g/L or 1.4 g/L), beetroot extract (extracted from cut whole beets, 1:50 dilution), and a concentrated anthocyanin extract (from grapes, provided by Eckes-Granini Finland Oy Ab, Turku, Finland, 1:1250 or 1:2500 dilution). The 'Weak' and 'Strong' colours were adjusted to correspond to the maximum UV absorbance of 0.7 g/L and 1.4 g/L spray dried beetroot powder solutions, respectively (see Supplementary material 1 for UV spectra of model juices). For storage test, spray dried beetroot powder (0.7 g/L in pH 3.4 juice and 1.4 g/L in pH 5.0 juice) was added to the base mixture and the juices were sweetened either with 100 g/L sucrose or 4 g/L commercial stevia product to produce two kinds of juices with different dry matter contents. The juices were then pasteurised for 10 min at 65 °C before packing into polypropylene (PP) cans with aluminium lids (pH 3.4 juices) or PP tubes with PP caps (pH 5 juices). The packages were different because the pH 3.4 juices were prepared at a different time than pH 5 juices.

2.4. Consumer acceptance

70 voluntary subjects (age 19–65; 43 females; 27 males) were recruited to the consumer acceptance test. They rated the

Table 1
Summary of model juice samples used in the study.

Sample	pH	Colourant	Sweetener
Consumer acceptance samples			
CBP1[a]	3.4	Spray dried beetroot powder 0.7 g/L	Sucrose
CBP2	3.4	Spray dried beetroot powder 1.4 g/L	Sucrose
CBP3[b]	5.0	Spray dried beetroot powder 1.4 g/L	Sucrose
CBE	3.4	Beetroot extract 1:50 dilution	Sucrose
CA1	3.4	Anthocyanin 1:2500 dilution	Sucrose
CA2	3.4	Anthocyanin 1:1250 dilution	Sucrose
Storage test samples			
SSU07[a]	3.4	Spray dried beetroot powder 0.7 g/L	Sucrose
SST07	3.4	Spray dried beetroot powder 0.7 g/L	Stevia
SSU14[b]	5.0	Spray dried beetroot powder 1.4 g/L	Sucrose
SST14	5.0	Spray dried beetroot powder 1.4 g/L	Stevia

CBP: Consumer test Beetroot Powder, CBE: Consumer test Beetroot Extract, CA: Consumer test Anthocyanin, SSU: Storage test SUcrose, SST: Storage test STevia.
[a] CBP1 and SSU07 have the same composition.
[b] CBP3 and SSU14 have the same composition.