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Producing ice cream using a substantial amount of juice from kiwifruit with green, gold or red flesh

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ABSTRACT

Ice cream prepared using a substantial amount of juice from kiwifruit with green, gold or red flesh may have consumer appeal, through the combination of kiwifruit's unique color, natural flavor and health-promoting constituents. The aqueous fractions from purees of kiwifruit with green, gold and red flesh (AFKWs) were added at 49% v/v to a basic low-fat ice cream mix that contained no commercial flavoring and coloring agents. The resultant ice creams were subjected to comparative product evaluation (e.g. overrun, melting behavior and rheological properties) and chemical analyses of bioactives (e.g. total extractable polyphenol content (TEPC), vitamin C, antioxidant capacity, polyphenol (PP) and carotenoid composition). Results revealed that both the pH pre-adjustment and pre-heating of the AFKW played critical roles in ice cream making. The ice creams retained the PP and vitamin C contents as well as natural color flavor of the kiwifruit used. The rheological properties of all ice creams showed non-Newtonian flow behavior, and the storage modulus G′ decreased in the same pattern following the order of green > gold > red. The melting rate, overrun and vitamin C content of the ice cream with green AFKW were the fastest, lowest and least, respectively. The TEPC and antioxidant capacity in the ice cream with red AFKW were the highest. The amounts of PPs and vitamin C were encouragingly high. Health beneficial compounds, dimethyl-caffeic acid hexoside, caffeic acid derivatives, protocatechuic acid, syringic acid, salicylic acid/*o*-coumaric acid, lutein and *beta*-carotene, were detected in the final products. Thus, there are commercial possibilities for using AFKW which should be further evaluated.

1. Introduction

The market for foods that provide nutritional function and new eating experiences for consumers has grown rapidly in recent years (de Graaf, 2007; Tuorila, 2007; Van Kleef, van Trijp, Luning, & Jongen, 2002; Williams, Stewart-Knox, & Rowland, 2004). Ice cream is one of the most consumed dairy products in the world (Gorski, 1997; Hoyer, 1997) but the ice cream available commercially is generally poor in natural antioxidants like vitamin C, colors and polyphenols (PPs). Thus, it is of interest to explore the possibility of improving the nutritional attributes of ice cream using ingredients with health benefits, focusing on natural antioxidants, natural colorants, vitamins, low fat and freedom from synthetic additives in light of consumer expectations (El-Nagar, Clowes, Tudoric , Kuri, & Brennan, 2002; Gidley, 2004; Starling, 2005; Van Kleef et al., 2002).

Kiwifruit (*Actinidia* sp.) has many appealing consumer traits including flavor, color and nutritional content, especially vitamin C (Ahmet, Sezai, & Nihat, 2007; Nishiyama, 2007). Consumption of kiwifruit offers health benefits including alleviating constipation and improving stool transit time and/or bulking (Chan, Leung, Tong, & Wong, 2007; Duttaroy & Jørgensen, 2004; Ferguson, Philpott, & Karunasinghe, 2004; Philpott, Mackay, Ferguson, Forbes, & Skinner, 2007; Rush, Patel, Plank, & Ferguson, 2002), because of constituents such as vitamin C, PPs, carotenoids and fiber polysaccharides (Dawes & Keene, 1999; Deters, Schröder, & Hensel, 2005; Lesperance, 2009). Dietary intake of vitamin C is essential for humans because humans cannot synthesize vitamin C (Davey et al., 2000; Ferraroni et al., 1994; Minnunni, Wolleb, Mueller, Pfeifer, & Aeschbacher, 1992; Rababah, Ereifey, & Howard, 2005). A single kiwifruit contains the minimum daily requirement for vitamin C (Ferguson, 1991), suggesting that kiwifruit-derived products could be an excellent source of this essential vitamin. Kiwifruit flesh can have different colors derived from pigments such as chlorophyll, carotenoids and anthocyanins (Cano, 1991; Comeskey, Montefiori, Edwards, & McGhie, 2009; McGhie & Ainge, 2002; Nishiyama, Fukudo, & Oota, 2005; Possingham, Coote, & Hawker, 1980). Thus, kiwifruit may be suitable for the development of a new ice cream product with a range of natural colors and enhanced nutritional content.

Ice cream preparation typically involves a mix-making and a freezing stage, with important processing steps being blending, pasteurization, homogenization, cooling, flavoring and coloring,

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freezing, packaging, hardening and frozen storage (Schmidt, 2004). Ice cream is made from milk ingredients (milk fat and milk solids-not-fat), sugar, water, and other optional ingredients such as flavorings, colors, stabilizers, and emulsifiers (Schmidt, 2004). The ice cream flavor and color is normally generated through adding a small amount (i.e. approximately 0.3% ice cream mix) of liquid flavors and colors after aging and before freezing (Schmidt, 2004). Homogenization can reduce the particle size and aggregation of fat globules at low temperature, compensate the function of stabilizer, enhance ice cream viscosity but elevate the oxidation of milk fat and instability of proteins (Bodyfelt, Tobias, & Trout, 1988; Goff, 1999; Spreer, 1998; Sweetsur & Muir, 1983). The pressure of homogenization influences the viscosity but not the melting resistance (Thomsen & Holstborg, 1998). During aging, it is essential that the adsorbed protein is partially desorbed from the fat globule surface. Overrun and melting property are important variables for evaluating an ice cream product and associated processing (Arbuckle, 1986).

The use of juice from kiwifruit for ice cream production may eliminate the need to add commercially available flavoring and coloring agents, but also presents technical challenges that are associated with the nature of fruit juice. When fruit juice is mixed with milk protein, various interactions are possible. Interactions among PPs and proteins may lead to the formation of PP–protein complexes (Haslam, 1998; Perez-Jimenez & Saura-Calixto, 2006; Rawel, Kroll, & Hohl, 2001; Rohn, Rawel, & Kroll, 2004). Such complexation may result in effects such as milk stabilization on heating (O'Connell, Fox, Tan-Kintia, & Fox, 1998) and synergy in antioxidant capacity (Skrede, Larsen, Aaby, Jorgensen, & Birkeland, 2004). The added fruit juice could change the pH of the ice cream mix, which may lead to protein aggregation and peptide precipitation if the pH approaches the isoelectric point (pI) (Amundson, Watanawanichakorn, & Hill, 1982; Pearce, 1983), and induce hydrophobic interactions (Blondelle, Bfittner, & Houghten, 1992; Bull & Breese, 1970; Léonil et al., 1994). Ice cream color may change with type of kiwifruit when various kiwifruit juices are added to milk. The naturally occurring pigments in kiwifruit (chlorophyll, carotenoids and anthocyanins) are generally unstable, but may be more attractive to consumers than synthetic coloring agents. The green pigments (chlorophyll a and b) tend to lose the Mg^{2+} ion to form brown pheophytin under acidic conditions (Cassano, Figoli, Tagarelli, Sindona, & Drioli, 2006; Johnson & Steele, 1995; Lodge & Perera, 1995). Carotenoids are particularly susceptible to heat destruction and oxidation, because of their highly unsaturated chemical structure (Stefanovich & Karel, 1982), while anthocyanins are degradable at high temperatures, and undergo structural transformations with the change in pH, forming interconvertible forms of red flavylium cation and blue quinoidal base (Kosir, Lapornik, Andersenk, Vrhovsek, & Kidric, 2004). Thus processing conditions need to be carefully managed if these natural colorants are to be preserved in processed products.

This study aimed to examine the feasibility of producing a new type of ice cream product through incorporating a substantial amount of AFKW in the absence of any added flavoring agent, and provide insights into the chemical and physical properties of this frozen dessert format.

2. Materials and methods

2.1. Materials and chemicals

Pams® instant skim milk powder, Chelsea® white sugar, whole milk (Anchor®), green and gold kiwifruits were purchased from the Foodtown supermarket, St Lukes, Auckland. Red kiwifruit were obtained from Plant & Food Research, New Zealand. Soya lecithin (Yelkin, liquid) was obtained from Archer Daniels Midland Co., Decatur, IL, USA. Gelatin was obtained from Gelita NZ Ltd, Christchurch, New Zealand.

Methanol, *n*-hexane and formic acid were purchased from Ajax Finechem (Auckland, New Zealand). Acetone was from Burdick & Jackson (Muskegon, MI, USA). Folin–Ciocalteu phenol reagent, catechin, epicatechin, phlorizin, phloretin, quercetin, rutin, and *p*-coumaric, chlorogenic and caffeic acids were purchased from Sigma-Aldrich (St. Louis, MO, USA). Cyanidin 3-*o*-β-glucopyranoside chloride was sourced from Polyphenols Laboratories AS (Hanaven, Sandnes, Norway). Milli-Q Plus water was used for all the reagent preparation.

2.2. Ice cream preparation

Green, gold and red kiwifruits were firstly washed with water to remove any external contaminants. Both ends of each fruit were cut off and the skin was removed with a sterilized stainless peeler (APS001; Andefia, Zhongshan, China). Kiwifruits were pureed using a Juice Fountain Juicer (Model BJE 200C; Breville, Sydney, New South Wales, Australia), centrifuged at a speed of 5000 $\times g$ for 25 min at 4 °C using a Sorvall Instrument RC5C (DuPont, Michigan, WI, USA) and a Fibrelite F10s rotor (Piramoon Technologies Inc, Santa Clara, CA, USA), and then filtered through a sterilized mesh cloth to separate the AFKW from particles.

Ice cream was prepared using modified standard methods (Marshall & Arbuckle, 1996; Schmidt, 2004). The gelatin (4.54 g) was dissolved in water (30 mL) by gentle stirring over a boiling-water bath. Skim milk powder (135 g) was first mixed with sugar (61 g) to generate a “dry mix”. AFKWs (500 mL) were subjected to pre-treatment which included adjustment of pH to 4.7–4.9 using baking soda (Edmonds, from Goodmans Fielder Ltd., Auckland, New Zealand) and heating at 55 °C for 1 min, and then mixed with whole milk (500 mL) to generate the “liquid mix”. The “liquid mix” was sealed, covered with tin foil, and heated to 30–40 °C in a water bath. The “dry mix” was added slowly to the “liquid mix” with gentle stirring, and gelatin solution and liquid lecithin ingredient (5.54 g) were then added. The obtained mixture was blended using a mixer (L5T, Silverson Machines Inc., East Longmeadow, MA, USA; emulsifying screen, 3000 rpm, 1-min plus 2-min burst), pasteurized in a double boiler at 80 °C for 30 s, homogenized using an Auestin EmulsiFlex C3 homogenizer (Ottawa, Canada) at 2000/500 psi, cooled to 4 °C, aged in the fridge at 4 °C for 20 h, frozen and whipped in the ice cream maker (Gelato di Amore M916, Artisan Gelato Systems, Bologna, Italy) at low speed for 23 min. The ice cream was collected at an exit temperature of −5.5 °C, placed in a 1 L plastic container, sealed, hardened for 1.5 h in a freezer (−80 ± 3 °C, Thermo Electron Corp., Revco, Cambridge, UK), and stored at −20 ± 2 °C (Skope TMEF65XL-D freezer, Skope Industries Ltd, NSW, Australia) for 24 h before analysis.

2.3. Overrun and melting properties

Three batches of each type of kiwifruit ice cream were produced for overrun and melting assessment (Arbuckle, 1986; Schmidt, 2004). The overrun was calculated using the equation of “% Overrun = (Vol. of ice cream − Vol. of mix used) / Vol. of mix used × 100%”. Melting behavior was assessed by withdrawing 120 g of ice cream from the freezer at −20 °C and putting it into a dish that was kept at 20 ± 2 °C (humidity 53 ± 2%). The times at which the first drop of ice cream dripped and when complete melting had occurred were recorded. The volume of unmelted ice cream was recorded at 30-min intervals using a graduated cylinder. Melted ice cream was removed and weighed.

2.4. Total soluble solid content and pH values

The total soluble solid content was measured in triplicate using a handheld refractometer (Pocket Pal-1, Atago, Tokyo, Japan) at 20 °C, and expressed as °Brix. The pH was determined in triplicate using a pH meter (CG837, Schott Instruments, Germany) equipped with a glass electrode (850, Schott Instruments, Mainz, Germany).