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Whole grain macaroni: Flavour interactions with sodium-reduced cheese sauce

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ABSTRACT

Despite whole grain products being excellent sources for nutrients, their bitterness and other off-flavours have generated disinterest in consumers. Pairing whole grain macaroni with a sodium-reduced cheese sauce may further compromise consumer acceptance. The objective of this research was to examine the change in flavour of whole grain macaroni via sensory and headspace analyses following the addition of a sodium-reduced cheese sauce. Descriptive analysis showed that macaroni increased in bran and wheat flavours as well as bitterness upon increasing whole grain content whereas starchy flavour and sweet taste had decreased. Although each attribute was uniquely affected by the addition of sauce, sauce type was not significant, suggesting that sodium reduction in whole grain macaroni and cheese did not impact its bitterness or bran flavour. Selected ion flow tube-mass spectrometry (SIFT-MS) was used to identify and quantify volatiles associated with macaroni and to measure any changes following addition of sauce. While concentration was positively correlated to whole grain content, compounds specific to macaroni reduced after the addition of sauce, likely caused by a physical barrier created by the sauce, which suppressed compound volatility.

1. Introduction

Whole grain products are excellent sources for fibre, minerals, and antioxidants. Consumption of whole grains may reduce the risk of diseases such as cardiovascular disease, type II diabetes, and some cancers (Liu, 2007). The antioxidant potential of whole grains even rivals that of fruits and vegetables on a per-serving basis (Slavin, 2003).

Some drawbacks to these products include darker colours, rougher and heavier textures, and the development of unpleasant off-flavours over time. Phenolic acids are also responsible for the bitter, sour, and astringent properties of whole grains (Armbrister, 1995). Despite these problems, consumers associate dietary fibre with providing health benefits beyond a regular diet so manufacturers are challenged with incorporating whole grains while maintaining acceptance (Mehta, 2005).

Another demand that the food industry faces is the option of sodium-reduced products for consumers. The daily intake of sodium chloride is approximately 3600 mg in women and 4800 mg in men, far exceeding the physiological need by more than twenty times (World Health Organization, 2007). Seventy-five percent of total sodium intake in Western countries comes from processed foods (McGregor, 2007). Increased consumer awareness of the health risks associated with a high sodium diet, such as hypertension, impacts purchases that are made (Schroeder, Bodyfelt, Wyatt, & McDaniel, 1988). In addition to the pressure enforced by media and government organizations, this has pushed many food companies towards revising current formulations of their products (McGregor, 2007).

Preference for salty taste has traditionally factored into the consumption of high sodium products. For example, cheese sauces are largely favoured for the saltiness they add to many dishes (Childs, Yates, & Drake, 2009). The desire for sodium is a learned behaviour rather than predisposed and craving sodium may even be described as an addiction in some individuals (Dahl, 1972; Wise, Hansen, Reed, & Breslin, 2007). Consumers are quick to recognize changes in sodium content of foods, sometimes leading to diminished acceptance. It was previously demonstrated that sodium could be reduced in cheese sauce by approximately 18% before differences were observed (Drake, Lopetcharat, & Drake, 2011). The effect of sodium-reduction on cheese quality has been studied in recent years with a large emphasis on the replacement of sodium chloride with potassium chloride (Agarwal, McCoy, Graves, Gerard, & Clark, 2011; Ayyash & Shah, 2011; Gomes et al., 2011; Grummer, Karalus, Zhang, Vickers, & Schoenfuss, 2012) Total replacement of sodium with potassium, however, will not be possible due to an inherent bitter taste of potassium (Van Der Klaauw & Smith, 1995) and replacement levels suggested for potassium vary depending on the food product (Agarwal et al., 2011; Gomes et al., 2011; Grummer et al., 2012). The current strategy adopted by many food processors is to gradually reduce sodium over several years so that palates may adapt without detection (Cruz et al., 2011). This reduction "by stealth" was adopted by the United Kingdom to meet the 2012 target intake of 6 g/day of sodium (He & MacGregor, 2009).

Abbreviations: SIFT-MS, selected ion flow tube-mass spectrometry.

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As mentioned, previously one concern with serving whole grain macaroni is its potential for bitterness and other off-flavours. Although healthy, this dish may be even further compromised if paired with a sodium-reduced cheese sauce. Reduced sodium foods have two potential issues: the lack of a desirable salty taste and reduced masking of negative attributes, such as bitterness, as has been shown in many model systems (Keast, Breslin, & Beauchamp, 2001; Keast, Canty, & Breslin, 2004; Ogawa et al., 2004). Studying model systems provides a general overview of changes in sensory properties due to sodium reduction, however, these results may not be indicative of what occurs with actual food products when sodium levels are reduced. When food products, such as pasta and cheese are mixed together, ingredient interactions will occur and perceived tastes and flavours in the mixed product will be a result of these interactions. There is currently little work that has investigated taste and flavour perception in mixed product systems such as a macaroni and cheese. The objective of this research, therefore, was to examine the change in flavour of whole grain macaroni from the addition of a sodium-reduced cheese sauce using sensory and headspace analysis. Headspace analysis was performed using Selected Ion Flow Tube- Mass Spectrometry (SIFT-MS). While chromatographic methods require large sample amounts and pre-concentration, SIFT-MS is a form of direct mass spectrometry that uses soft chemical ionization (Phillips & Greenberg, 1992; Smith & Španěl, 2005). Multiple reagent ions are used to increase specificity and accuracy of compound identification. The volatile concentrations can be calculated based on the known rate constants and branching ratios provided in an electronic library (Syft Technologies, 2009). This approach is a new technique for analyzing volatile concentrations and recent publications include work conducted to measure headspace volatiles in adulterated honey (Amal & Barringer, 2013), headspace analysis of meat oxidation (Olivares, Dryahina, Spanel, & Flores, 2012) and headspace analysis of potatoes treated with anti-browning agents (Mosneaguta, Alvarez, & Barringer, 2012).

2. Materials and Methods

2.1. Macaroni preparation

Canadian western hard white wheat flours [protein content (N × 5.7) for refined and whole grain flours were 14.9 ± 0.0 and 15.4 ± 0.1%, respectively] were supplied by Kraft Mississauga Mill (Mississauga, Canada) and manufactured into macaroni by the University of Milan (Milan, Italy) at whole grain levels 0%, 25%, 75%, and 100%. The moisture content of the dried macaroni ranged from 10.1 ± 0.0 to 10.8 ± 0.3%.

For cooking of the macaroni, although total mass of uncooked macaroni and cooking water changed to fit the needs of each experiment, their proportion to each other remained constant. One part of uncooked macaroni was added to 10 parts boiling water (tap, unsalted) and stirred periodically. After 5 min, the macaroni was strained, rinsed under tap water for 30 s, and spread onto an oven roaster to allow even cooling.

2.2. Macaroni and cheese preparation

Commercial and sodium-reduced cheese sauce powders were supplied by Kraft Cheese Operations (Ingleside, Canada). In a double boiler, 75 g of powder and 94 g 1% partly skimmed milk (Beatrice, Parmalat Canada, Inc., Toronto, Canada) were added to 70 g of melted unsalted butter (Gay Lea, Missisauga, Canada) and stirred until a smooth sauce was obtained. The sodium content of commercial and sodium-reduced sauces were 3.1 ± 0.1 and 2.6 ± 0.1%, respectively. The fat content of the sauces were 24.3 ± 0.4 and 19.5 ± 0.7%, respectively. The protein content (N × 5.7) of the sauces was 5.1 ± 0.1 and 6.0 ± 0.1%, respectively.

Although total mass of macaroni and cheese sauce changed to fit the needs of each experiment, their relative proportion remained the same. Three parts cooked macaroni was added to two parts cheese sauce by weight and mixed until evenly coated. The macaroni and cheese samples were placed in a slow cooker set to warm (55 °C) and filled with an inch of water so as not to dry out the samples.

2.3. Sensory analysis

Generic descriptive analysis, as described by Lawless and Heymann (2010) was performed on cooked macaroni without sauce, cheese sauce without macaroni, and macaroni and cheese sauce combined. Ethics approval was obtained from the University of Guelph Research Ethics Board (REB# 09MY20). All panelists taking part in the study were experienced in descriptive analysis and had taken part in previous trained panels. Training of the panelists involved the use of consensus training, as outlined by Lawless and Heymann (2010). Individuals were provided with a range of products and were asked to generate a list of attributes to describe the flavours and tastes of the products. During training, the panelists were provided with references for each attribute to assist them with refining the attribute definition as well as to assist with identification and evaluation of attribute intensity. At the completion of training, panelists had agreed upon the order of evaluation as well as all attributes and definitions used during the evaluation. The final list of taste and flavour attributes and the order of their evaluation is described in Table 1.

During testing, each sample was labelled with a random three digit blinding code. Samples were presented in random order to the panelists with a 1 min break between each sample. The samples were evaluated on a 15 cm line scale using the program Compusense *Five* © 2008 (Compusense, Guelph, Canada). Testing was completed under red light.

For macaroni, eight individual pieces of macaroni were served at room temperature. Panelists (n = 12) were trained for 18 hourly sessions and testing was performed in triplicate. Between samples, Premium Plus crackers (unsalted), and a glass of filtered water served at room temperature, were provided to cleanse the palate. The panelists were instructed to bite the macaroni in half and to make their evaluation on that half.

For cheese sauce, 6 g of each sample was maintained and served at 55 °C. Temperatures lower than this led to solidification of the sauce. Panelists (n = 10) were trained for 8 hourly sessions and testing was performed in triplicate. Between samples, sliced apples and a glass of filtered water served at room temperature were provided to cleanse

Table 1
Flavour and taste attribute definitions and rating scale used in descriptive analysis.

Attribute	Definition	Rating scale
Branny	A grainy aromatic with a light, dusty impression	0 = Not branny 15 = Very branny
Wheaty	A light aromatic associated with many wheat-based cereals	0 = Not wheaty 15 = Very wheaty
Starchy	Aromatics associated with wheat starch	0 = Not starchy 15 = Very starchy
Bitter	The taste on the tongue stimulated by caffeine and other bitter compounds	0 = Not bitter 15 = Very bitter
Sweet	The taste on the tongue stimulated by sucrose and other sugars	0 = Not sweet 15 = Very sweet
Salty	The taste on the tongue stimulated by sodium salt	0 = Low salt 15 = High salt
Sour	The taste on the tongue stimulated by acids	0 = Not sour 15 = Very sour
Buttery	The fatty, mild flavour of melted butter	0 = Not buttery 15 = Very buttery
Cheddar	Aromatics associated with processed cheddar	0 = Not cheddary 15 = Very cheddary
Free fatty acid	Aromatics associated with butyric acid, aged Italian cheese, or rancid butter	0 = Low fatty acid 15 = High fatty acid