VACUUM BELT DRIED APPLE POMACE POWDER AS A VALUE-ADDED FOOD INGREDIENT IN BAKED AND EXTRUDED PRODUCTS

by

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(Under the Direction of WILLIAM L. KERR)

ABSTRACT

Oatmeal cookies prepared with vacuum belt dried (VBD) apple pomace (AP) and varying dough moisture content (MC) were evaluated for physical, chemical and sensory properties. Higher AP substitution resulted in higher a_w and produced lighter with stronger yellow saturation. Increased AP also increased cookie thickness, but decreased cookie width and spread factor. Greater AP substitution resulted in tougher and chewier cookies. Total dietary fiber (TDF) and total phenolics content (TPC) increased with more AP. No significant difference was found in overall acceptability from sensory evaluation. Physicochemical and sensory properties were evaluated for an extruded oat-based cereal product with VBD apple pomace substitution and varying exit temperatures. Increased AP did not greatly affect ($p \leq 0.05$) textural properties or sensory ratings. Hardness and crispness were not statistically different between treatments. Higher AP resulted in darker and more yellow saturated product. TDF and TPC increased with increasing pomace level.

INDEX WORDS: apple pomace, vacuum belt drying, total dietary fiber, total phenolics content, oatmeal cookies, extruded cereal, sensory evaluation

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CHAPTER 1

INTRODUCTION

Apple pomace is the waste product containing the skins, flesh and seeds from juice processing and has been found to contain high levels of dietary fiber and phenolics. Dietary fiber is the nondigestible components which are made up of polysaccharides from plant cell wall materials. The main fiber components in pomace are the nonstarch polysaccharides, celluloses, hemicelluloses, pectins, β-glucans, gums, and lignins (Gallaher and Schneman 2001). Apples have been found to be a rich source of phenolics such as phloridzins, quercetins, catechins, epicatchin, cyanidins, gallic acids, chlorogenic acids, and courmaric acids (Boyer and Liu 2004; Lu and Foo 1997).

The following research focuses on the utilization of apple pomace powders in baked and extruded products as a value-added ingredient. The objective was to evaluate the physicochemical and sensory properties of the addition of vacuum belt dried apple pomace powders in baked and extruded products. The work has been divided into five chapters:

The first chapter contains short summaries of the content in each chapter.

The second chapter is a literature review of the relevant topics. It details the market of apples, what dietary fiber and phenolics are present in apples, health benefits of consuming apples are in apples, the health benefits of consuming apples, what other uses have been published on apple pomace, drying techniques, health benefits of oats, the baking process, the extrusion process, ready to eat cereals, and other studies looking at fruit and vegetable powders as a value-added ingredient.

The third chapter focuses on the physical, chemical and sensory properties of oatmeal cookies with the addition of vacuum belt dried apple pomace powder. The researcher investigated the effects of pomace powder (0, 5, 10, 15 g AP/100 g dry ingredients) and dough moisture content (13, 15, 17 g H_2O/100 g cookie) on the final moisture content of the cookies, water activity, color, cookie width, cookie thickness, spread factor, texture qualities (toughness, hardness, and chewiness), total phenolic content, and total dietary fiber. Consumer sensory evaluations were conducted to determine acceptability in appearance, texture, flavor and overall acceptability.

The fourth chapter focuses on the physical, chemical, and sensory properties of an oat-based extruded cereal product with the addition of vacuum belt dried apple pomace pomace. The effects of pomace level (0, 2, 4 g AP/100 g dry feed) and exit temperature (115, 125, 135 °C) were evaluated for expansion ratio, bulk density, texture qualities (hardness, crispiness), color, moisture content before and after impingement, total dietary fiber, and total phenolic content. A consumer sensory panel was recruited to determine acceptability in appearance, texture, flavor and overall acceptability of the extruded cereal snacks.

The final chapter contains the overall conclusions of the entire study.

CHAPTER 2

REVIEW OF LITERATURE

Apples (*Malus domestica*) are the fourth most widely consumed fruit globally after bananas, oranges and grapes. They are generally consumed fresh, but can also be consumed in its processed forms such as juices, ciders, sauces, frozen and dried. Globally, the United States was the second largest producer of apples processing nearly 9.1 billion pounds apples in 2012. While apples are grown in every state in the US, only 29 states grow apples commercially. Washington state leads apple production by producing over half of the apples grown. Approximately 32% of apples produced in the United States are then furthered processed into juice, cider, frozen and other goods (NASS 2012 - table 3). Recently, fresh-market apples production has grown significantly with an increase of approximately 7 % since the eighties and nineties (Pollack and Perez 2005). As a result, the gap between prices of fresh-market apples and production apples have increased accordingly.

Dietary Fiber

Dietary fiber is the components of a food and/or food product that cannot be digested. Generally, dietary fiber is composed of polysaccharides from the plant cell wall material (cellulose, hemicelluloses and lignins). Dietary fibers are classified into soluble and insoluble. Insoluble fibers include celluloses, lignins, hemicelluloses entrapped in a lignocellulosic matrix, and resistant starches. Soluble fibers are comprised of the rest of the polysaccharides, hemicelluloses not entrapped in lignocellulosic matrix, and pectins (BeMiller 2010). Recently, oligosaccharides like resistant starches and inulin have been included in the definition of dietary fiber. In the human diet, sources of dietary fiber include fruits, vegetables, whole grains including oat and wheat brans, legumes, and nuts. Apples contain a balanced proportion of soluble and insoluble fibers (Gorinstein et al. 2001). One large raw apple in weight with skin contains 5.4 g total dietary fiber (U.S. Department of Agriculture. Agricultural Research Service. National Nutrient Database for Standard Reference). Main components of fibers in apples are nonstarch polysaccharides, celluloses, hemicelluloses, pectins, β-glucans, gums, and lignins (Gallaher and Schneman 2001).

Apple Phenolics

In addition to fiber, apples are a good sources for antioxidants. Vinson et al. (2001) found that apples served a significant level of phenols at 186 mg total phenols/100 g fresh weight. Apples contain high levels of polyphenols such as quercetins, catechins, epicatechins, procyanidins, cyanidins, gallic acid, chlorogenic acid, courmaric acid, and phloridzin (Boyer and Liu 2004; Lu and Foo 1997). While phenolic compounds also exist in the flesh, there is a higher concentration of these flavonoids in the skin (Lata 2007; Drogoudi et al. 2007; Wolfe et al. 2003). Garcia et al. found the antioxidant capacity, via DPPH and FRAP assays, for apple pomace was within 4.4 and 16.0 g ascorbic acid per kg dry matter (2009). They also found that the antioxidant activity of apple pomace generally could be predicted by the levels of phloridzin, procyanidin B2, isoquercitrin + rutin , pro-catechic acid and hyperin.

Health Benefits of Consuming Apples

The function of fiber in the human gut helps to regulate the level of lipids in the blood as well as having a protective effect on the colon. This has implications to help reduce the risk of diseases such as obesity, hypertension and cardiovascular diseases, coronary heart disease, stroke, diabetes, and gastrointestinal disorders. The consumption of dietary fiber helps to decrease the serum lipid concentrations, to decrease blood pressure, to improve blood glucose control in diabetes and improves regularity in excretion. Additionally, the consumption of foods with high fiber helps with weight loss and results in an improvement in immune system. Fiber has been found to have blood cholesterol lowering actions (Kaushal and Joshi 1995). Functional properties of fibers include water holding capacity, swelling capacity, viscosity or gel formation, bile acid binding capacity, cation exchange capacity (Femenia et al. 1997; Gallaher and Schneeman 2001).

Diets high in fruits and vegetables have been attributed to risk reductions of certain chronic diseases such as cardiovascular diseases, diabetes, and even cancer due to their levels of phytochemicals (Boyer and Liu 2004). Apples, a large contributor of phenolics in the diet, make up 22% of phenolics consumed in the United States (Vinson et al. 2001). They also contain the second highest total phenolic content and total antioxidant activity compared with other fruits (Sun et al. 2002).

The reduction of risks for lung cancer, cardiovascular diseases, asthma and diabetes have been attributed to the high flavonoid content, specifically phloridzins and quercetins, of apples. Several studies found the consumption of apples and onions helped decrease risks of lung cancer (Feskanich et al. 2000; Le Marchand et al. 2000). An inverse relationship between consumption of flavonoids and the development of lung cancer was observed in a Finnish study of 10,000 men and women over a 24 year period (Knekt et al. 1997). Apple flavonoids have also been attributed to a reduction of cardiovascular disease risk in women (Sesso et al. 2003; Knekt et al. 2003). Consumption of other flavonoids like epicatechins and catechins have been linked to a lowered risk of coronary heart disease (Arts et al. 2001). People whose diets were high in apples had a decreased risk of thrombotic stroke as compared with people whose diets were low in apples (Knekt et al. 2000). The consumption of apples have also been linked to a lower risk of asthma due to its quercetin content (Knekt et al. 1997; Shaheen et al. 2001). Increased intake of apples have been associated with reduced risk of type II diabetes (Knekt et al. 2002).

Epicatechins, catechins, and procyanidins have been found to have low density lipoprotein (LDL) oxidation reducing properties *in vivo* as well as high antioxidant activity (da Silva Porto et al. 2003). The LDL oxidation inhibition of various commercial apple juices was compared with the whole fruit, the flesh, and the peel of Red Delicious apples. In comparison to various commercial apple juices, the LDL oxidation inhibition of Red Delicious peels, flesh and whole apples were higher than that of the commercial juices (Pearson et al. 1999). Additionally, the Red Delicious peels had greater oxidative inhibition compared to that of just the flesh.

Apple Pomace

The two waste products generated from apple processing are belt rejections and pomace. Belt rejections are apples discarded due to bruises or spoilage. Pomace is the remaining skins, flesh, leaves, seeds, and core of the fruit after juice pressing; generally, juice processing recovers three quarters of the fresh weight as juice and the remaining quarter is the pomace (Francielo et al. 2008). Because raw apple pomace is a high moisture medium (70 - 75 %), it becomes an ideal medium for microbial growth followed by fermentation. Because of its highly fermentable nature and high chemical oxygen demand (COD) of 250 - 300 g/kg if directly disposed into landfills, raw apple pomce could potentially contribute to pollution problems (Kaushal et al. 2002). Alternative solutions and usages have been explored. Apple pomace can be a potential source for ethanol, pectin, citric acid, coloring and flavoring agents, or even serve as a processing aid (Mahawar et al. 2012). Because pomace also contains the whole skin of the apple, it is thought to be more healthful due to the higher concentration of antioxidants in the skin. Flavonoids found in the peel may be two or three times higher than found in the flesh (Boyer and Liu 2004). Current cheap uses of apple pomace are fed to animals as a part of feed (Hang and Walters 1989).

The high total phenolic content and antioxidant activity, along with high dietary fiber content, of apple pomace makes for a great value-added food ingredient. Pectin has been successfully extracted from apple pomace (Sharma et al. 1985; Maria et al. 2009). Min et al. used the pectin extracted from apple pomace as a fat replacer in a model food system (2010). They found that apple pomace pectin resulted in a more tender and lighter colored product. Apple pomace has also been incorporated into food products like jams and jellies successfully (Joshi et al. 1995; Madieta et al. 2006).

The incorporation of apple pomace powder has also been incorporated into cakes as a source of added fiber and polyphenols (Sudha et al. 2007; Masoodi et al. 2002). While the addition of apple pomace powder increased water absorption, interfered with leavening, and increased in shrinkage and uniformity index, the pomace increased fiber and polyphenols in the cakes. Additionally, wheat flour muffins containing apple skin powders increased total dietary fiber and total phenolics as well as antioxidant activity and were found to be organoleptically acceptable for up to a 24 % replacement (Vasantha Rupasinghe et al. 2009).

The addition of apple fibre powder in cookies also affects the water absorption, and dough development time. The powder reduced the specific volume and volume index of the cookies (Kohajdova et al. 2011). Additionally, spray-dried apple fiber was incorporated into different baked goods and similar results were found. The apple fibre decreased volume within the final baked good (Chen et al. 1988). Drum-dried apple pomace have also been incorporated into various baked products such as pie filling and oatmeal cookies with moderately liking from sensory panels (Carson et al. 1994). Apple pomace powder has also been incorporated into breads at 20% and cookies at 30% successfully (Ivy and Singh 2006).

Because toxicity incidents have been documented from the consumption of apple seeds, they should be removed from the pomace prior to any processing for human consumption. Apple seeds contain the compound, amygdalin, a cyanogenic glycoside (Lu and Foo 1998). Cyanide, in the form of HCN, functions as a stimulant for seed germination in apple seeds (Gniazdowska et al. 2010). Ethylene contributes to the ripening of a fruit; studies have found a relationship between cyanide metabolism with ethylene biosynthesis in apples (Mizutani et al. 1987). Amygdalin has historically been used as an anti-cancer agent but it has been linked to fatal rat studies as well as cyanide poisoning from human ingestion (Khandekar and Edelman 1979; Humbert et al. 1977).

Drying Techniques

Processing apple pomace into powder form is advantageous to improve its handleability, transportation, shelf-life, and retention of bioactive compounds. Previously, freeze drying was found to be the best method to retain more total phenolic compounds within the apple peels when compared with oven drying and air drying (Wolfe and Liu 2003). However, Yan found the physical properties, flowability, hygroscopicity, and color, as well as the concentration of total phenolics and total dietary fiber, between vacuum belt dried apple pomace powder were no different than freeze dried powder; they concluded that apple pomace powders were acceptable as a potential functional food ingredient (2012).

Vacuum belt drying is a semi-continuous method of dehydration in which the product is heated by both conductive and radiative plates under high vacuum. Originally, continuous vacuum drying methods were utilized to dehydrate juices and extracts (Brown et al. 1964). Advantages for using vacuum belt drying are the improved quality and retention of critical nutritional compounds due to the high drying rate, relatively low drying temperature, and low oxygen environment. Vacuum belt drying of *Panax notoginseng* yielded a higher recovery of the desired bioactives as compared with vacuum freeze drying and spray drying (Liu et al. 2008). Maltini et al. found vacuum belt drying was successful in the dehydration of apple, pear, apricot, and peach concentrates (1992). Vacuum belt drying is a gentle process that can help retain heat labile compounds.

Oats

Oats (*Avena sativa* L.) have been traditionally used in animal feeds, but have increased in popularity in human consumption due to its health benefits. While they generally serve as carbohydrates to provide energy in our diets, they also contain proteins, essential vitamins, minerals and fatty acids. More importantly, they are a valuable source of soluble fiber (Peterson 1992).

Oats contain high levels of fiber from their fibrous hull. The fiber concentration of whole oats range from 200- 370 g/kg (Frolich and Nyman 1988). Generally, the dietary fiber content for oatmeal was found to be around 120 g/kg (Shinnick et al. 1988). Compared with other cereals, oatmeal contains high concentration of soluble fibers. These soluble fibers are mainly (1→3), (1→4)-β-D-glucans, or β-glucans. The health benefits have been attributed to presence of β-glucans in oatmeal which include reduced levels of blood cholesterol. Food products containing oats may carry a FDA approved health claim due to its β-glucan content "0.75 g soluble fiber per serving can reduce the risk of heart disease" (FDA 2013).

Baking Process

Baking is a process that involves cooking a product with convective heat which heats the product from the surface towards the center. Common foods that are baked include breads, cakes, muffins, scones, and cookies. During the baking, many chemical transformations occur within the food product that would not naturally happen at room temperature. One of the first things that happens once the product is in the oven is the melting of solid fats. In general, the melting temperature of solid fats range from 30 to 50 °C. This step aids in leavening of a product because trapped air and water leave the fats as steam which help to expand the little cells in the product. Once the fat melts, it begins to interact with compounds that affect the structure and matrix, like gluten, egg proteins, and starches; these interactions limit the formation of structure and tenderizes the product. Fats also contribute to thinning dough/batters which may be desirable in some cases like cookie spread.

The formation and expansion of gases also occur in this process. Three important gases that contribute to leavening in a baked product are air, steam and carbon dioxide. Air would have been whipped into the batter or dough during the mixing step. The steam is a result of water in the batter that has evaporated. Carbon dioxide is formed from either the fermentation step with yeasts before it dies or from chemical leavening agents. As these gases are formed, they expand air pockets in the batter and dough to create volume.

In most batters and doughs, sugars will have dissolved during the mixing step and prior to baking. However in most cookie doughs and most cake batters that are high in sugar and low in moisture, the sugars are not completely dissolved prior to baking. These undissolved sugars end up melting during the baking process and interacting with water molecules in proteins and starches that results in thinning of the batter/doughs.

Prior to baking, gluten is formed from hydration and working of the dough. Coagulation of proteins like egg and gluten begins around 60-70 °C and helps to form the porous structure in many baked goods. The volume of the final product depends on the gas expansion paired with the coagulation of the proteins.

Additionally, starch gelatinization contributes to the formation of the final matrix and crumb structure. Granules of starch swell and soften as they absorb water molecules released by gluten and proteins. This process begins around 50 – 60 °C and continues until 95 °C if water molecules are still present. As the granules absorb water, this causes thickening in the dough/batter. Factors that affect starches gelatinization include water, time, temperature, as well as other ingredients that may increase the temperature at which gelatinization occurs. Often times, starches in baked products are never fully gelatinized because of limiting time and water content.

Additionally, the evaporation of gases contributes to the leavening process. Gases, such as flavoring agents and alcohols produced from fermentation, moves around the dough during the initial stages of the baking while the dough is still moist and has not set. Once enough gas has formed and expanded, they cause ruptures in the air bubbles as they escape. Simultaneously as the gases evaporate, the protein coagulation linked with starch gelatinization processes are occurring. These result in the hardening and the setting of the structure as a result of moisture loss with protein coagulation and starch gelatinization.

Other important reactions that occur during the baking process include the Maillard reaction occurs in the presence of reducing sugars and proteins and contributes to the browning and flavor compounds found desirable by consumers. Additionally, due to the high temperature in the oven, enzymes may become inactivated and some of the nutritive compounds may breakdown. Most microorganisms such as yeasts, molds, and bacteria generally die in between 55- 60 ºC. Microbe death may also depend on sugar and salt content as well as the temperature resistivity of the specific microorganism. After the baked product is removed from the oven, carryover cooking occurs while the product cools down back to room temperature (Figoni 2011).

Cookies

In America, cookies are a flat, sweetened small. They are generally formulated with flour, sugar, eggs, fats, and leavening. The texture of cookies can range from crispy to chewy, flaky to crumbly, or dry to moist. Cookies are often classified by how they are prepared: drop cookies, cut-out cookies, hand-shaped cookies, bar cookies, and icebox cookies. Drop cookies are portioned in spoonfuls from soft dough and dropped onto the baking sheet. Cut-out cookies are prepared from rolled-out stiffer doughs and then cut with cookie cutters. Hand-shaped cookies are prepared from prior chilling of the dough and then formed by piping or molding. The shape of bar cookies are formed and molded after baking. Icebox cookies are prepared from slicing the cross section of chilled dough logs (McGee 2004). Cookies are a popular snack food all over the world. In 2012, the sales for cookies grew to $4,410.5 million, which was a 3 % growth (Malovany 2013). Popular trends like calorie-controlled packaging, all-natural, healthier and premium alternatives are emerging for the cookie market.

Oatmeal cookies are an example of drop cookies. Their origins have been linked with the Scottish oat cakes. The first recorded recipe was written by Fannie Merritt Farmer in 1896 and was marketed originally as a health food (Anon. 2010). The recipe was later printed on Quaker Oats containers in the United States. They are a better vehicle to contain apple pomace because of their dense structure, comparatively to breads or cakes which are more voluminous and airy, and their easy-to-grab and snackable form. As previously stated, oatmeal cookies were originally marketed as a health food and the addition of apple pomace powders would potentially increase the nutritive value of oatmeal cookies.

Extrusion Process

Many food products, such as puffed snacks, pastas, ready-to-eat cereals, and pet foods, are produced with extrusion technology. The extrusion process involves a moving screw placed tightly within a barrel in which the product is quickly cooked by thermal energy and the shearing mechanisms. This is highly efficient as it is a high temperature and short time processing method.

Prior to extrusion processing, food products were cooked first and then formed into desired shape with forming extruders. This machinery can be utilized to provide low shearing, through low screw speed as well as deep flight, to help reduce starch retrogradation as well as product heating. However in the more recent years, both cooking and forming steps can be accomplished within one extruder. These extruders typically require longer screw lengths (L/D up to 30) (Miller 1990). Most of the barrel is dedicated to cooking the dough while the forming section is very short and cool. The sections are separated with a vent which helps to quickly remove the heat from the cooking step.

The moisture content within the barrel is another important factor because water is involved with starch gelatinization. At high moisture content, starch granules are able to swell and gelatinize. Starch conversion become an important factor as the melt structure loses crystallinity and becomes more amorphous. Bubble nucleation and growth during the glassy state impacts expansion, which is critical for texture development for puffed foods (Altan and Maskan 2012). Expansion occurs at the exit of the barrel as a result of the pressure difference between the water vapors in the bubbles and the atmospheric pressure (Arhaliass et al. 2003). A secondary drying step is required after the puffing in order to develop the crispiness, color and flavor.

Extrusion parameters that affect the final product include barrel temperature, screw speed, water feed rate, and dry feed rate. The temperature of the barrel affects the degree of vaporization from the product as it leaves the extruder. This in turn affects how much the product expands; an increase in the barrel temperature will increase expansion and decrease moisture. The screw speed impacts the length of the cooking section in the extruder; an increase in the speed results in a decrease in the cooking zone because not as much of the barrel is required to move the material (Miller 1990). An increase on the water feed generally increases the moisture content of the dough. However, the degree of puffing depends on both the moisture and the barrel temperature. An increase in the dry feed rate reduces the residence time in the barrel and results in a lower product temperature, higher melt viscosity and a denser product (Yacu 2012).

Sugars often reduce the apparent viscosity and reduces the extent of gelatinization. So, higher cooking temperatures are needed in order to offset the reduction in gelatinization as well as to increase water activity in improving puffing (Miller 1990). Reducing sugars may react and result in Maillard Browning products that may destroy essential amino acids such as lysine (Harper 1981). Salt is generally added for flavors, and has no expansion qualities. The addition of fiber often results in a denser extruded product (Yacu 2012). It was thought that fibers compete with starches for water as why fibers generally do not expand as starches do.

Expansion is an important factor in puffed extruded snacks to develop the crispness and texture of the food product. Crispness is a textual quality of the food related to the brittle cell structure along with the high-pitched sound upon fracturing (Les Meste et al. 2002). The difference between the vapor pressures within the cells of the extrudate and the atmosphere leads to the immediate flashing and expansion. Expanded volume and bulk density are measures of expansion. High concentration of fiber will limit expansion because of dilution of starches. The addition of fiber creates a product that does not expand readily and decrease results in the eating quality of the cereals. The addition of expansion agents such as wheat starches, potato starches, tapioca starches, and rice flour is used to help improve texture, processing and quality.

Ready to Eat Cereals

According to the US Food and Drug Administration, a ready-to-eat food is defined as a food already in ‘form that is edible without additional preparation’ (Food Code 2013). Ready-to-eat (RTE) cereals have been a popular breakfast choice in the modern world due to their shelf stability, high convenience, little to no preparation, and easy storage. The first step of RTE cereal processing usually involves a cooking step to impart flavors into the grains using sweeteners and flavoring agents. Fortifying heat stable nutrients are added before this step. The cereals are cooked by a batch-wise steam injection into a rotating drum or a continuous extrusion process (Fast 1990). Continuous processes are economically advantageous due to the lower costs for energy and labor, better usage of plant space, and lower ingredient costs. Continuous processes also offer greater control, increased uniformity, and the ability to create large quantities without compromising the quality (Caldwell et al. 1990). The extrusion technology became more prevalent in the cereal foods industry in the early 1950s. The earliest extruders used were the single-screw extruders which are still used today. Single-screw extruders moved the product at low screw speeds with low shear and high temperature (Caldwell et al. 1990). In the 1970s, both the counter-rotating and co-rotating twin-screw extruders were adapted from the plastics industry into cereal processing (Yacu 2012).

The main types of breakfast cereals are flaked, expanded, and shredded. Flaked cereal grains are typically wheat, corn, rice and oats. Grains are cooked first then shaped in a forming extruder. The forming section of the barrel is often kept at a lower temperature than the cooking section. Expanded cereals are grains that are puffed either through oven puffing or gun puffing. Puffing occurs when cooked grains under high pressure undergo a sudden pressure drop. Grains typical in conventional oven puffing are rice and corn; in gun puffing, rice or wheat are the more typical grains used. Shredded cereals are most commonly made using a wheat base (Seker 2012). A rotating knife at the die exit can be used to cut the extrudate into pieces called collets that can be subsequently flavored or coated (Burns et al. 2000).

RTE foods have become a convenient fast food that fit the eating habits of current consumers (Fast 1999). However many of these food products are made of processed grains which contain high starch content such as corn, rice, oats, and wheat. Due to the high starch content and low levels of other nutritional compounds like vitamins, amino acids, and fiber, many RTE foods are considered to be energy dense and nutrient deficient (Brennan et al. 2013). As current consumers have become more aware of foods they eat and more health conscious, there is a drive for healthier RTE snack.

Fruit/Vegetable Powders as a Value-Added Ingredient

The recommended dietary intake of fiber in the United States is 25-30 g/day for adults (USDA and USDHSS 2010). However, the typical American adult consumed only about 10-15 g/day. There is great interest in development of a value-added food ingredient that could be incorporated into commonly consumed food products yet additionally contain a higher amount of fiber.

According to Larrauri, the ideal dietary fiber fruit powder must accomplish the following: little flavor, color and odor; must be highly concentrated; no nutritionally questionable composition; decent shelf life; processing compatibility; well-balanced component of nutrients and bioactives (1999).The addition of plant fibers to a food product contribute to the products water holding capacity as well as the viscosity (Kethireddipalli et al. 2002). Citrus and apple fibers were deemed to be better quality due to their high levels of antioxidant like flavonoids, polyphenols and carotenes (Fernandez-Gines et al. 2003).

Baked products can serve as a vehicle to deliver dietary fiber (Lebesi and Tzia 2011). The incorporation of pomace powders from both fruit and vegetables into baked products have been studied for cookies, cakes, breads, muffins (Table 2.1). Because pomace powders often contain a higher fiber content compared to the refined grain flours typically used in baked goods, they can be used to increase fiber content (Sudha et al. 2007; Acun 2014; Gorecka et al. 2010; Kohajdova et al. 2012). The addition of pomace powders may also increase the total phenolic contents of the cookies without any negative sensory effects (Sudha et al. 2007; Vasantha Rupasinghe et al. 2008). However, the incorporation of pomace into baked products may result in decreased volume and a denser product (Sudha et al. 2007; Kohajdova et al. 2011; Kohajdova et al. 2012). In some cases depending on the type of product, the addition of pomace may improve desirable textual qualities such as increased softness in breads and biscuits (Kohajdova et al. 2012; Mildner-Szukudlarz et al. 2013).

One of the first studies on the incorporation of fruit powders in an extruded product explored the possibility for imparting flavors within the extrudate as opposed to on the surface (Maga and Kim 1989). Fruit and vegetable powders have been incorporated in many different types of cereal bases such as corn, rice, barley, sorghum, and oats (Table 2.2). In general, because the pomace contains relatively high levels of dietary fiber, its incorporation into an extruded snack results in decreased expansion and puffiness (O'Shea et al. 2014; Karle et al. 2012; Selani et al. 2014). Its addition may result in a harder or crisper product (Dar et al. 2014). Loss of phenolic compounds is also a concern with extrusion due to processing conditions like temperature (Riaz et al. 2009). While pomace can be a valuable source of phenolic compounds and its addition may improve phenolics content in the final extrudate, the extrusion process may degrade these products (Altan et al. 2008a). However, extrusion processing potentially may improve bioavailability of certain phenolic compounds (Brennan et al. 2011). For example, the extrusion process increased the levels of procyanidin monomers, dimers, and trimers from blueberry pomace in a sorghum extrudate (Khanal et al. 2009).

Table 2.1 – Fruit and Vegetable Pomace Incorporation in Baked Products

Type	Product	Notes	Reference
Apple	Cake	Addition of pomace increased water absorption, decreased dough stability, and decreased cake volume decreased. Total phenolics content and total dietary fiber increased with the increase of apple pomace.	Sudha et al. 2007.
Apple fibre	Cookies	Apple fibre powder was substituted at 0, 5, 10, and 15% of fine wheat flour. Addition of fruit powder reduced specific volume, volume index, thickness and width. Cookies with up to 10 % apple fibre substitution was sensorially acceptable.	Kohajdova et al. 2011.
Apple skin	Muffins	Total dietary fibre, total phenolics and total antioxidant capacity increased with the increasing levels of apple skins added into the muffins.	Vasantha Rupasinghe et al. 2008.
Carrot	Wheat rolls	Pomace replaced fine wheat flour at 1, 3, 5, and 10%. Carrot pomace was found to be a good source of total dietary fiber and increased water absorption, dough development time and dough stability while decreasing loaf volume. Loaves made with 3% carrot pomace were found to be most acceptable.	Kohajdova et al. 2012.
Grape	Cookies	Grape pomace incorporated at 10% with seeds were found have higher total dietary fiber and total phenolics. Pomace did not have a significant effect on width, thickness, and spread ratio of cookies. Cookies with 5% pomace with seeds were most acceptable.	Acun and Gul. 2014.
Raspberry	Cookies	Crumbled and non-crumbled raspberry pomace replaced flour at 25 and 50%. The substitution with raspberry pomace increased the total dietary fiber with no negative affects on the sensory properties.	Gorecka et al. 2010.
White Grape	Wheat biscuits	White grape pomace was added at 10, 20, and 30% in wheat flour. Addition of pomace decreased water absorption and reduced hardness. Using radical-scavenging activity assay, the addition of pomace increased antioxidant properties of biscuits. Most sensorially acceptable cookies were the 10% pomace addition.	Mildner-Szukudlarz et al. 2013.

Table 2.2– Recent Fruit and Vegetable Pomace Incorporation in Extruded[1] Products

Type	Base	Notes	Reference
Apple	Corn Flour	The increase of apple pomace and screw speed resulted in lower expansion. Additionally, an increase in bulk density increased as screw speed increased. Screw speed had the greatest effect on quality of extrudate compared to die temperature.	O'Shea et al. 2014.
Apple	Corn Flour	The increase of apple pomace resulted in a decreased radial expansion but an increased in cell number density as well as longitudinal expansion.	Karkle et al. 2012.
Blueberry	Sorghum	Procyanidin monomers, dimers, and trimers from blueberry pomace increased with extrusion processing.	Khanal et al. 2009.
Carrot	Rice Flour	An increase in the extrusion temperature resulted in a higher crispness for carrot pomace-based rice extrudates as well as a harder and more compact texture.	Dar et al. 2014.
Tomato/ Grape	Barley	Total phenolics and antioxidant activity decreased for barley, barley-tomato pomace, and barley-grape pomace extrudates from processing. B-glucan content was higher in extrudates of only barley flour compared to that of barley-pomace extrudates.	Altan et al. 2008.
Pineapple	Corn flour	While the addition of pineapple pomace decreased expansion, hardness and bulk density of extrudates containing 10.5% pomace to be no different than the control.	Selani et al. 2014.

[1] All extruded products in this table were processed using a twin-screw extruder

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CHAPTER 3

EVALUATION OF VACUUM BELT DRIED APPLE POMACE POWDERS IN OATMEAL COOKIES[1]

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Abstract

Oatmeal cookies were prepared with vacuum belt dried (VBD) apple pomace (AP) powder (0, 5, 10, 15 g/100 g dry ingredients) and varying dough moisture content (13, 15, and 17 g H_2O/100 g cookie), and evaluated for physical, chemical and sensory properties. Greater levels of AP and dough moisture resulted in slightly higher a_w. Higher levels of AP also produced a slightly lighter cookie with a stronger yellow saturation.

Higher AP levels also resulted in increased cookie thickness, and decreased width and spread factor. Puncture tests indicated that greater AP levels resulted in tougher, but differences were not great. Both total phenolics content (TPC) and total dietary fiber (TDF) increased with pomace incorporation. For 1 serving size, cookies of the highest pomace substitution contained 4.09 g TDF and 33.04% more TPC. Overall consumer acceptability for the cookies fell in acceptable range with cookies of highest substitution rated least acceptable.

Introduction

Apple pomace (AP), the waste product from juice processing, contains the skins, flesh, seeds and sometimes leaves of the full apple after pressing. It is a significant contributor to environmental waste, and due to its high moisture content serves as a potential fermentable medium that could lead to microbial hazards (Kaushal et al. 2002). Traditionally, apple pomace has been sent to landfill or used for animal feed (Hang and Walters 1989). Apple pomace can be dried into powders to improve shelf life, transportability and ease of use in formulating products. The powder contains relatively high levels of dietary fiber and polyphenols which could be incorporated into other food matrices as a value-added food ingredient.

Many drying technologies use hot air, and these can be detrimental to AP powder color, nutrient and phytochemical content. While freeze drying can produce powders with minimal chemical changes, the costs and lengthy drying times can be prohibitive. Previous research has shown that continuous vacuum belt drying could be used to produce AP powders with good color and polyphenolics content comparable to freeze drying (Yan 2012). Vacuum belt drying (VBD) results in less chemical changes in the product, as the low pressure environment allows drying at relatively low temperatures. This process allows for the product to retain more of the heat sensitive chemical compounds compared to other drying techniques (Liu et al. 2008).

The dietary fiber in apples consists mainly of celluloses, hemicelluloses and lignins from the plant cell wall, and cannot be readily digested by humans. The consumption of dietary fiber has been linked to lowered risks of obesity, hypertension, cardiovascular disease, stroke, diabetes, and gastrointestinal disorders (Kaushal and Joshi 1995). Fiber helps regulate lipid levels in blood serum, promote regularity in the colon, and lower blood cholesterol levels. Apples contain both soluble and insoluble dietary fibers and are mostly made up of celluloses, hemicelluloses, pectins, lignins, non-starch polysaccharides, β-glucans, and gums (Gallaher and Schneman 2001; Lamghari 2000).

The consumption of fruit and vegetable phytochemicals may also provide health benefits. Many contain flavonoids and other phenolic compounds that have been linked to lowered risks of cardiovascular diseases, diabetes and cancer (Boyer and Liu 2004).

Approximately 20 % of all phenolics consumed in the United States (Vinson et al. 2001) come from apples. Apples also have the second highest total phenolics content and total antioxidant activity when compared with other fruits (Sun et al. 2002). The phenolics in apple pomace include phloridzins, quercetins, epicatechins, catechins, procyanidins, courmaric acids, gallic acids, and chlorogenic acids (Boyer and Liu 2004; Lu and Foo 1997). Phloridzins and quercetins have also been found to help reduce risks of lung cancer, cardiovascular diseases, asthma and diabetes (Feskanich et al. 2000; Le Marchand et al. 2000). The higher concentration of flavonoids in the apple skin allows for pomace to be considered more healthful because it contains both skin and flesh (Wolfe et al. 2003; Lata 2007).

While the daily recommended dietary fiber intake for American adults is 25- 30 g/day, the typical American adult consumes only 10-25 g/day (USDA and USDHSS 2010). The development of foods containing value-added ingredients such as fruit and vegetable powders to deliver additional dietary fiber is increasing due to consumer demand for healthier alternatives (Brennan et al. 2013). The ideal dietary fiber fruit powder would have: high levels of fiber; mild flavor, color and odor; no nutritionally compromising compounds; reasonable shelf life; good ability to be processed into foods; and balanced composition of nutrients and bioactives (Larrauri 1999). Because apples also contain high levels of phenolics such as flavonoids, polyphenols, and carotenes, they make for an excellent value-added fruit powder (Fernandez-Gines et al. 2003).

Few studies have investigated the use of apple pomace as an ingredient for snack foods. Drum-dried AP has been used as an ingredient in pie filling and oatmeal cookies, without any changes in product physical properties (Carson et al. 1994). When hot-air dried AP was incorporated at 0-15% into cake batter, it increased cake weight and shrinkage with increasing pomace addition (Masoodi et al. 2002). No studies have been done investigating freeze-dried or VBD apple pomace in formulated food products. Cookies are a convenient snack vehicle because they are ready-to-eat, widely consumed, and relatively stable shelf life (Tsen et al. 1973). Additionally, cookies for their relatively dense and compact structure can potentially deliver higher amounts of pomace without compromising physical qualities like volume and density comparatively to high volume baked products like breads and cakes. The purpose of this study was to evaluate the physical and chemical characteristics, and consumer acceptability of oatmeal cookies with 0, 5, 10, and 15 g/100 g dry ingredients (DI) pomace substituted for all-purpose flour. In addition, the levels of added moisture were also studied as the AP may have different water binding properties, and the amount of water needed to optimize the properties of cookies with AP may be different than that of cookies with flour only.

Materials and Methods

Chemicals and reagents

Food grade ascorbic acid was supplied by Prinova USA (Carol Stream, Il). Citric acid was obtained from Tate & Lyle (Decatur, Il). Sodium hexametaphosphate and NaOH were obtained from the JT Baker Chemical Co. (Phillipsburg, NJ). Folin-Ciocalteu reagent and the total dietary fiber assay kit (including amyloglucosidase solution from *Aspergillus niger*, α-amylase, and protease from *Bacillus licheniformis*) were obtained from the Sigma-Aldrich, Co. (St. Louis, MO). Acetone, hexane, methanol, and hydrochloric acid (HCl) were purchased from by Fisher Scientific (Fair Lawn, NJ). Ethanol was purchased from AAPER Alcohol & Chemical Co. (Shelby, KY).

Apple pomace powder processing

Apple pomace was obtained August 27, 2013 from Mercier Orchards (Blue Ridge, GA) and included a mix of Gala, Honeycrisp, and Ginger Gold varieties. Apples were fed to an on-site continuous belt press to squeeze out the juice, and pomace was directly collected upon exit. The pomace was immediately dipped into an anti-browning solution of 2% (w/v) ascorbic acid, 1% (w/v) citric acid and 1% (w/v) sodium hexametaphosphate for 3 min before dewatering with a cheesecloth. The pomace was stored in polyethylene buckets and kept frozen at -20 °C.

The pomace was left to thaw overnight at 4 °C prior to drying. Prior to processing into pomace powder, the thawed pomace was then rinsed with the same volume deionized water twice to remove sugars in order to prevent Maillard browning during dehydration. Pomace powder was produced by VBD as described by Yan and Kerr (2013), using a Zwag CH-5312 VBD (Zchokke Warman Ltd. Bucher, Dottingen, Switzerland) as shown in Figure 2.1. The pomace was rolled to 4-5 mm thickness and placed on the Teflon-coated fiberglass conveyor belt. The pressure in the chamber was maintained at 2.5 - 3.3 kPa. The pomace was dried at plate temperatures of 95 °C for approximately 120 min until a a_w of 0.25 ± 0.05 was reached. Dried pomace was chopped with a sabatier blade in a food processor (Model: KFP600WH, KitchenAid, St Joseph, MI) for 40 s. Further grinding was completed in a high speed blade 4-blade chopper (NutriBullet, Homeland Housewares, LLC., Los Angeles, CA) for 60 s. The powder was separated through a No. 70 sieve (USA Standard Sieve Series, Wire Cloth Company, Newark, NJ), leaving particles < 210 µm in size. The powder was then stored in metallized plastic bags (ABC Packaging, Avon, OH) at -20 °C until used.

Oatmeal cookies

The basic oatmeal cookie contained: 120 g old fashioned oatmeal (Publix Super Markets, Inc., Lakeland, FL), 110 g brown sugar (The Kroger Co, Cincinnati, OH), 76.8 g Crisco vegetable shortening (The JM Smucker Company, Orrville, OH), 50 g granulated sugar (The Kroger Co, Cincinnati, OH), 25 g liquid egg (Egg Beaters Original Liquid Eggs, ConAgra Foods, Omaha, NE), 13 g all-purpose flour (The White Lily Foods Company, Memphis, TN), 2.1 g pure vanilla extract (McCormick & Co., Inc., Hunt Valley, MD), 1.15 g baking soda (Arm & Hammer Baking Soda, Church & Dwight, Co., Inc., Princeton, NJ), 1.5 g salt (Great Value Iodized Salt, Wal-Mart Stores, Inc., Bentonville, AR), and 1.3 g cinnamon (Tone's, AchFood Companies, Inc., Memphis, TN). The apple pomace powder replaced the all-purpose flour as percentages of the dry ingredients (shortening, old fashioned oatmeal, baking soda, salt, and all-purpose flour). The water was added accordingly to achieve final dough moisture content in the dough of 13, 15 and 17 g H_2O/100 g cookie dough. From moisture measurements from the control dough, all-purpose flour, and pomace powder (Anon 1999b), the final dough moisture content could be determined from calculations. The cookie batter was mixed in a stand mixer (Model: KP26M1XWH, KitchenAid, St Joseph, MI) with a flat beater attachment. Oatmeal cookies were prepared by first beating the sugars and the shortening together at speed 2 (54 rpm) for 1 min. Eggs, vanilla extract, and water were added and then the mixture was beaten at speed 4 (104 rpm) for 30 s. All other ingredients were considered to be dry ingredients, which included the flour, the oats, baking soda, salt, cinnamon, and apple pomace powder. The dry ingredients, including apple pomace powder when appropriate, were then mixed in for 1 min at stir speed (40 rpm). The cookie dough was scooped with a No. 60 scoop and deposited 4 rows down and 4 across on a parchment paper-lined cookie sheet pan (40.64 x 35.56 cm, T-Fal Original Insulated Bakeware AirBake, Tefal S.A.S. France, Rumilly, France). The cookies were flattened by placing another sheet of parchment paper on top of the cookies, then placing a second cookie sheet on top and gently pressing down twice (first up and down; second left right); dough guides (15.875 mm) were used to maintain consistent thickness. Oatmeal cookies were baked at 176 °C for 12 total min; at 6 min, the cookie sheet was rotated 180 ° (Perry et al. 2003). Cookies were stored in plastic Ziploc bags at room temperature until further testing.

Physicochemical properties

The cookie spread was determined in duplicate for all treatments following Method 10-50D and was conducted on the day of baking (AACC 1999a). The spread factor was calculated as the ratio of the width to the height as measured using calipers for six cookies. The spread factor was adjusted for barometric pressure of each day of baking.

Water activity was measured in triplicate at 24 h post-bake using an AquaLab Model Series 3 (Decagon Devices, Inc., Pullman, Washington).

Colorspace values L*c*h were obtained at 24 h post-bake for the surface of the cookies, using a Minolta spectrophotometer (model CM-700d, Konica Minolta Sensing, Inc., Ramsey, NJ) in triplicate. The spectrophotometer was calibrated with a white calibration tile (CM-A177). A D65 illuminant system was used, which mimics ‘average’ daylight with T~6500K.

Textural attributes were measured with a TA-XT2i texture analyzer (Texture Technologies Corp, Scarsdale, NY) using a puncture test (Gaines et al. 1992a; Gaines et al. 1992b; Perry et al. 2003). Each cookie was placed on a 9.6 mm thick aluminum stage, with a center hole 6 mm in diameter. A 3 mm diameter probe was lowered through the cookie at 5 mm/s, and travelled 25 mm after a minimum force of 10 g was measured. The force response was monitored over time with a 5 kg load cell. For each treatment, six cookies were tested at 24 h post-bake. The probing pattern was 1 puncture in the center and 4 radial punctures (Figure 3.2). The outer 15 % of the cookies was not probed to avoid edge effects. Each probe gave a force-time curve for which the slope, peak force, time to peak force, and area under the curve was determined.

Chemical tests

The moisture contents for both the dough and cookies were determined using a modified vacuum oven method 12 h post-bake (Anon 1999b). Samples were weighed into tared aluminum pans and dried at 70 ºC in a vacuum oven (Model 1430 MS, VWR Scientific, Radnor, PA, USA) until a constant mass was reached, and the moisture content determined from the change in mass. Measurements were taken in triplicate per treatment.

For total phenolics content and total dietary fiber tests, samples were freeze-dried to achieve an essentially moisture-free sample. The dried material was ground with a Sabatier blade in a food processor for 60 s (Model: KFP600WH, KitchenAid, St Joseph, MI). Samples were stored in aluminized PET bags (ABC Packaging, Avon, OH) at -40º C until further testing.

Total Phenolics Content (TPC)

Phenolic compounds were extracted by methods reported by Wolfe and Liu (2003). The freeze-dried samples were reduced to a uniform particle size using a 0.85 mm sieve (USA Standard Sieve Series, Wire Cloth Company, Newark, NJ). For each treatment, 15 ± 0.3 g samples were mixed with 120 g chilled 80 % (v/v) ethanol solution using a Polytron PT1200 homogenizer (Kinematica Ag, Luzern, Switzerland). The homogenized slurry was then filtered under vacuum using Whatman No. 1 filter paper in a Buchner funnel. The filter cake was washed twice with 15 ml ethanol solution. The filtrate was concentrated using a rotary evaporator (Model R110, Buchi Labortechnik, Flawil, Switzerland) at 45 °C until less than 10 % original volume remained. Extracts were made up to 50 mL with distilled water and stored in amber vials at -20 °C until further analysis. All extractions were done in duplicate.

A modified colorimetric method was used to measure the total phenolics content of the cookie samples in triplicate (Wolfe and Liu 2003). Deionized water (0.5 mL), known dilutions of the extracts (0.125 mL), and the Folin-Ciocalteu reagent (0.125 mL) were added into a test tube and gently vortexed for 10 s. The solution was left to react for 6 min. A 7 % sodium carbonate solution (1.25 mL) was then added to each tube. The solution was diluted to 3 mL with deionized water and then gently vortexed for 10 s.

Color was developed for 90 min and the absorbance at 760 nm was read with a spectrophotometer (Spectronic Geneys 2, ThermoFisher Scientific, Waltham, MA). A standard curve for gallic acid was developed in which the concentration, in units of mg gallic acid equivalents (GAE)/100 g cookie were determined. The percent change of TPC was determined by subtracting all average values of TPC by that of the control and dividing by the value of the control.

Total dietary fiber

Total dietary fiber (TDF) content of cookies was determined in duplicate using an enzymatic-gravimetric method (AOAC 985.29) with modifications. Prior to TDF analyses, the samples were freeze-dried as described above, then the fat extracted to remove fat from shortening. Approximately 30 g of dried sample was placed in a thimble, which was connected to a Soxhlet apparatus. The fat was removed with hexane, which was continuously refluxed and passed through the sample for 8 h.

The defatted samples (1 g ± 20 mg) were mixed with 50 mL pH 6.0 0.08M phosphate buffer and 0.1 mL heat-stable α-amylase in a 250 mL Erlenmeyer flask. Samples were then incubated in a 95 - 100 °C water bath for 20 min with gentle agitation every 5 min. The pH was adjusted to 7.5 ± 0.2 with 10 mL 0.275M NaOH solution, and then protease (5 mg) was added to the solutions. Samples were then incubated in a 60 °C water bath with continuous agitation for 30 min. The final pH was adjusted to 4.0 – 4.6 with 10 mL of 0.325M HCl solution, and then amyloglucosidase (0.3 mL) was added. Samples were incubated once more in a 60 °C water bath with continuous agitation for 30 min. Preheated 95 % ethyl alcohol (280 mL at 60 °C) was added to precipitate the soluble dietary fibers. Samples were filtered in fritted crucibles (with 0.5 g celite) with three 20 mL volumes of 78 % ethyl alcohol, two 10 mL volumes of 95 % ethyl alcohol, and two 10 mL of volumes of acetone. Crucibles containing residues were dried overnight at 70 °C in a vacuum oven (Model 1430 MS, VWR Scientific, Radnor, PA, USA). One portion was ashed for 5 h at 525 °C in a muffle furnace (Model: F46025, 48000 Furnace, Barnstead/Thermolyne, Dubuque, IA). A second portion was used to determine the nitrogen content with the Kjeldahl method completed by the University of Georgia Soils Lab. A conversion factor of 6.25 was used to calculate protein content. The total dietary fiber (%) of defatted cookies was calculated as:

$$TDF, \% = \frac{R_{sample} - P_{sample} - A_{sample} - R_{blank} - P_{blank} - A_{blank}}{SW} \times 100 \qquad (1)$$

where R is mean residue weight (mg), P is the mean protein weight (mg), A is the mean ash weight (mg), and SW is the average initial sample weight (mg).

Sensory evaluation

A consumer sensory panel (n=79) evaluated four samples of oatmeal cookies, containing four levels of AP powder, at the FST Sensory Laboratory at the University of Georgia. Panelists consisted of a cross-section of students, staff and faculty. Samples were accessed 24 h post-bake using a 9 pt hedonic scale (9=like extremely and 1 = dislike extremely) for appearance, flavor, texture and overall acceptability. Each treatment was labeled with a randomized three-digit code. Cookies were presented in a random and nearly balanced order. Panelists evaluated each cookie sample individually under white light and were given baby carrots and water for palate cleansing.

Statistical Analysis

Experiments were designed using a full factorial with 4 pomace levels and 3 moisture levels. Analysis of variance (ANOVA) and Tukey's Test ($\alpha<0.05$) was performed using JMP Pro 10 (SAS Institute, Cary, NC).

Results and discussion

Moisture content and water activity

The moisture content and water activity of food products are key properties that determine the textural and sensory properties. In this study, the moisture content of the dough was formulated to have 13, 15 or 17 g H_2O/100 g. This resulted in moisture contents ranging from 6.72 to 8.74 g H_2O/100 g in the baked cookie (Table 3.1). Neither pomace level nor original moisture were significant factors. a_w values ranged from 0.517 to 0.632, which were all higher than previous reported by Kane et al. (2011). Both pomace level and the interaction with moisture were significant, with the general trend that higher levels of pomace resulted in slightly higher a_w. Chen et al. (1988) indicated that the fiber in apple pomace has relatively high water holding capacity. Baked goods with a_w in this range have a relatively longer shelf life at room temperature compared to higher moisture baked goods such as breads and cakes (Smith et al. 2004), with osmophilic yeasts and molds being the only concern. Cookies also contain a relatively high percent of fat and sugar which helps to slow staling and microbiological growth (Galic et al. 2009).

Colorspace L*c*h

The two-way ANOVA results showed that pomace level (and interaction with moisture content) were statistically significant ($p \leq 0.05$). In this study, AP powder (L*=72.11, c*=25.06, h=83.56) was substituted for the all-purpose flour (L*=97.91, c*=4.18, c=113.4) in percentages of the total dry weight. L* ranged from 21.23 to 37.14, and surprisingly, increasing levels of pomace produced a slightly lighter cookie when the L* value for pomace was lower compared to that of the all-purpose flour. This indicated that the inherent color of the pomace powder did not influence the color of the final cookie product. The pH of the washed pomace dried to drying was approximately 3.02. The addition of pomace powders reduced the extent of Maillard browning resulting in a lighter cookie because of the added acidity to the cookie dough. Traditionally, the baking soda functions to neutralize any acidic ingredients in the cookie formulation which helps to promote browning. However, it was possible that the amount of baking soda was inadequate to neutralize the acidity coming from the AP powders. As expected, higher levels of pomace resulted in slightly greater color saturation, with c* ranging from 20.86 to 27.85 because c* of the AP powders were higher than that of the flour. Hue angle (h*) varied from 78.25 to 79.30 (orange-yellow region) although differences were not significant (Table 2.3).

Cookie spread

With increasing levels of AP powder added, the cookie thickness increased while the width and adjusted spread factor decreased (Table 2.3). Both pomace and moisture content were significant factors affecting the width, although pomace levels had a greater influence on the width. Pomace level was the only significant factor for thickness. Thus, cookies with the highest AP powders levels were thicker and less wide. Both pomace and moisture content levels were significant factors affecting adjusted spread factor, although again pomace had a greater influence on the adjusted spread factor. The adjusted spread factor was determined to be the width divided by thickness with corrections for barometric pressure from the day of baking. The addition of AP powder resulted in cookies with a reduced spread factor. For example, cookies with 0 g AP/100 g dry ingredients had a spread factor between 62.38 and 70.9, while those with 15 g AP/100 g dry ingredients had a spread factor of 29.8 to 34.73. However, the spread factors for cookies containing 10 and 15 g AP/100 g dry ingredients were not significantly different. Kohajdova et al. (2011) also found that the incorporation of apple fiber powder in cookies resulted in less spread. Chen et al. (1988) suggested that apple fibers have strong water absorption capacity, which might reduce shrinkage during bake-off. However, major changes in moisture properties due to inclusion of AP were not detected. One possibility is that the high fiber pomace powder that includes pectins, hemicelloloses and other large polysaccharides contributes to a continuous or gel-like network that resists deformation under the forces of gravity. As previously discussed, the pH of the washed pomace was approximately 3.02 which caused an increased acidity in the cookie dough with the addition of pomace powder. Acids promote protein coagulation which in turns sets the cookie shape quickly and reduces spread (Corriher 2008).

Texture analysis

Results from the puncture texture tests are shown in Table 3.4. The maximum force reached as the probe penetrates the cookie has been related to hardness (Gaines et al. 1992a,b), while the area under the force-time curve is an indicator of toughness (Sanchez et al. 1995). The combination of time to max peak and the initial slope may indicate the cookies chewiness (Perry et al. 2003). Both dough moisture content and AP level were significant factors for toughness. While the toughest cookies contained the highest levels of AP powder and had the lowest dough moisture content, the least tough cookies contained no AP powder and had the highest dough moisture content. The addition of AP may increase toughness by gluten dilution when fiber is added, creating a more continuous fiber network that is more difficult to break apart (Pomeranz et al. 1977). The addition of water may help to thin out the dough, which could potentially improve cookie spread and reduce toughness.

Both AP level and dough moisture were significant factors for hardness. In general, samples starting with lower moisture dough were harder, as were those with greater AP levels. The hardest cookies were those containing 10 g AP/100 g dry ingredients and starting with 13 g H_2O/100 g cookie dough. The least hard cookies were those containing 10 g AP/100 g dry ingredients and dough moisture content of 17 g H_2O/100 g. Previous studies have found that increasing levels of pomace or fiber-rich materials in cookies and biscuits-like products resulted in a less hard product (Mildner-Szkudlarz et al. 2013; Kim et al. 2013).

Chewiness is an attribute related to a persistent resistance against penetration (Perry et al. 2003). Samples with longer time to peak force and smaller slopes would reflect higher chewiness. However, there were no similar trends found between the time to peak and the initial slope, potentially due to high standard deviations for both. For time to max peak, AP, moisture content and the interaction effects were all significant ($p \leq 0.05$) with the interaction effects being the most significant. While both AP and moisture content were significant affecting ($p \leq 0.05$) moisture content was more significant. The increase of dough moisture resulted in higher slope. The increase in moisture, as previously stated, may help thin out the cookie dough to help reduce toughness and chewiness.

Total phenolics content

The moisture content of dough was not a significant factor for total phenolics content (TPC) in the finished cookies, but the addition of AP increased TPC. The TPC of the 0 and 5 g AP/100 g dry ingredients cookies were significantly different than that of the higher AP substitution. The average percent change of TPC for all AP powder substitution was determined (Table 3.5). While it appears there is less TPC in the cookies containing 5 g AP/100 g dry ingredients, but from Tukey's mean difference testing found no difference ($\alpha = 0.05$) between this and that of the control. Previous studies showed that the TPC levels for vacuum belt dried apple pomace powder ranged from 44.9-51.9 g Gallic Acid Equivalents/kg (Yan and Kerr 2013). The amount of TPC found in the cookies were comparatively not as high as reported in literature could be due to loss of thermally labile phenolics during baking. Processing at temperatures above 60 °C have been shown to degrade thermally labile phenolics (Asami et al. 2003). However, addition of the AP powder significantly increased the amount of total phenolics compared with a control. Other studies have found the incorporation of pomace also significantly increased phenolics in cookie-like products (Mildner-Scukudlarz et al. 2013; Acun and Gul 2014; Turksoy et al. 2011). It should be noted that the TPC values were reported as percent change because there may be loss or gain in these values due to certain processing steps that were required to create better quality pomace powders.

Total dietary fiber (TDF)

As expected, the substitution of apple pomace resulted in a cookie with higher dietary fiber (Table 3.5), and as with TPC, AP level was the only significant factor. While the control contained only 2.04 g TDF per serving (1 serving = 28 g), the cookie with 15 g AP/100 g dry ingredients contained 4.09 g TDF per serving. With the current dietary recommendations for fiber of 25-30 g/day for an adult, 1 serving of oatmeal cookies containing the highest percentage of apple pomace would fulfill approximately 16% of the daily recommended needs. Similar results were achieved previously that found elevated fiber levels in cookies containing pomace compared with that of the control (Wang and Thomas 1989; Kohajdova et al. 2011). One study found that pomace from raspberries could also be used as a potential fiber source in shortbread cookies and could serve up to approximately 30 g TDF/100 g cookie (Gorecka et al. 2010).

Consumer acceptability

In general, there were not large differences in sensory scores due to the addition of AP powder; all scores fell in the acceptable range of the scale (Table 3.6). With respect to appearance, cookies with 5 and 10 g AP/100 g dry ingredients cookie were rated significantly higher than that of the control. The appearance of the cookies may have been rated higher because they were not as dark as compared to the control. While there were no significant differences between the cookies containing 0, 5, 10 g AP/100 g dry ingredients and cookies made with 0 and 15 g AP/100 g dry ingredients were not significantly different, it suggests the best acceptability for texture falls in between the control and the highest AP substituted cookie. These results may be related to those for cookie spread for which consumers may have found control cookies having too much spread and cookies of the highest AP substitution having too little spread. Panelists may not have expected the 15 g AP/100 g dry ingredients cookie to be an oatmeal cookie, in that it did not have the wider spread associated with an oatmeal cookie. The increasing toughness from the increasing pomace level may have also impacted acceptability in texture. In terms of flavor, the scores for the 0 and 5 g AP/100 g dry ingredients cookies were rated no differently. The lowest score for flavor was found for the 15 g AP/100 g dry ingredients cookies. This might be expected as the AP powder contributed to a mild tart taste, and greater AP levels resulted in a more noticeable flavor not characteristic of a traditional oatmeal cookies. Only cookies containing 15 g AP/100 g dry ingredients were less acceptable overall when compared with those with the control.

Conclusion

Overall, vacuum belt dried AP powder may provide several benefits when incorporated into oatmeal cookies. The final moisture content was not affected by the pomace level or the dough moisture content. Addition of pomace did not greatly alter the color of the cookies, although those with higher levels of AP were slightly lighter and with more color saturation potentially from increasing acidity from the pomace itself. Addition of AP had a marked effect on cookie spread during baking. Cookies with high levels of AP did not spread to the expected degree. For texture attributes of the cookies, both moisture content and pomace had a significant influence on the toughness, hardness, and chewiness.

Of most benefit, both total phenolics content and total dietary fiber increased significantly as a result of increasing apple pomace substitution. The cookies containing the highest level of AP substitution would deliver 4.09 g TDF for one serving size and would have 33.04% greater amount of TPC compared to the control.

In addition, addition of apple pomace did not greatly affect sensory attributes. In general, cookies with 15 g AP/100 g dry ingredients were rated significantly lower by panelists; in particular, the ratings for flavor were the lowest which may be due to the pomace powder having an acidic and tart flavor.

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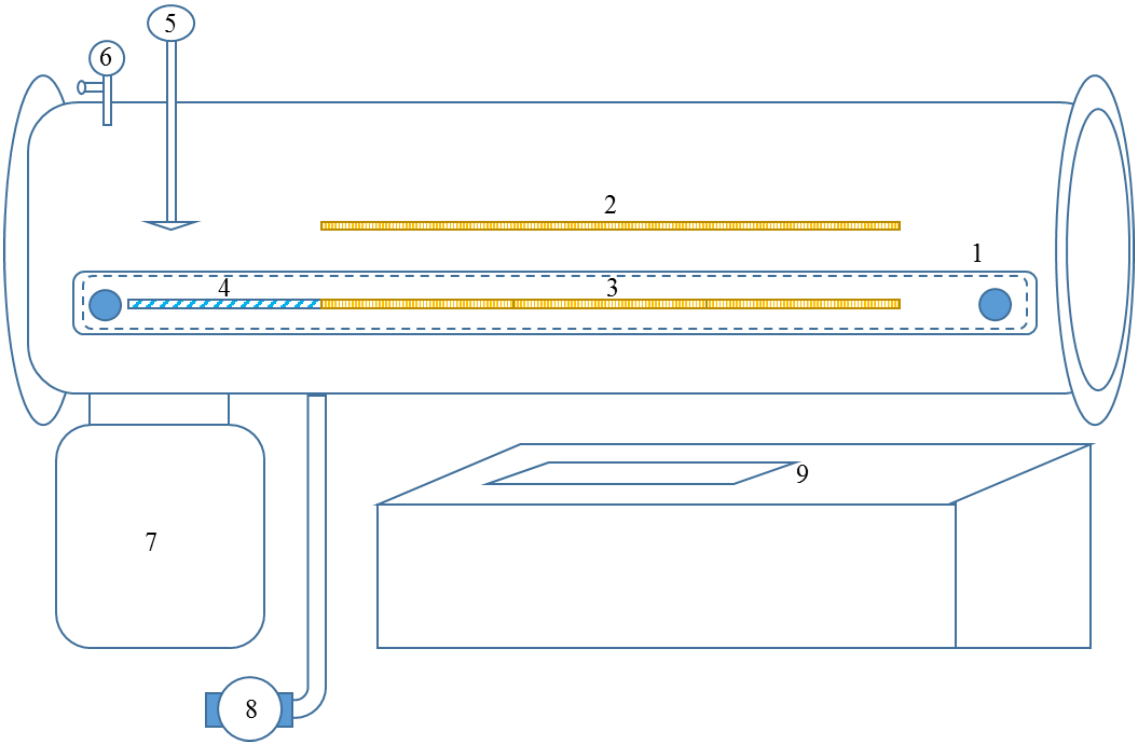

Figure 3.1 – Schematic of Vacuum Belt Drier

1 – Teflon belt, 2 – convective heating plate, 3 – conductive heating plate, 4 – cooling plate, 5 – scraper, 6 – vacuum gauge, 7 – collection tank, 8 – vacuum pump, 9 – control panel

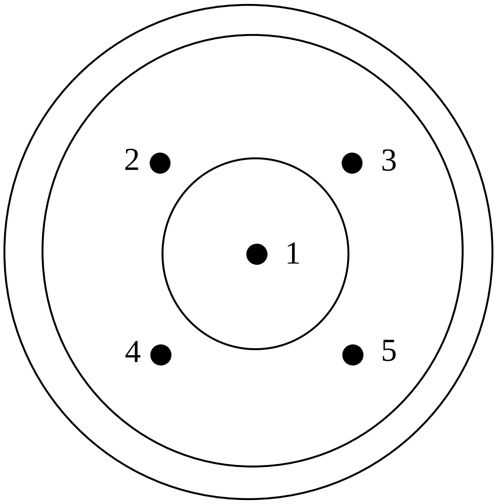

Figure 3.2 – Punching Pattern for Cookie Texture Analysis

Each point represents a one probe using the 5 kg capacity texture analyzer with a 0.3 cm diameter probe at cross-arm speed 5 mm/s. For each cookie, five probes were obtained while the outer 15 % was not probed to reduce edge effects.

Table 3.1 – Final Moisture Content and Water Activity (A_w) of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	Moisture Content (g H_2O/100 g dough)	Final Moisture Content Cookie (g/100 g Sample)	Aw
		Means[1] (SD)[2]	
0	13	6.80^{a} (0.30)	0.561^{cde} (0.051)
	15	6.81^{a} (0.31)	0.568^{bcde} (0.032)
	17	7.08^{a} (0.65)	0.552^{cdef} (0.011)
5	13	6.72^{a} (1.68)	0.517^{f} (0.009)
	15	6.77^{a} (0.61)	0.538^{def} (0.019)
	17	8.48^{a} (2.96)	0.565^{bcde} (0.013)
10	13	7.05^{a} (0.37)	0.532^{ef} (0.009)
	15	7.65^{a} (1.16)	0.555^{cdef} (0.006)
	17	8.59^{a} (0.46)	0.632^{a} (0.013)
15	13	8.37^{a} (1.10)	0.586^{bc} (0.006)
	15	7.60^{a} (0.23)	0.578^{bcd} (0.033)
	17	8.74^{a} (1.16)	0.607^{ab} (0.009)

[1] Means followed by a different superscript letter within a column are significantly different (p≤0.05) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within parentheses are standard deviations

Table 3.2 – L*c*h colorspace of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	Moisture Content (g H_2O/100 g dough)	L*	c*	h
			Means[1] (SD)[2]	
0	13	17.88^{b} (2.99)	20.15^{b} (1.38)	77.39^{a} (1.10)
	15	21.97^{ab} (5.17)	19.80^{b} (1.23)	78.52^{a} (0.57)
	17	17.50^{b} (3.09)	19.39^{b} (1.03)	77.42^{a} (1.75)
5	13	23.39^{b} (5.07)	21.50^{b} (3.44)	77.66^{a} (2.25)
	15	24.60^{ab} (3.35)	22.08^{ab} (1.19)	78.96^{a} (1.06)
	17	19.94^{b} (4.93)	20.89^{ab} (2.41)	78.24^{a} (1.88)
10	13	25.10^{ab} (5.28)	23.28^{ab} (2.22)	78.72^{a} (0.60)
	15	22.28^{b} (5.24)	22.07^{ab} (2.52)	78.09^{a} (0.92)
	17	23.66^{b} (4.88)	22.47^{ab} (1.77)	78.60^{a} (1.10)
15	13	25.03^{ab} (3.83)	24.51^{ab} (1.63)	78.56^{a} (0.15)
	15	22.70^{b} (4.75)	23.09^{ab} (1.67)	78.70^{a} (0.81)
	17	32.25^{a} (4.56)	25.50^{a} (2.14)	79.15^{a} (0.42)

[1] Means followed by a different superscript letter within a column are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within parentheses are standard deviations

Table 3.3 – Width, Thickness, and Spread Factor of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	Moisture Content (g H_2O/100 g dough)	Width (mm)	Thickness (mm)	Adjusted Spread Factor (W/T)
			Means[1] (SD)[2]	
0	13	72.14^{a}	10.29^{d}	68.75^{a}
		(1.38)	(0.91)	(0.79)
	15	69.39^{ab}	10.88^{cd}	62.38^{ab}
		(2.62)	(0.74)	(0.69)
	17	73.53^{a}	10.14^{d}	70.90^{a}
		(0.27)	(0.82)	(0.64)
5	13	65.41^{b}	12.03^{c}	52.97^{b}
		(1.00)	(0.70)	(0.30)
	15	66.50^{b}	11.75^{cd}	55.08^{b}
		(1.27)	(0.41)	(0.28)
	17	65.71^{b}	11.68^{cd}	55.03^{b}
		(4.37)	(0.72)	(0.71)
10	13	56.85^{c}	14.18^{b}	39.00^{c}
		(1.84)	(0.37)	(0.20)
	15	56.57^{c}	14.43^{b}	38.17^{c}
		(2.05)	(0.36)	(0.22)
	17	56.42^{c}	14.03^{b}	39.15^{c}
		(1.63)	(0.55)	(0.22)
15	13	50.35^{d}	16.46^{a}	29.80^{c}
		(1.56)	(0.84)	(0.22)
	15	52.68^{cd}	15.00^{ab}	34.73^{c}
		(4.96)	(1.52)	(0.70)
	17	50.71^{d}	15.08^{ab}	32.93^{c}
		(3.73)	(1.19)	(0.41)

[1] Means followed by a different superscript letter within a column are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within parentheses are standard deviations

[3] Width, thickness, and adjusted spread factor was determined in duplicate for all treatments following the Method 10-50D (AACC 1999a)

Table 3.4 – Area, Force, Time, and Slope from Texture Probing Tests of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	Moisture Content (g H_2O/100 g dough)	Area[3] (g/s)	Force (g)	Time (s)	Slope (g/s)
		Means[1] (SD)[2]			
0	13	1262^{efg} (667)	600^{abc} (464)	0.443^{abc} (0.421)	1747^{ab} (1041)
	15	1037^{gh} (578)	471^{bc} (365)	0.354^{c} (0.368)	1603^{abc} (952)
	17	946^{h} (472)	485^{bc} (331)	0.628^{ab} (0.820)	1352^{bcd} (988)
5	13	1463^{de} (623)	559^{abc} (387)	0.374^{bc} (0.399)	1921^{a} (1070)
	15	1351^{ef} (583)	609^{abc} (372)	0.532^{abc} (0.474)	1589^{abc} (988)
	17	1145^{fgh} (605)	507^{bc} (371)	0.493^{abc} (0.405)	1281^{cd} (774)
10	13	2057^{ab} (770)	719^{a} (433)	0.586^{abc} (0.541)	1663^{abc} (1030)
	15	1767^{bcd} (748)	628^{ab} (441)	0.568^{abc} (0.592)	1587^{abc} (1001)
	17	1299^{efg} (512)	432^{c} (267)	0.546^{abc} (0.523)	1109^{d} (607)
15	13	2126_{a} (888)	642^{a} (404)	0.586^{abc} (0.517)	1387^{bcd} (716)
	15	1826^{abc} (479)	564^{abc} (284)	0.537^{abc} (0.459)	1365^{bcd} (717)
	17	1738^{cd} (597)	523^{bc} (290)	0.703^{a} (0.656)	1123^{d} (708)

[1] Means followed by a different superscript letter within a column are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within parentheses are standard deviations

[3] Means were determined from five points per cookie with six cookies/two replicates determined with a 5 kg-capacity texture analyzer with a 3 mm probe at cross-arm speed of 5 mm/sec (Gaines et al. 1992a; Gaines et al. 1992b; Perry et al. 2003)

Table 3.5– Total Phenolics Content (TPC) and Total Dietary Fiber (TDF) of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	% change TPC (mg GAE[2]/100 g dry cookie)	TDF (g/100 g dry solids)
	Means[3] (SD)[4]	
0	0.00^{a}	5.78^{c} (0.67)
5	-2.63^{a}	7.37^{bc} (0.55)
10	32.16^{b}	10.2^{ab} (1.30)
15	33.04^{b}	11.4^{a} (0.71)

[1] 1 serving = 28 g
[2] GAE = Gallic acid equivalents
[3] Means followed by a different superscript letter within a column are significantly different (p≤0.05) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)
[4] Values within parentheses are standard deviations

Table 3.6 – Consumer Acceptability[1] of Oatmeal Cookies

Pomace Level (g/100 g Dry Ingredients)	Appearance	Texture	Flavor	Overall
	Means[2] (SD)[3]			
0	6.19^{b} (1.76)	6.44^{ab} (1.90)	7.04^{a} (1.62)	6.76^{a} (1.57)
5	7.03^{a} (1.31)	6.95^{a} (1.58)	6.78^{ab} (1.53)	6.81^{a} (1.50)
10	6.89^{a} (1.45)	6.82^{a} (1.58)	6.24^{bc} (1.86)	6.35^{a} (1.69)
15	6.49^{ab} (1.73)	6.01^{b} (2.07)	5.58^{c} (2.13)	5.62^{b} (1.79)

[1] Consumer acceptability was rated on a 9-pt hedonic scale for which 1=dislike extremely and 9=like extremely

[2] Means followed by a different superscript letter within a column are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[3] Values within parentheses are standard deviations

CHAPTER 4

EVALUATION OF VACUUM BELT DRIED APPLE POMACE POWDERS IN EXTRUDED BREAKFAST CEREAL SNACKS[1]

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[1] Liu M, Kerr WL. To be submitted to Journal of Food Processing and Preservation.

Abstract

The physicochemical and sensory qualities of an oat-based cereal snack extruded with twin-screw extruder were evaluated with flour substitution with vacuum belt dried apple pomace powder (0, 2, 4 g AP/100 g dry feed) and varying exit temperatures (115, 125, 135 °C). The addition of pomace increased expansion ratio and bulk density but was not statistically significant. Pomace incorporation resulted in a darker and more yellow product. Hardness, crispiness, and final moisture contents were not significantly different for all treatments. Total dietary fiber and total phenolic content increased with increased pomace incorporation. For 1 serving size, cereal with pomace could contain about 4.38-4.82 g TDF. Cereals were not significantly different in likeability for appearance, texture, flavor, and overall acceptability according to a consumer sensory panel.

Introduction

The US Food and Drug Administration defines ready-to-eat (RTE) foods as those that can be consumed without additional preparation (Food Code 2013). RTE cereals have become a staple in the American breakfast due to their convenience, shelf life stability, need for minimal preparation and ease of storage (Fast 1990). Common forms of grains used in many cereals (such as wheat, corn, oats and rice) often have high starch content and low in fiber. As such, these foods are energy dense and short on nutrients. As consumers become more health conscious and aware of the foods they eat, there has been an increasing demand for healthier RTE foods containing low fat and high dietary fiber content, and which can be coated with nutrients such as vitamins and minerals (Brennan et al. 2013).

Dietary fibers are non-digestible food components, often composed of plant cell wall materials such as celluloses, hemicelluloses, and lignins. The consumption of fiber helps regulate lipid levels in blood serum and protect the colon by promoting regularity in excretion. Consumption of sufficient dietary fiber has been linked with reduced risks of obesity, hypertension, cardiovascular disease, stroke, diabetes, and gastrointestinal disorders. Fiber has also been found to lower blood cholesterol levels (Kaushal and Joshi 1995).

Other phytochemicals found in fruits and vegetables have also been linked with reduced risks of cardiovascular diseases, diabetes and cancer (Boyer and Liu 2004). Specific flavonoids such as phloridzin and quercetin have been linked with reduced risks of lung cancer, cardiovascular diseases, asthma and diabetes (Feskanich et al. 2000; Le Marchand et al. 2000). Up to 22% of the phenolic compounds consumed in the American diet originate from apples due to the high availability and utilization in the typical American diet with the per capita consumption for fresh weight was 30.7 g/d in 1997 (Vinson et al. 2001). As compared with other fruits, apples contain the second highest total phenolics content and total antioxidant activity (Sun et al. 2002).

Apple pomace, the waste product from juice processing, contains high levels of dietary fiber as well as phenolic compounds residing primarily in the skins. The main component of dietary fibers found in apples are celluloses, hemicelluloses, pectins, lignins, non-starch polysaccharides, β-glucans, and gums (Gallaher and Schneman 2001; Lamghari 2000). The major phytochemicals found in apple pomace include phloridzin, quercetin, epicatechin, catechin, procyanidins, courmaric acid, gallic acid, and chlorogenic acid (Boyer and Liu 2004; Lu and Foo 1997). Because there is a higher concentration of flavonoids in the apple skin as compared with in the flesh, it is thought that pomace, which contains a greater proportion of skin, may provide particular health benefits when consumed in the diet compared to consumption of the flesh (Lata 2007; Drogoudi et al. 2007; Wolfe et al. 2003).

The typical American adult consumes only 10-25 g dietary fiber per day out of the 25-30 g/day recommended intake (USDA and USDHSS 2010). Due to increased demand for healthier food choices, there is great interest in developing foods containing value-added ingredients such as fruit and vegetable powders. The qualities of an ideal dietary fiber fruit powder are that it must have no objectionable flavor, color or odor; be highly concentrated in fiber; have no nutritionally questionable compounds; have a reasonably long shelf life; be easy to formulate with and process in foods; and contain well-balanced levels of nutrients and bioactive compounds (Larrauri 1999). Apple fiber has been investigated for its use in food products as it contains relatively high levels of flavonoids, polyphenols, and carotenoids (Fernandez-Gines et al. 2003). Apple pomace as a dried food additive has had limited success as it does tend to brown and lose nutrient content during both wet processing and subsequent drying. Yan and Kerr (2013) showed that an apple pomace powder could be produced with minimal color and phytochemical changes, by rapidly processing the wet pomace and drying in a continuous vacuum-belt dryer (VBD). To date, no publications have been produced in which the resulting powder was used as an ingredient in a value-added food product.

The purpose of this study was to evaluate the physical, chemical and sensory properties of an oat-based extruded breakfast cereal containing VBD apple pomace (AP) powder. The cereals were produced with AP powder substituting for oat flour at 0, 2, and 4 g/100 g dry feed, and with three different barrel exit temperatures (115, 125, and 135 °C).

Materials and Methods

Chemicals and reagents

Food grade ascorbic acid was obtained from Prinova USA (Carol Stream, Il). Citric acid was supplied from Tate & Lyle (Decatur, Il). Sodium hexametaphosphate and sodium hydroxide (NaOH) was supplied from the JT Baker Chemical Co. (Phillipsburg, NJ). Folin-Ciocalteu reagent and the total dietary fiber assay kit (including amyloglucosidase solution from *Aspergillus niger*, α-amylase, and protease from *Bacillus licheniformis*) were purchased by Sigma-Aldrich, Co. (St. Louis, MO). Acetone, methanol, and hydrochloric acid (HCl) were obtained from Fisher Scientific (Fair Lawn, NJ). Ethanol was purchased from the AAPER Alcohol & Chemical Co. (Shelby, KY).

Apple pomace (AP) powder processing

Pomace from Gala, Honeycrisp, and Ginger Gold apples were obtained from Mercier Orchards (Blue Ridge, GA) on August 27, 2013. The pomace was collected right after juice was expressed from the apples using a belt press. The pomace was immediately treated with an anti-browning solution of 2% ascorbic acid, 1% citric acid and 1% sodium hexametaphosphate for 3 min then dewatered with cheesecloths. The treated AP was frozen in polyethylene buckets and stored at -20 °C until furthering processing.

Samples were left to thaw overnight prior to drying in the vacuum belt drier. The thawed pomace was rinsed with deionized water (1:1 v/v ratio) twice to remove excess sugars and organic acids in order to prevent Maillard browning during drying. The pomace was rolled to 4 - 5 mm thickness onto a Teflon belt, which rested immediately above the conduction heaters. The pressure in the chamber was maintained at 2.5-3.3 kPa. The pomace was dried at plate temperatures of 95°C for approximately 120 min until an A_w of 0.25 ± 0.05 was reached (Yan 2012). Dried pomace was then ground in a food processor using an S-blade (Model: KFP600WH, KitchenAid, St Joseph, MI) for 40 s. Further grinding was accomplished with a JT-6 Homoloid Mill (The Fitzpatrick Company, Elmhurst, IL) equipped with a stainless steel mesh screen, No. 1522-0020 (0.51 mm round holes). The powder was then stored in metallized plastic bags (ABC Packaging, Avon, OH) at -20 °C until usage.

Extrusion Processing

The regular rolled oats were obtained from Grain Millers (St. Ansgar, IA). The oats were milled into flour using the JT-6 Homoloid Mill (The Fitzpatrick Company, Elmhurst, IL) equipped with a No. 1521-0050 steel mesh screen (1.27 mm holes). The oat flour was vacuum-sealed in high barrier vacuum Cryovac plastic bags (Sealed Air, Duncan, SC) and stored at -40 °C until usage. For 100 g dry feed (DF), the control formulation (0 g pomace) contained 80 g oat flour, 7 g rice flour (Erawan Marketing Co. Ltd, Bangkok, Thailand), 6 g sugar (Domino Sugar, Domino Foods, Inc., Yonkerse, NY), 5 g tapioca starch (Erawan Marketing Co. Ltd. Bangkok, Thailand), 1 g PureSet modified food starch (Grain Processing Corporation, Muscatine, IA), and 1 g salt (Morton Salt, Chicago, Il). Apple pomace powder was added as a substitute for oat flour at 2 and 4 g/100 g dry feed. Tapioca starch and rice flour were added as an expansion aid. All dry ingredients were weighed and mixed thoroughly the day before extrusion runs.

To produce the expanded breakfast cereals, a pilot scale 25:1 co-rotating twin-screw extruder (Model MPF30, APV Baker Limited, Staffordshire, England) was used with exit die diameter of 2 mm. A dry feed rate calibration for each treatment was conducted prior to each run. The mass accumulated after 1 min was considered the dry feed rate (g/min). Additional water was introduced just after the the barrel entrance by means of a calibrated reciprocating pump. The wet feed rate was set at 6 g/min and the dry feed rate was set accordingly for each sample, so that the in-barrel moisture content was 17.0 %. The barrel screw speed was 450 rpm. The screw configuration was: 4 1.5D twin lead screws, 5 30 ° forward peddles, 3 1.5D twin lead screws, 1 1D twin lead screw, 2 60 ° forward peddles, 3 60 ° backward peddles, 3 60 ° forward peddles, 2 1D twin lead screws, 7 60 ° forward peddles, 2 1D twin lead screws, 1 1.5D twin lead screw, and 2 discharge single lead screws. The cutter speed was set at 433 rpm. Samples went through a secondary drying step using an impingement oven (Model 1450, Lincoln, Food Service Products Inc., Fort Wayne, IN) at 150 °C for 2 min. This process was duplicated for each treatment. Extrudates before and after impingement were collected in aluminized PET bags (ABC Packaging, Avon, OH), sealed and stored at room temperature until subsequent analyses.

Physical tests

Expansion Ratio

The expansion ratio was determined as the diameter of the extrudate divided by the diameter of the die opening (2 mm). The cross-sectional diameters were measured using a digital caliper (Model: CD-6"CSX, Mitutoyo Corp, Kanagawa, Japan). These measurements were taken from 10 random samples for each treatment on the day of extrusion.

Bulk Density

The bulk density was determined by the mass of the extrudate divided by the volume. Extrudate from each condition were lightly packed into a tared 400 mL glass beaker and weighed on an analytical balance. Measurements were replicated three times on the day of extrusion.

Hardness and Crispness Texture Analysis

A Model 3344 Universal Testing System (Instron, Norwood, MA), fitted with a 2000N force transducer, was used to compress oat cereal samples in an Ottawa cell attachment. For each treatment, 50 g was weighed prior to testing and loaded into the cell. The probe was lowered at 5 mm/s, a distance of 15 mm once the probe contacted the sample. The resultant force-time curves were analyzed using the Bluehill 2 software (Instron, Norwood, MA). Both replications of the process were tested and each treatment was tested five times at 24 h post extrusion. The maximum force attained during compression was taken as a measure of hardness.

Crispness results from the multiple fracture events that occur when products such as extruded dry snacks break apart under compression. The 'linear distance' in the force-time response is one indicator of crispness. In this approach, the algorithm assesses the jaggedness in the force curve, by calculating the total pathlength traversed in going from point to point in the dataset. Crispness was also measured using sounds produced as the products were compressed. Audio samples were recorded for each test using an Audix TM1 measurement microphone (Audix, Wilsonville, OR) connected to a USB Audio Interface (Fast Track, M-Audio, Cumberland, RI), and captured with Audacity audio editing software (Version 2.0.5, The Audacity Team). All audio samples were analyzed using Matlab (version R2013b, MathWorks, Natick, MA) to determine the total intensity and number of sound peaks.

*L*c*h colorspace*

To measure color, extrudate amples were first ground for 20 s in a cross-blade grinder (NutriBullet LLC, Pacoima, CA). The colorspace L*c*h values were recorded for impinged ground treatments in triplicate using a chroma meter (Model CR-410, Minolta, Konica Minolta Sensing, Inc., Tokyo, Japan). The white calibration plate (No. 13333105) was used for calibration (Konica Minolta Sensing, Inc., Tokyo, Japan), and measurements were made under the D65 illuminant system (T~6500K).

Chemical tests

Prior to performing chemical tests, extrudate samples before and after impingement drying were ground for 20 s to form a coarse powder. The powders were then stored in sealed aluminized PET bags at -20 ºC until subsequent testing.

Moisture Content

The moisture content for samples before and after impingement drying were determined in triplicate and on the day of extrusion. A modified AOAC vacuum oven (Anon. 1999) method was used. Samples were weighed into tared aluminum pans and dried until constant weight at 70 ºC in a vacuum oven (Model 1430 MS, VWR Scientific, Radnor, PA, USA).

Total Phenolics Contents

Phenolic compounds were extracted following methods developed by Wolfe and Liu (2003). Samples of 15 g were mixed with 120 g chilled 80 % (v/v) ethyl alcohol and homogenized for 5 min using a Polytron (Model: PT1200; Kinematica Ag, Switzerland). The sample was then vacuum-filtered through Whatman No. 1 filter paper, and the filter cake was washed twice with 15 mL chilled 80% ethyl alcohol. The filtrate was then evaporated using a rotary evaporator (Rotavap R110, Buchi Labortechnik, Switzerland) at 45 °C until 10% or less of the original volume remained. Extracts were diluted to 50 mL with deionized water and stored in amber vials at -20 ºC until subsequent testing. All treatments were extracted in duplicate.

The total phenolics content (TPC) of the extruded cereals was measured in triplicate using the modified colorimetric Folin-Ciocalteu method (Wolfe and Liu 2003). Volumes of a known dilution extract (0.125 mL) was mixed with 0.5 mL deionized water and 0.125 mL Folin-Ciocalteu reagent in a test tube. The contents were gently vortexed for 10 s and then allowed to react for 6 min. Aliquots (1.25 ml) of a 7 % sodium carbonate solution was added to the solution and further diluted to 3 mL with deionized water. The test tubes were gently vortexed for 10 s. Color was developed for 90 min and the absorbance at 760 nm was read with a spectrophotometer (Spectronic Geneys 2, ThermoFisher Scientific, Waltham, MA). A standard curve for gallic acid concentration was developed in which the concentration, in units of mg gallic acid equivalents (GAE)/100 g extrudate for the cookie samples were determined. The percent change

Total Dietary Fiber

Total dietary fiber (TDF) in the extruded samples was measured in duplicate following the AOAC Official Method 985.29 with modifications (Anon. 2005). Heat-stable α-amylase (0.1 mL) was added to 50 mL pH 6.0 0.08M phosphate buffer with pre-dried sample (1 g ± 20 mg) in a 250 mL Erlenmeyer flask. Samples were incubated in a 95 - 100 °C water bath with agitation at every 5 min for 20 min. The pH was adjusted to 7.5 ± 0.2 with 0.275M NaOH (10 mL) solution. Protease (5 mg) was then added, and the samples incubated with continuous agitation in a 60 °C water bath for 30 min. The final pH was adjusted to 4.0 – 4.6 using 0.325M HCl (10 mL). Amyloglucosidase (0.3 mL) was added and samples were incubated in a 60 °C water bath for 30 min with continuous agitation. Preheated 95% ethyl alcohol (280 mL) at 60 °C was added to precipitate the soluble dietary fibers. Samples were filtered in fritted crucibles (with 0.5 g celite) with three 20 mL portions of 78 % ethyl alcohol, two 10 mL portions of 95% ethyl alcohol, and two 10 mL portions of acetone. Residues collected in the crucibles were dried overnight at 70 °C in a vacuum oven (Model 1430 MS, VWR Scientific, Radnor, PA, USA). A muffle furnace (Model: F46025, 48000 Furnace, Barnstead/Thermolyne, Dubuque, IA) was used to ash one portion for 5 h at 525 °C. The Kjeldahl method was used on the second portion to determine nitrogen content. A conversion factor of 6.25

was used to calculate protein content. The total dietary fiber (%) of extruded cereals was calculated as:

$$TDF, \% = \frac{R_{sample} - P_{sample} - A_{sample} - R_{blank} - P_{blank} - A_{blank}}{SW} \times 100 \qquad (1)$$

where R is mean residue weight (mg), P is the mean protein weight (mg), A is the mean ash weight (mg), and SW is the average initial sample weight (mg).

Sensory evaluation

A preliminary sensory evaluation team determined that samples with varying levels of pomace and extruded at exit temperature (125 °C) would be most appropriate to present to the larger consumer panel. A consumer panel was recruited (n=61, 28M 33F) to evaluate three samples on a 9-pt hedonic scale (1=dislike extremely and 9=like extremely). Dry cereals were weighed (50 g) and presented in half-cup Styrofoam cups without milk. Samples were labeled with a random code and presented in a nearly balanced random order. Panelists evaluated samples in individual booths under white light and were presented samples individually. Carrots and water were provided to the panelists to cleanse the palate between samples.

Statistical Analyses

JMP 10 (SAS Institute, Cary, NC) was utilized to perform statistical analyses. Two-way ANOVA was performed to determine statistical significance of independent variables. Tukey’s Test was performed for mean difference testing.

Results and Discussion

Expansion ratio

Overall, expansion ratios of the cereal products varied from 2.79 to 3.12 (Table 4.1). Thus, there was not a great variation in expansion at the temperatures and pomace levels studied. According to two-way ANOVA, both pomace and exit temperature were significant factors ($p \leq 0.05$) influencing the expansion ratio (Table 4.1), suggesting that higher extrusion temperature and pomace levels produced greater expansion. Samples with 0 g AP/100 g dry feed had expansion ratios 2.79-2.94, while those with 4 g AP/100 g dry feed had an expansion ratio of 2.96-3.07. All cereals extruded with 0 g AP/100 g were significantly different ($p \leq 0.05$) than cereals extruded at 2 g AP/100 g dry feed at exit temperature 115 °C and cereals extruded at 4 g AP/100 g dry feed at exit temperature 125 °C.

Fibers, specifically pectins, from the pomace may compete with the starch for water and reduce the degree of starch gelatinization, which then hinders expansion (Yanniotis et al. 2007). Furthermore, oat flours tend to have a higher lipid content (5-8%) compared to other extruded grains such as corn (0.8-4%), wheat (1-2%), and rice (0.3-3%) (Ilo et al. 2000). During the extrusion process, fats act as a plasticizer that increases mobility as well as reduces the melt viscosity of the food polymer in the barrel. The reduced viscosity in turn reduces the shear and mechanical forces. The decrease in these forces negatively affects expansion due to hindering starch gelatinization. Thus, the relatively higher fat content of oats may have contributed to the lower expansion ratios as observed from these extruded cereals. In a similar study with hazelnut flour, Yagci and

Gogus found a decrease in radial expansion was related to starch dilution and higher fat content (2009).

Previous studies have found that the addition of fruit and vegetable fibers often decrease expansion (Altan et al. 2008b; O'Shea et al. 2014; Karkle et al. 2012; Selani et al. 2014). However under the conditions of this experiment, expansion ratio increased with increasing pomace levels at 125 and 135 °C. The increase of expansion with the substitution of pomace may also be due to particle size differences. The apple pomace powders were ground to a finer size (particle size less than 510 μm) compared to the oat flour (particle size less than 1270 μm). Alternatively, the addition of pomace powder was decreasing the lipid content in the polymer, thereby increasing the melt viscosity and increasing expansion.

Bulk density

Bulk density is an important physical property related to extrudate expansion and becomes a parameter to quantify texture properties of foods (Koksel et al. 2003). Pomace level was the only significant factor affecting bulk density (Table 4.1). The bulk density of the extruded cereals ranged from 0.277 – 0.302 g/ml, with increased pomace level leading to greater bulk density but not significant. The added fibers may disrupt cell formation during expansion causing cells to collapse (Lue et al. 1991). Similarly, increases in bulk densities were reported with additions of wheat and oat fibers in extruded corn meal product (Hsieh et al. 1989). The fibers from apple pomace may be competing with starches for water, which affects expansion and consequently bulk density.

Textual properties

Hardness was determined as the maximum peak force extracted from force-time plots during compression in an Ottawa cell. The hardness of the cereals ranged from 781 – 1223 N with no significant differences found amongst the treatments (Table 4.1). Others have found that pectin or other soluble fibers may reduce hardness and help in developing crispness in a product due to a lubricating effect (van der Sman and Broeze 2013). Similar results were found in a corn flour based extrudate containing apple pomace (O'Shea et al. 2014).

Crispness is another textual attribute important to extruded cereal snacks that is related to how brittle the cellular structure is. 'Linear distance', intensity and number of peaks were all parameters used to quantify crispness (Vincent 1998; Luyten et al. 2004). The 'linear distances' for the extruded cereals ranged from 789 – 1161 with no apparent trend in relation to pomace or temperature. Peak intensities as determined from the audio samples for each treatment is another parameter that characterizes the crispiness of a sample. The intensity refers to relative loudness of the sample fracturing as the structure collapses. Crispness is also associated with a high-pitched sound when fractured (Les Meste et al. 2002). The sound intensities ranged from 125 – 198 and had no relationship with pomace or temperature. The number of peaks determined from the audio samples ranged from 39.3 to 46 and also had no apparent relationship with either variables.

Extruded dry snacks and cereals are by nature irregular in shape, resulting in considerable variability in measured mechanical properties as shown in the standard deviations. Thus, differences would likely only be measured if they were relatively large. Further, only modest levels of AP powders (0, 2, and 4 g AP/100 g dry feed) were incorporated in the extrudates, as higher levels produced a product with objectionable waxiness.

L*c*h color

Color of the samples was measured in the L*c*h system (Table 4.1). L* is an indicator of lightness (0=whiteness, 100= blackness), c* measures color saturation, and h is the hue angle (0-360 °) describing the fundamental color. For all samples, pomace was a significant factor for all color values. This was expected as pomace powders (L*=72.11, c*=25.06, h=83.56) were visibly different in color compared to the oat flour (L*=87.77, c*=12.53, h=92.23). The L* values for extruded cereals ranged from 75.86 – 79.40. Because apple pomace powders were darker than oat flour, cereals extruded with pomace had lower L* values compared to the control. Chroma values ranged from 18.88 – 23.98, and generally increased with increasing pomace levels, as the pomace powders had higher chroma than oat flour base. Hue angles ranged from 88.4-88.84° for samples no pomace, to 85.08 - 85.58° for samples containing 4 g AP/100 g dry feed. Thus, the addition of pomace powders resulted in cereals with a slightly more yellow color.

Moisture Content

The average moisture content of samples prior to impingement were not statistically different for all treatments (Table 4.2). Similarly, the average moisture content after impingement of extrudates were not statistically different for all treatments. The moisture loss after impingement was expected as the secondary drying step necessary to develop the crisp texture helped drive off excess moisture.

Total dietary fiber (TDF)

According to ANOVA, both pomace level and temperature, as well as the interaction effects, were significant factors affecting the TDF. While it appears the inclusion of pomace increases the TDF in the cereal, the differences between the control and the 2 g/100 g DF was not statistically significant (Table 4.2). Only samples with 4 g/100 g DF pomace had higher levels of TDF than found for other pomace levels. The TDF of the 4 g pomace/100 g DF ranged from 15.67 – 17.20 g/100 g extrudate or, assuming that 1 seving size has 28 g, approximately 4.38 – 4.82 g fiber/serving.

Total phenolics content (TPC)

According to ANOVA, only pomace level was the significant factor ($p \leq 0.05$) affecting TPC. As the level of apple pomace powders increased, the amount of TPC found in the cereals increased as well. The highest concentration of phenolics was found in cereals containing 4 g pomace/100 g dry feed extruded at an exit temperature of 115 °C (Table 4.2). The exit temperature had no significant effect on phenolics at all AP level. Previous studies found the high temperatures and shearing mechanisms involved with extrusion processing may degrade phenolic compounds (Khanal et al. 2009; White et al. 2010).

Additionally, it should be noted that the phenolics content of the cereals were measured under the condition where additional ascorbic acid was present. The addition of ascorbic acid, while a necessary processing step in order to inhibit polyphenoloxidase (PPO) activity (Pizzocaro and et al. 1993; Son and et al. 2001), may have skewed the concentrations of TPC found. It was found that total phenolics were generally higher in apple peels that were pretreated with solutions of ascorbic acid, however they noted that the higher phenolics content may have been from the added ascorbic acid and not from native phenolics (Wolfe and Liu 2003). However without the presence of ascorbic acid to inhibit PPO, the oxidation of the important phenolic compounds would result in apple browning (Coseteng and Lee 1987) and impact quality of the dried powders.

Sensory evaluation

All samples were ranked equally for appearance, flavor, texture and overall acceptability with no statistical difference with Tukey's Test ($\alpha = 0.05$) (Table 4.3). The scores for appearance were in the middle of the scale (5.10-5.24) indicating that panelists did not particularly like or dislike it. This may be a matter of not meeting consumer expectations for an oat cereal and disparities between the presentation and the normal cereal eating habits of the consumers. Many commercially available oat cereals are extruded with complex dies, and may include an additional puffing step. The cereals produced in this study were more pellet-like with slightly pinched ends (Figure 4.2).

Additionally, it can be noted that the control had the lowest score from the panelists as well as the lowest values in L* from color measurements. It can be suggested that consumer panelists found the darker colored cereals containing AP powder more acceptable than the lighter color found in the control

Conclusion

In general, the incorporation of vacuum-dried apple pomace powder did not greatly affect the textural properties or sensory scores of the extrudates. Samples with 4 g AP/100 g dry feed extruded at 125 °C were more expanded than was the control. Hardness and crispness also were not statistically significant amongst treatments. Addition of pomace at any level did result in a darker and more yellow saturated color. As expected, the inclusion of pomace increased total dietary fiber as well as total phenolics content. The appearance, flavor, texture and overall acceptability were not statistically different due to pomace levels and exit temperatures according to consumer panelists.

For future studies, it would be recommended to investigate the relationships between both temperatures, screw speeds, as well as moisture content. The incorporation of higher percentages of apple pomace powders have been tested in an extruded corn flour matrix, so it suggests that higher percentages of apple pomace powders could be added to a medium that will more readily expand and puff (O’Shea et al. 2014). In addition, it may be possible to improve acceptability by applying and optimizing flavors and coatings on the cereal.

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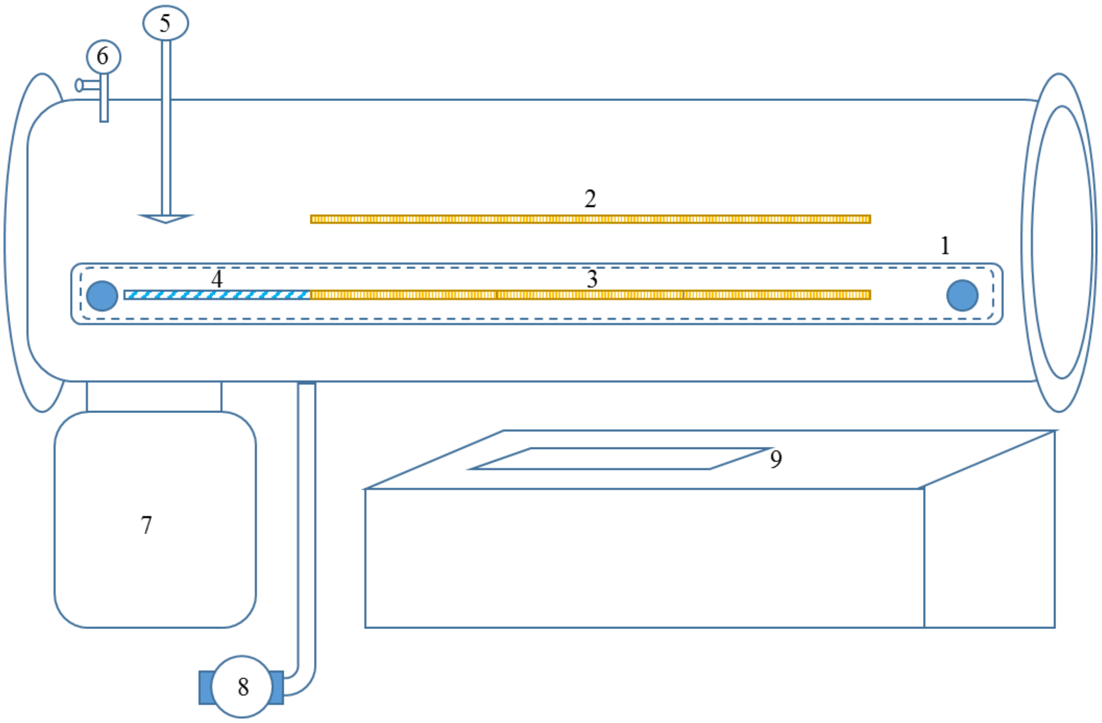

Figure 4.1 - Vacuum Belt Drier Schematic

1 – Teflon belt, 2 – convective heating plate, 3 – conductive heating plate, 4 – cooling plate, 5 – scraper, 6 – vacuum gauge, 7 – collection tank, 8 – vacuum pump, 9 – control panel

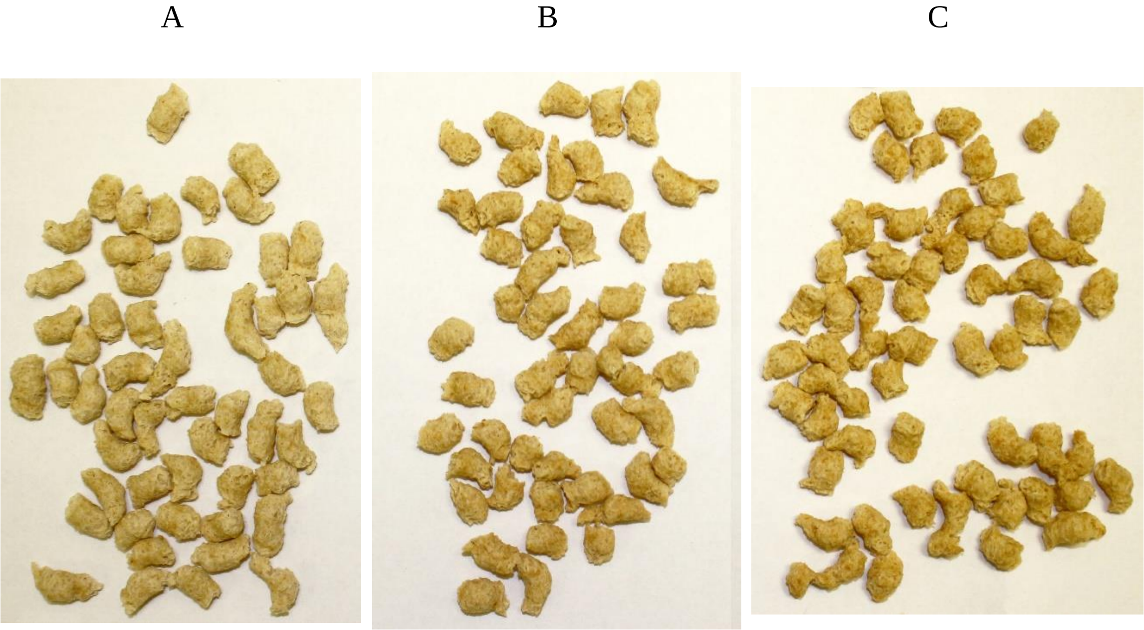

Figure 4.2 – Extruded Oat-based Apple Pomace (AP) Cereals

From left to right: (A) 0g AP/100g Dry Feed, (B) 2 g AP/100g Dry Feed, (C) 4 g AP/100g Dry Feed

Table 4.1 – Physical Properties of Oat-Apple Pomace Based Cereals

Pomace Level (g/100 g Dry Feed)	0			2			4		
Exit Temperature (°C)	115	125	135	115	125	135	115	125	135
					Means[1] (SD)[2]				
Expansion Ratio	2.79^{c} (0.11)	2.83^{c} (0.14)	2.94^{bc} (0.13)	3.12^{a} (0.15)	3.06^{ab} (0.15)	3.05^{abc} (0.23)	2.96^{abc} (0.19)	3.11^{a} (0.15)	3.07^{ab} (0.21)
Bulk Density (g/ml)	0.285^{abc} (0.008)	0.288^{abc} (0.012)	0.289^{abc} (0.017)	0.277^{c} (0.008)	0.280^{bc} (0.006)	0.291^{abc} (0.007)	0.298^{ab} (0.010)	0.294^{abc} (0.009)	0.302^{a} (0.006)
Hardness (N)	979^{a} (322)	1156^{a} (470)	1223^{a} (461)	820^{a} (251)	781^{a} (229)	798^{a} (364)	876^{a} (311)	974^{a} (304)	1098^{a} (431)
Linear Distance	994^{a} (340)	1161^{a} (472)	1230^{a} (461)	829^{a} (247)	789^{a} (227)	808^{a} (365)	884^{a} (311)	979^{a} (303)	1107^{a} (430)
Intensity[3]	198^{a} (73)	183^{a} (66)	190^{a} (72)	135^{a} (35)	128^{a} (38)	125^{a} (42)	134^{a} (39)	166^{a} (95)	153^{a} (54)
Number of Peaks	40.5^{a} (10.7)	40.0^{a} (7.3)	41.0^{a} (4.8)	42.6^{a} (4.06)	40.3^{a} (7.4)	39.3^{a} (9.2)	40.6^{a} (12.5)	43.5^{a} (9.5)	46.0^{a} (7.9)
L*	78.9^{a} (0.3)	79.0^{a} (0.52)	79.4^{a} (0.15)	76.5^{b} (0.6)	76.5^{b} (1.0)	76.5^{b} (1.1)	75.6^{b} (0.4)	75.9^{b} (0.5)	76.2^{b} (1.2)
c*	19.2^{c} (0.3)	18.9^{c} (0.45)	18.6^{c} (0.18)	22.5^{b} (0.4)	22.1^{b} (0.8)	22.3^{b} (0.9)	23.9^{a} (1.1)	24.0^{a} (0.5)	23.2^{ab} (1.3)
h	88.4^{a} (0.2)	88.9^{a} (0.46)	88.8^{a} (0.19)	86.2^{b} (0.2)	85.9^{bc} (0.5)	86.0^{bc} (1.0)	85.1^{c} (0.5)	85.5^{bc} (0.4)	85.6^{bc} (0.8)

[1] Means followed by a different superscript letter within a row are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within the parentheses are standard deviations

[3] Intensity and number of peaks were data sets acquired from recorded audio samples during texture analysis.

Table 4.2 – Chemical Properties of Oat-Apple Pomace Based Cereals

Pomace Level (g/100 g Dry Feed)	0			2			4		
Exit Temperature (°C)	115	125	135	115	125	135	115	125	135
					Means[1] (SD)[2]				
MC, before impingement (g H_2O/100 g extrudate)	9.23^a (0.86)	8.34^a (1.64)	8.95^a (0.76)	9.68^a (0.71)	9.75^a (0.51)	10.1^a (1.0)	8.59^a (2.07)	9.24^a (2.03)	10.3^a (0.90)
MC, after impingement (g H_2O/100 g extrudate)	2.99^a (0.38)	3.10^a (0.14)	2.79^a (0.31)	1.74^a (1.15)	1.57^a (1.00)	1.44^a (1.16)	1.73^a (1.16)	2.07^a (2.30)	1.62^a (1.21)
TDF[3] (g/100 g extrudate)	11.8^b (0.6)	9.24^b (0.91)	11.1^b (1.0)	10.1^b (0.0)	12.1^b (0.7)	12.1^b (1.2)	15.7^a (0.3)	17.2^a (0.9)	16.4^a (1.1)
TPC[4] (mg GAE[5]/100 g extrudate)	2.50^b (0.54)	3.43^b (1.01)	4.05^b (1.16)	4.36^{ab} (1.14)	4.82^{ab} (3.76)	4.46^{ab} (0.23)	7.95^a (2.3)	5.46^{ab} (2.1)	4.43^{ab} (2.31)

[1] Means followed by a different superscript letter within a row are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[2] Values within parentheses are standard deviations

[3] TDF refers to total dietary fiber

[4] TPC refers to total phenolic content

[5] GAE = gallic acid equivalents

Table 4.3 – Consumer Acceptability[1] of Oat-Apple Pomace Based Extruded Cereal

Pomace Level (g/100 g Dry Feed)	Appearance	Texture	Flavor	Overall
	Means[2] (SD)[3]			
0	5.10^a (1.59)	6.51^a (1.72)	6.21^a (1.45)	6.06^a (1.40)
2	5.21^a (1.69)	6.41^a (1.69)	5.79^a (1.46)	5.84^a (1.47)
4	5.24^a (1.71)	6.35^a (1.66)	5.90^a (1.58)	5.90^a (1.46)

[1] Consumer acceptability was rated on a 9-pt hedonic scale for which 1=dislike extremely and 9=like extremely

[2] Means followed by a different superscript letter within a column are significantly different ($p \leq 0.05$) according to Tukey's Test via JMP (Version 10, SAS Institute, Cary, NC)

[3] Values within parentheses are standard deviations

CHAPTER 5

CONCLUSION

The study at hand found success in incorporating vacuum belt dried apple pomace powder into baked and extruded products because the addition of the pomace powder increased the phenolics and total dietary fiber without greatly compromising the consumer acceptability of the product and the physical properties.

From chapter three, physical, chemical, and sensory qualities were investigated in oatmeal cookies baked with 4 levels of apple pomace (0, 5, 10, 15 g/100 g dry ingredients) and 3 levels of dough moisture content (13, 15, and 17 g H_2O/100 g cookie). Higher pomace incorporation resulted in cookies of lighter color and more yellow saturation. The addition of pomace had an effect on cookie spread as cookies containing higher levels of AP had reduced spread. From puncture tests, cookies prepared with higher AP were slightly harder, but cookie with higher dough moisture content were less hard. Cookies containing pomace also contained higher levels of total dietary fiber and total phenolics; cookies containing 15 g AP/100 g dry ingredients contained 4.09 g total dietary fiber for 1 serving size and had 33.04% more total phenolics content compared to the control. Overall consumer acceptability for the cookies were found to not be significantly different for all levels except for the cookie containing the highest amount of AP substitution. Apple pomace powders can be substituted into oatmeal cookies with no significant effects on quality and likeability for overall acceptability.

In chapter four, physicochemical and sensory properties of an oat-based extruded cereal snack were evaluated with 3 levels of vacuum belt dried apple pomace (0, 2, 4 g/100 g DF) and 3 exit temperatures (115, 125, 135 °C). It was possible using an oat-based cereal hindered results and was not the best vehicle to develop a puffed cereal snack. However, the addition of pomace did not greatly affect textural properties like hardness and crispness. The incorporation of pomace resulted in a darker and more yellow saturated product. Total dietary fiber and total phenolics increased as a result of increased pomace levels. Cereals of the highest pomace substitution contained almost 8 mg GAE/100 g extrudate. For 1 serving, the total dietary fiber of the cereal would range from 4.38 – 4.82 g. Even so, the likeability of the cereals were not statistically different from each other.

Overall, apple pomace can be used as a value-added ingredient to develop a healthier alternative to commonly consumed baked and extruded products. The incorporation of pomace did not have strong detrimental effects on quality and can deliver increased concentrations of total dietary fiber as well as total phenolics.