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CHARACTERISTICS OF APPLE POMACE AND ITS USE IN FOOD SYSTEMS

A Thesis

Presented for the

Master of Science

Degree

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Kimberlee J. Carson

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DEDICATION

The author dedicates this thesis to her parents Donald L. and Jane K. Carson. Their support and encouragement were the inspiration needed for the completion of this project and degree. The author can finally say that "the little boy on the train will not have to come home empty-handed!"

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ABSTRACT

Apple pomace consists of the solid material that remains after the juice has been extracted from apples for juice and cider production and the waste generated during the preparation of apples for canning, drying or freezing. Approximately 1.3 million tons of apple pomace are produced each year and the total annual disposal fee exceeds $10 million. Although there are alternatives to the disposal of pomace, relatively little progress has been made to minimize the cost of pomace disposal. In this study the physical and chemical characteristics of apple pomace obtained from 'Golden Delicious', 'Red Delicious' and 'Winesap' apples after the juice was extracted as unfiltered cider was measured, the effect of drum-drying on the pomace was determined and the acceptability of apple tart filling and oatmeal cookies prepared with apple pomace was evaluated. The severe heat treatment of the drum drying process caused significant loss, when compared to the milder vacuum oven drying, of all solids components except insoluble dietary fiber and carbohydrate. The level of all solids components of pomace except soluble dietary fiber was related to cultivar of the fruit. Drum-dried pomace was low in moisture, 1.38%; crude protein, 2.18%; ether extract, 1.08%; ash, 5.51% and soluble dietary fiber, 3.19% and high in insoluble dietary fiber, 33.56% and carbohydrate, 51.70%, on the dry weight basis (DWB). Drum-dried pomace had a pectin content of 11.85-20.20%. 'Winesap' pomace had the highest calculated caloric content at 217.81 Kcal per 100 g (DWB) and 'Red Delicious' pomace, the lowest at 184.71 Kcal per 100 g. The drum-dried pomace blend used in the apple tart filling and the oatmeal cookies had Hunter L, 'a' and 'b' color values of 51.48, 5.42 and 18.16, respectively. The water hydration capacity of drum-dried pomace was 3.36-3.96 mL per g, depending upon the cultivar. Because of the low a_w, 0.12-0.15, and pH, 4.33± 0.03, of pomace, microbial counts, on drum-dried pomace of all cultivars stored over desiccant at ambient room temperature for 90 days were log 0.7-2.8 CFU per g pomace. The sensory panel did not indicate a difference in acceptability between the apple tart fillings or among oatmeal cookies prepared with pomace and scored the sensory characteristics of acceptability for the products as "like very much" to "like slightly." Pomace may be used successfully as a food ingredient in apple tart filling at levels of 10 and 20% of the total formula weight and oatmeal cookies at levels of 30, 40, and 50% of the amount of oatmeal in the cookie formula.

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CHAPTER I

INTRODUCTION

Apple pomace is the solid material that remains after the juice has been extracted from apples in juice production (Walter et al., 1985). In the United States, approximately 46% of the apple crop produced is processed into products of which approximately one-half is apple juice. More than 500 food processing plants in the United States produce approximately 1.3 million tons of apple pomace a year with a total annual disposal fee that exceeds $10 million (Hang, 1987). Although there are alternatives to disposal of the pomace, relatively little progress has been made to minimize the cost of pomace disposal (Jewell and Cummings, 1984).

Although the sources from which apple pomace are obtained influence its characteristics and composition, its content is generally high in moisture and insoluble carbohydrate and low in soluble carbohydrate, protein, ash, fat and plant nutrients. Pomace has a low pH (Stapleton, 1982).

The direct disposal of apple pomace to the soil presents many problems; however, non-biological and biological methods have been explored to convert apple pomace into marketable by-products. Several fuels can be produced from apple pomace including charcoal, ethanol and methane, and pomace has been used as animal feed in the United States (Rumsey, 1975; Oljsen et al., 1977) and in many other countries (Dreyer and van der Walt, 1979; Toyokawa et al., 1980). Pomace can be used to produce food ingredients such as citric acid (Hang and Woodams, 1984, 1986), pectin (Jain et al., 1984), hydrocolloidal extracts (Walter et al., 1986) and cellulose (Walter et al., 1977). Because of the functional and compositional properties of apple pomace, it has been used successfully in products such apple pie filling, pasta, cookies, muffins and yeast breads (Chen et al., 1988; Morris, 1985; Nolan, 1983; Wang and Thomas, 1989).

This study was conducted to determine the composition and physical attributes of apple pomace obtained from 'Golden Delicious', 'Red Delicious' and 'Winesap' apples that had been used for the production of unfiltered apple cider, to determine the effect of drum-drying on the pomace and to evaluate the acceptability and measure caloric value of products prepared with apple pomace.

CHAPTER II

REVIEW OF LITERATURE

A. Apple Pomace

Apples (*Malus domestica* Borkh) constitute the third most important fruit crop in the United States, and approximately 46% of the fruit is processed (Way and McLellan, 1989). In the worldwide annual apple production the United States ranks second, totaling 3,737,000 metric tons (MT), while the Soviet Union produces 7,567,000 MT. In the United States, apples are processed into six main product categories: juice, canned sauce, canned slices, frozen slices, dried apples and other processed products such as vinegar, jelly, apple butter, mincemeat or fresh slices (Way and McLellan, 1989). The International Apple Institute estimated that the United States processed 42.1% of the total apples grown in 1989. Of this amount, 52.8% was processed into juice; 31.3%, canned slices and sauce; 7.0%, dried; 7.2%, frozen and 1.7%, as other products (IAI, 1989).

Large quantities of waste are generated in the production of processed apple products. Apple pomace is the principle solid waste generated in the apple processing industry, and approximately 1.3 million MT are produced annually in the United States alone (Jewell and Cummings, 1984). The Environmental Protection Agency (EPA) has established effluent limits for the apple-processing industry which are based on advanced control technology. This current technology involves screening and secondary biological treatment systems (EPA, 1973). Table 1 presents the limits on effluent biochemical oxygen demand, total soluble solids and pH from apple processing (EPA, 1981).

B. Factors Affecting Apple Pomace Characteristics and Composition

Several factors such as preharvest treatment, postharvest treatment, fruit selection and processing procedure may affect the characteristics and composition of apple pomace. Preharvest maintenance of apple orchards varies by region (Kiviat, 1982). Many chemicals or pesticides are used in apple orchards for controlling

Table 1- Limits of effluent biochemical oxygen demand (BOD), total soluble solids (TSS) and pH from apple processing established by the Enviromental Protection Agency[a]

	Maximum for any 1 day		Maximum average value for 30 consecutive days	
Effluent characteristics	Apple juice	Apple products except juice	Apple juice	Apple products except juice
BOD (kg/kkg)	0.6	1.10	0.30	0.55
TSS (kg/kkg)	0.8	1.40	0.40	0.70
pH	6.0-9.0	6.9-9.0	6.0-9.0	6.0-9.0

[a] EPA (1981).

fungi, insects and rodents. Although the chemicals used theoretically degrade and become harmless by harvest time, there is concern over the persistence of some chemicals. Tolerances and regulations have been developed for chemical residue levels in apple pomace used in animal feed (Stapleton, 1982). Pressing and drying of the fruit residue during and after processing might concentrate some chemicals. Chemicals such as naphtaleneacetic acid (NAA), napthalacetamide (NAD) and "Sevin" have been used in apple orchards to thin the fruit set of the trees (Forshey, 1976). There are no data available on the extent of use or persistence of residues. Preharvest orchard spraying with the ripening-retarding chemical daminozide is used to promote storage longevity (Liu, 1979; Looney, 1968). Calcium (Ca) - containing compounds are used often as orchard sprays to decrease Ca deficient related physiological disorders. The primary functions of Ca within plants fall into three general categories: enzyme activation and metabolism, membrane formation and activity and cell wall structure (Christiansen and Foy, 1979). Calcium chloride, calcium phosphate and polyphenolic acid chelate of Ca are commonly used orchard sprays. Bramlage et al. (1985) reported that, depending on the frequency, concentration and spraying compound and the Ca concentration of outer cortex tissue in mature apples could be increased by at least 46 ppm and could reduce senesence breakdown after storage and reduce scald. An alternative to orchard spraying is postharvest Ca treatment by dipping or infiltration. Conway and Sams (1983), Mason et al. (1974) and Scott and Wills (1977) reported that postharvest infiltration of Ca into apples immediately upon harvest increased firmness and maintained firmness during storage. Ca content of untreated apple flesh is approximately 200 μg per g and may be as high as 1200 μg per g in Ca treated fruit (Sams and Conway, 1987).

Often, apples used in processing have been stored in controlled atmosphere, temperature regulated and/or ambient conditions and are seldom utilized immediately following harvest (Massey, 1989). The function of storing apples is to permit further ripening of the fruit and to lengthen the processing season (Woodruff and Luh, 1988). As mentioned, chemicals are often applied directly to the orchards as preharvest treatment and also are used as a chemical dip for harvested apples to control microbial spoilage and quality deterioration during storage (Doores, 1983). The Processed Apple Institute (PAI, 1977) reported that the application of fungicides to the fruit is effective in reducing the mycotoxin, patulin. Also, insecticides which inhibit growth of molds and patulin production *in vivo* have been investigated (Draughon and Ayres, 1979). There have been reports of other chemical means sought to decrease rot in storage (Edney, 1978; Rosenberger et al., 1979; Spalding et al., 1969; Spalding and Hardenburg, 1971).

There are many quality characteristics of raw apples (ripeness, damage, decay, fruit size, shape, seed pocket size, specific gravity, skin color, flesh color, firmness, soluble solids, total solids, total acid, pH, organic flavor compounds, tannins, tendency to become brown by oxidation and juiciness) that are necessary for the manufacture of high-quality apple products (Woodruff and Luh, 1988). Quality characteristics of raw apples, cultivar and maturity determine the characteristics of the product as well as the characteristics of the apple pomace (Kiviat, 1982).

Since approximately 52.8% of the processed apples is converted into juice, the selection of fruit for juice and juice pressing systems has the greatest influence on pomace characteristics (Hang and Walter, 1989). Although there are no regulations by FDA for a standard of identity for juice or cider, the USDA has a grade standard for canned apple juice (USDA, 1982). According to Bump (1989), it is well accepted that the use of a single apple cultivar rarely produces a quality juice. Often, blends of cultivars are used to obtain a balance between acidity, sweetness, aroma and astringency. There are many classifications of apple cultivars for juice and cider blending and apple characteristics may vary regionally (Emerson, 1983).

Mechanical press systems and other extraction systems are used for pressing and extracting apples, and numerous variations have been developed to optimize juice extraction (Bump, 1989). The mechanical presses include hydraulic, screw, basket, belt and pneumatic. Other extraction systems include The Murch Process, diffusion extraction, centrifuge juice extraction and single pass metallic membrane ultrafiltration (Bump, 1989; Thomas et al., 1986). Pressing aids and enzymatic treatment are often used to maximize juice extraction (Bump, 1989). The function of pressing aids is to provide firmness to the apple mash and create channels for juice to exit (Hurler and Wey, 1984). Sterilized rice hulls, defibrated bleached Kraft fiber made from southern pine wood, ground wood pulp and cellulose fibers are commonly used pressing aids (Bump, 1989). They are often used at 1-6% on an apple weight basis. Enzymatic treatment of over-ripe or stored fruit is reported for more effective juice extraction and juice clarification (Deelen and Steinbuch, 1983). Treating the apple mash with pectic enzymes and incubating the mash increase juice yield by about 5% by weight (Kilara, 1982). Enzymatic treatments and pressing aids may be used individually or in combination which may affect apple pomace characteristics and composition.

Maximum recovery of cider and apple juice is essential from an economic stand point (Glunk, 1981). Although most pressing and extracting systems are reported to operate at 78-83% yield by weight of the fruit, Kiviat (1982) reported that approximately 25-30% of the weight of the apple resulted in apple pomace. Several types of auxiliary equipment and primary pressing systems are available to extract juice from pomace (Bump, 1989). The secondary treatment may extend over several stages to include enzymatic and heat treatment and effect the apple pomace characteristics conclusively.

The remaining 48.2% of the processed apple products produces a slightly different by-product. Apple sauce and other canned products require coring and peeling of the apple by mechanical, chemical or steam operations (Wiley and Binkley, 1989). Steam peeling has received increased attention recently because of the effluent problems associated with chemical-peeling residues. The pomace produced from these processes contains more core and peel and less flesh and moisture are characteristically different than the pomace produced from the juice and cider industry.

C. Apple Pomace Characteristics and Composition

Apple pomace is the press cake that remains after juice is extracted from apples and the peel and core waste generated during the preparation of apples for canning, drying and freezing. Pomace may include skins, seeds, ovary walls, stems and pulp (Smock and Neubert, 1950). Although the sources influence characteristics and composition of pomace, it is generally high in moisture and insoluble carbohydrate and low in soluble carbohydrates, protein, ash, fat and plant nutrients and has a low pH (Stapleton, 1982). Table 2 presents the chemical composition of apple pomace (Smock and Neubert, 1950).

The moisture content of the pomace ranges between 66 and 77%, depending upon the process used (Smock and Neubert, 1950). Walter et al. (1975) and Walter and Sherman (1976) reported that the soluble carbohydrate content of apple pomace on a dry weight basis (DWB) was 34-35%. Toyokawa et al. (1980) reported that the percentage of reducing sugars of apple pomace was 23.6 (DWB) and the non-reducing sugar, 10.6 (DWB). The cell wall material provides strength to the plant

Table 2 - Chemical composition of apple pomace[a]

Constituent	Fresh pomace	Dried pomace
	%	%
Moisture	66.39-78.15	11.00-12.50
Carbohydrate	9.50-21.98	-
Nitrogen-free extract	-	54.77-59.29
Pectin	1.5-2.5	15.00-18.00
Crude fiber	4.3-10.5	15.33-20.55
Proteins	1.03-1.82	4.45-5.67
Fat (ether extract)	0.82-1.43	3.75-4.65
Ash	0.56-2.27	2.11-3.50
Potassium (as K_2O)	0.2-0.6	-
Phosphorus (as P_2O_5)	0.4-0.7	-

[a]Smock and Neubert (1950).

structure and is composed of complex of natural polymers including cellulose, hemicellulose and pectin. According to Smock and Neubert (1950), apples contain 3.5% cellulose (DWB), and apple pomace contains 12-16% cellulose (DWB). Jain et al. (1984) reported that the pectin content of 'Golden Delicious' and mixed variety apple pomace was 22.85% and 21.91% (DWB), respectively. Also, pectin content was reported as 13.5% (DWB) (Toyokkawa et al., 1980) and 22-25% (Kertesz and Green, 1931) (DWB). The crude fiber content of dried apple pomace was 15.3-20.6% (Smock and Neubert, 1950). Dreyer and van de Walt (1979) showed that the amount of indigestible matter of apple pomace was 67% or approximately three times that of crude fiber. Goldstein (1979) reported that fresh apple pomace contained 0.2% nitrogen or 1.25% crude protein, and Smock and Neubert (1950) reported that apple pomace contained 4.45-5.67% crude protein. The results of Toyokawa et al. (1980) were in agreement with those of Smock and Neubert (1950). Dreyer and van der Walt (1979) reported crude protein as 4.1% (DWB), while Walter et al. (1975) reported, 6.0% (DWB).

The availability of minerals in the soil affects the mineral content of the whole apple (Mattick and Moyer, 1983). Generally, potassium constitutes more than 40% of the total ash in fresh apples. Phosphorus and calcium are the next most prevalent minerals in fresh apple while magnesium, iron, zinc, copper, sodium and manganese exist in lower concentrations (Gebhardt et al., 1982). Goldstein (1979) reported comparatively lower values of potassium, phosphorus, calcium, magnesium, iron, zinc, copper, sodium and manganese in apple pomace. Apple pomace ash contains approximately 12% potassium and slightly more than 3% phosphorus. There are other minor constituents in apple pomace such as 'apple wax' which is primarily composed of alkanes (Kiviat, 1982) and 'apple essence' or flavor compounds which are composed of esters and ketones (Bomben et al., 1971). Lee and Mattick (1989) regarded the organic acids of apples as one of the most important group of constituents because of their effect on cooking quality. The primary acid in apples is malic with citric, lactic and oxalic also being present.

D. Uses of Apple Pomace

Jewell and Cummings (1984) estimated the cost of apple pomace disposal to exceed $10 million per year and concluded that although numerous efforts have been made to minimize the pomace disposal problems, relatively little progress has been made to minimize the cost of disposal. Although some apple processing plants, especially the smaller ones, dispose of the pomace without much cost, there are some facilities which are burdened with a disposal fee (Kiviat, 1982). Depending upon the method of disposal, the average disposal cost is $10-$20 per MT (Hang et al., 1982). The direct disposal of apple pomace presents many problems; however, many non-biological and biological methods have been explored to convert apple pomace into marketable by-products.

Several fuels can be produced from apple pomace including charcoal, ethanol and methane. Combustion techniques have been applied also to apple pomace. Walter and Sherman (1976) obtained a charcoal briquet by converting apple press cake to carbon products via low temperature pyrolysis. The gross heat of combustion of apple charcoal briquets is approximately 90% of that of commercial briquets. Anaerobic digestion and bio-drying processing systems have been evaluated by several authors as being useful for converting apple pomace into beneficial resources. Jewell and Cummings (1984) applied anaerobic digestion to apple pomace and converted approximately 80% into a substitute for natural gas with an energy value of $10-30 per wet MT. A process called 'bio-drying,' a two-stage aerobic digestion and drying process, combines a high rate composting reactor with a low energy consuming dryer. When applied to wet apple pomace, pomace mass and volume were reduced by more than 70% and a dry, stable, odorless product of 0.2-0.4 kJ (0.8-1.6 Kcal) per MT of wet pomace was produced. Lane (1979) investigated the industrial potential of the anaerobic digestion process to convert fruit and vegetable processing wastes to methane and concluded that a digestor gas, containing 50-55% methane, could be produced from 1 kg of dry material. Sargent et al. (1986) reported that in-plant combustion of apple processing wastes by pile-burning, fluidized-bed and suspension-fired systems is cost-effective for small and large apple processors when considering waste disposal fees, combustion of packaging wastes and fossil fuel costs. Hang et al. (1982) developed a solid state fermentation system for the production of ethanol from apple pomace, using a Montrache strain of *Saccharomyces cerevisiae*. The ethanol yield varied from 28.6-43.1 g per kg of wet pomace and was dependent on the initial sugar concentration of the apple pomace. Hang and Woodams (1985) reported the average rate of heat evolved during fermentation measured under adiabatic conditions was 2.8 kJ per kg per hour (669 cal per kg per hour) and the total amount of heat generated was calculated to be 52.1 kJ per kg (12.4 Kcal per kg). The results indicated that the amount of heat generated in solid-state fermentation of apple pomace to produce ethanol was not detrimental to the process and would not require a heat-removal system.

Apple pomace has been used as animal feed in the United States (Rumsey, 1975; Oltjen et al., 1977) and in many other countries (Dreyer and van der Walt, 1979; Toyokawa et al., 1980). Apple pomace may be fed fresh, before fermentation, ensiled or dried, and can be ensiled by compacting the pomace to remove oxygen and moisture (Kiviat, 1982). Rumsey (1975) stated "apple pomace is equivalent to corn silage in total digestible nutrient content, deficient in digestible protein and higher in pectin content, pentoses and ether extract than most common feedstuffs." Apple pomace should be used in combination with natural protein supplements such as soybean, cottonseed or peanut meal and may be used up to 10% in the diet of dairy cows (Kiviat, 1982). There are, however, a few objections to feeding pomace to dairy cows; these objections include low-protein content and lack of trace minerals in the pomace, a potential flavoring or contamination of milk and decreased milkfat content (Herold et al., 1977). Apple pomace has been successfully fed to beef cattle and other animals such as sheep, pigs, horses, rabbits and geese (Kiviat, 1982).

Although land application is widely practiced and an effective way to dispose of liquid waste generated from apple processing plants, the solid material presents a more difficult disposal problem because of the bulkiness, high moisture content and residual acidity (EPA, 1973; Hang and Walter, 1989). According to Kiviat (1982), apple pomace, when landfilled in large amounts, does not decay readily because under anaerobic fermentation because apple pomace produces lactic acid which preserves the pomace from decay. There are other attributes of apple pomace such as the presence of cutin, cellulose, tannic acid and pesticides that prevent degradation (Brown and Kolattukudy, 1978; Kiviat, 1982). Apple pomace has been used also for landspreading to acidify the soil but has some drawbacks such as attracting insects and wild animals and promoting fungal growth that could damage roots of fruit crops (Kiviat, 1982).

Food grade citric acid has been produced from apple pomace under solid-state fermentation conditions (Hang and Woodams, 1984, 1986). The worldwide demand for citric acid exceeds 200,000 MT per year and it is used in the food, beverage, pharmaceutical industries and elsewhere (Kapoor et al., 1982). The yield of citric acid is dependent on the amount of methanol added to the apple pomace before fermentation, the strain of *Aspergillus niger* used, fermentation time and temperature and the cultivar used to produce apple pomace. According to Hang and Woodams (1984, 1986), the production of citric acid is approximately parallel to the consumption of sugar, and under optimum conditions, 90 g of citric acid per kg of pomace fermented can be produced. The yield was greater than 88% based on the amount of sugar consumed.

Dietary fiber is an important food component found in or associated with the cell walls of plants (Schneeman, 1989). The structural polysaccharide components include cellulose, hemicellulose, pectin and lignin and the nonstructural components include various gums and mucilages. Dietary fiber is of interest to clinicians, nutritionists and food scientists because epidemiological studies have linked the lack of fiber in the diet to chronic gastric disorders such as constipation, diverticulitis and cancer of the large bowel. Conditions prevelant in the Western and developed countries include risk of obesity, cardiovascular disease and diabetes that have also been linked to a lack of dietary fiber in the diet (Burkitt and Trowell, 1975).

Jain et al. (1984) examined the isolation and characterization of pectin from apple pomace. Pectin was isolated from apple pomace of mixed cultivars by acid extraction and alcohol precipitation. The yield on an oven-dry basis was 18.06-19.32% which is equivalent to jelly grades of pectin of 170-130, respectively. Jelly grade was determined by the method described by IFT (1959).

Walter et al. (1986) studied the characterization of hydrocolloidal extracts from apple pomace. Hydrocolloids were extracted with dilute solutions of sodium hydroxide, ethylenediaminetetraacetic acid (EDTA), hydrochloric acid and water. The water-extracted solutes included high-methoxyl pectin, and the EDTA- and sodium hydroxide-extracted solutes were products of an alkaline solubilization of protopectin. Walter et al. (1986) found an exponential relationship between viscosity and concentration which is adaptable to Newtonian dispersions and between apparent viscosity and concentration which is adaptable to non-Newtonian dispersions. The effect of concentration was investigated to indicate the potential use of high levels in liquid foods.

Cellulose was isolated from apple pomace in the form of a hydrogel, using dilute sodium hydroxide and hydrogen peroxide (Walter et al., 1977). The gel was characterized as a pseudo-plastic fluid with flow properties similar to those of furcellaran, guar and xanthan gums. Walter et al. (1985) isolated the α-cellulose fraction and the uronide fractions from apple pomace and evaluated them for hydrocolloidal functionality. The pomace was subjected to a mild alkaline degradation that resulted in production of the insoluble α–cellulose fraction. Approximately 26% of the untreated matter was recovered as α-cellulose. The crude fiber content of this fraction was approximately 39%. Extraction by various aqueous solvents (water and solutions of sodium hydroxide, EDTA or dimethlysulfoxide) yielded pectic substances and pentosans of 10-18% of the untreated dry matter. Approximately 44% of the washed, air-dried apple pomace was recovered by the methods outlined by Walter et al. (1985). All the extracted fibers have the potential to provide non-nutritive bulk to low-fiber, fabricated foods.

By enzymatic or thermal treatment of apple pomace, chemical composition and physical properties may be altered (Arrigoni et al., 1986; Caprez et al., 1987). Caprez et al. (1987) investigated the modifications of apple pomace prepared with technical grade enzymes in order to improve the quality of enriched products. The authors concluded that enzymatic modification of apple pomace led to an obvious improvement of the sensory properties due to change in the chemical composition. The soluble fiber content of the pomace was reduced by approximately 20% compared with that of untreated apple pomace. The softer texture of the modified pomace may facilitate processing and results in products with improved quality and increased acceptability. Arrigoni et al. (1986) reported that the chemical composition of apple pomace was altered only slightly when thermally treated, while depectinized apple pomace had significant loss of total dietary fiber when subjected to heat treatment. Water uptake, water binding capacity, rheological behavior and oil absorption were all affected by the thermal modifications. Arrigoni et al. (1986) concluded that the exact measurements of the physical properties were very important for technical purposes and supplementation to food products.

Wang and Thomas (1989) determined the compositional changes in apple pomace after different drying processes and the sensory values of bakery products containing dried apple pomace. Apple pomace was obtained from a single-pass metallic membrane ultrafiltration of apple puree. The entire fruit was comminuted into a puree before filtration and pressing aids were not used. The pomace was drum-dried (DDAP) or freeze dried (FDAP) and both types of pomace were ground to pass through a 20-mesh screen. The total dietary fiber content was significantly higher ($p < 0.05$) in the FDAP than that in the DDAP. The total sugar of the DDAP was significantly lower ($p < 0.01$) than that of the FDAP. It was demonstrated that experimental muffins in which 50% (w/w) of the plain wheat bran ingredient was substituted by powered apple pomace were more desirable ($p < 0.01$) than the control muffins. Experimental moon cookies prepared with flaked apple pomace, substituted for 40% (w/w) of the all-purpose flour in the crust and 40% (w/w) of the quick-cooking oatmeal in the filling, were more desirable ($p < 0.01$) than control moon cookies. These results demonstrated the value of using apple pomace directly in bakery products. Such use would provide consumers with an alternative source of fiber and bakers with an option for reducing the amount of sugar and increasing the amount of fiber in the products. The disposal cost of the processors would be eliminated.

Researchers investigated the use of apple pomace and concluded that it could be processed into a thickening and flavoring ingredient for apple pie fillings (USDA, 1974). It was determined that a starch substitute can be produced by separating the peel and core from the stems and seeds, macerating, pressing, drying and then grinding the pomace into a fine powder. Apple pie fillings with 2-3% apple pomace were brownish in color, imparting a homemade appearance, a slightly grainier texture and increased flavor. By grinding the pomace to a finer mesh the problem of graininess may be eliminated.

A number of commercial apple fiber products are on the market today. Tree Top Inc. has developed a pure apple fiber product free of seeds, stems and pressing aids. This dehydrated product typically contains 56.1% total dietary fiber (Morris, 1985). Prospective applications studied by Tree Top Inc. include variety breads and other baked goods, cereal and granola products, pharmaceuticals, laxatives and pet foods. Chen et al. (1988) characterized spray-dried apple fiber, obtained from Tree Top Inc., chemically and physically and evaluated its effect on bread, cookies and muffins. Apple fiber was found to be higher in total dietary fiber than wheat and oat brans and an excellent water binder based on studies on water sorption isotherm and water holding capacity. The researchers found that wheat and oat brans were less detrimental to bread quality than apple fiber and that apple fiber may be added to cookies and muffins at a flour replacement level of 4% or less without adverse effects on cookie and muffin quality. Tastee Apple Inc. developed an apple fiber product that contained seeds and stems but did not contain pressing aids. The total dietary fiber content of the product was approximately 42.9% (Duxbury, 1987). Tastee Apple Inc. literature suggested that the product may be used in bakery products, as a thickener in apple butter-type fillings and a 3% replacement of flour in a basic muffin mix and 21% level in cream fillings (Feinberg, 1990).

CHAPTER III

MATERIALS AND METHODS

A. Source of Apple Pomace

Apple pomace of 'Golden Delicious,' 'Red Delicious' and 'Winesap' apple cultivars was obtained after the juice had been extracted for cider production by The Apple Barn and Cider Mill, Sevierville, Tennessee. The apples were grown in Tennessee and harvested a short time before juice extraction. Samples of apple pomace for each cultivar were collected on the days of processing on October 6th and 25th, 1989. A 'Shinko Press' was used as part of the continuous juice pressing system in which a thin layer of pressed apple mash, blended with rice hulls, was fed onto a cloth which moved around a large drum. Stainless steel rollers exerted increasing pressure to extract the juice from the apple material as it was moved along the belt. The juice was collected in a holding tank and the pomace was unloaded from the cloth into a container. The pomace ('as received') was stored in doubled plastic bags in 2.27-kg quantities and placed in a freezer at -18°C until processed or analyzed.

B. Processing of Apple Pomace

The apple pomace was prepared for processing by the following procedures. The frozen pomace was thawed and ground in a Hobart Meat Grinder, model 4722 (Hobart Mfg. Co., Troy, OH) with the one-way 22 R 1/8 die. The ground pomace was held at 4°C for 24 hours. The pomace was processed further by passing it through a double-drum dryer (15.3-cm diameter x 19.1-cm length), model 214-501 (Stokes Processing Equipment, Philadelphia, PA) with an internal pressure of 689 kPa (100 psi), a surface temperature of 162.8°C, a drum distance of 0.051 cm and a rotation of 2.86 rpm. The drum dried pomace was allowed to dry further at 55°C in a cabinet dehydrator for 3 hours. The pomace was ground first with a Viking Hammer Mill (Viking Mfg. Co., Jackson, MI) to pass through a 1.65-mm mesh screen, next with a No. 2 Wiley Mill model (Arthor H. Thomas Co., Philadelphia, PA) to pass through a 1-mm mesh screen and finally with a Fitz Mill, model J (The Fitzpatrick Co., Elmhurst, IL) to pass through a 60-mesh screen. The pomace of the apple cultivars was mixed thoroughly in the following weight percentages: 'Golden Delicious' and 'Winesap' 40% each and 'Red Delicious' 20%. The pomace was placed into glass jars with a packet of desiccant and stored at room temperature until analyzed.

C. Preparation of Apple Pomace for Chemical Analysis

The thawed, unprocessed apple pomace was dried in a vacuum oven, model 29 (GCA Corp., Chicago, IL) at 635 mm Hg at 70°C for 24 hours. The vacuum oven-dried pomace was milled with a No. 4 Wiley Mill model (Arthor H. Thomas Co., Philadelphia, PA) to pass through a 30-mesh screen and stored in glass jars with desiccant until analyzed.

D. Preparation of Apple Tarts

Apple tart filling was prepared by using the formulation presented in Table 3. 'Red Delicious' apples were bought at a local grocery, peeled, cored and sliced, combined in a covered pan with water and partially cooked for 20 minutes at 90°C. Sugar and cinnamon were mixed with the apples, and the mixture was allowed to cook for an additional 5 minutes. Apple pomace and water were combined in a separate pan, covered and heated for 20 minutes at 90°C. The cooked apple and pomace mixtures were combined and blended together in a Cuisinart Food Processor model DLC-7P (Cuisinarts Inc., Greenwich, CT) for 13 seconds with the material being scrapped from the sides of the processor twice. Approximately 15-g quantities of filling were placed onto 6.8-cm precut pie crust shells and baked at 235°C on tart pans for 12 minutes in an electric Rotary Despatch Oven, Style 154B (Despatch Oven Co., Minneapolis, MN). Tarts were cooled for approximately 40 minutes before being evaluated by a sensory panel.

E. Preparation of Oatmeal Cookies

Oatmeal cookies were prepared by using the formulation in Table 4. A Kitchen Aide mixer, model K45SS (Kitchen Aide Inc., St Joseph, MI) equipped with a cake paddle was used to mix the ingredients. First, the shortening was creamed on speed 4 for 30 seconds. Second, brown sugar was added to the

Table 3 - Formulation[a] for apple tart filling prepared with apple pomace

Ingredient	Formula %
apples	80.3
water	3.2
sugar	16.3
cinnamon, ground	0.2
apple pomace[b]	-
water[c]	-

[a] (Anon., 1983).
[b] Apple pomace was added at 10 and 20% of the total formula weight.
[c] Water was added at 80% of the pomace weight.

Table 4 - Formulation[a] for oatmeal cookies prepared with apple pomace

Ingredient	Formula %
flour, cake	16.36
apple pomace[b]	-
starch[c]	1.00
baking powder	0.47
salt	0.38
nutmeg, ground	0.18
cinnamon, ground	0.16
baking soda	0.09
shortening, vegetable	11.85
brown sugar	24.21
egg	8.29
milk, 3.2% fat	6.69
oatmeal[a]	19.63
raisins	10.69

[a] (Anon, 1982).
[b] Apple pomace was substituted for 30, 40 and 50% of the oatmeal in the formula.
[c] Mira-Gel #463 (A.E. Staley Mfg., Co., Decatur, IL).

shortening and creamed on speed 4 for 1 minute. Third, the egg was beat in on speed 2 for 30 seconds. Fourth, the dry ingredients (flour, apple pomace, starch, baking powder, salt, nutmeg, cinnamon and baking soda) were mixed together and added alternatively with the milk to the creamed mixture and mixed for a total of 1.5 minutes on speed 2 with periodic scrappings of the bowl. The oats and raisins were combined and stirred into the dough on speed 2 for 1 minute. Cookies were portioned with a No. 50 scoop onto a greased cookie sheet and baked at 202°C for 8 minutes in an electric Rotary Despatch Oven, Style 154B (Despatch Oven Co., Minneapolis, MN). The cookies were cooled on wire racks for approximately 30 minutes, sealed in clear plastic bags and stored at room temperature for approximately 18 hours before sensory evaluation.

E. Chemical Analysis

Proximate Analysis

Proximate analysis was performed on the oven-dried and drum-dried pomace samples of each apple cultivar. Moisture content was determined by the AOAC vacuum oven Method 14.003 (AOAC, 1984). Two-gram samples were dried to constant weight at 70°C at 635 mm Hg for 24 hours. Ether extract content was determined on moisture-free samples (2 g) by extraction with anhydrous ethyl ether for 6 hours, using the Goldfisch apparatus according to AOAC Method 7.062 (AOAC, 1984). Soluble and insoluble fiber contents were determined by the method described by Prosky et al. (1988). This method uses a combination of enzymatic and gravimetric procedures in the Fibertec System E (Tecator AB, Hoganas, Sweden) with model 1024 Shaking Water Bath and model 1023 Filtration Module. Duplicate moisture-free samples were hydrolized with termamyl, heat-stable α-amylase, No. 120L (Sigma Chemical Co., St. Louis, MO) and then enzymatically digested with protease, No. A-9913 (Sigma Chemical Co., St. Louis, MO) and amyloglucosidase, No. P-3910 (Sigma Chemical Co., St. Louis, MO) to remove protein and starch. After preparing the dried filtrate residue duplicates from the insoluble and soluble fiber, one residue was analyzed for nitrogen content and the other residue, for ash. Nitrogen content was determined by AOAC Method 7.021 (AOAC, 1984), using the Kjeltec Digestion Unit, model 1615 and Kjeldahl Distillation Unit, model 1026 (Tecator AB, Hoganas, Sweden) (% nitrogen x 6.25 = % crude protein). Ash content was determined by AOAC Method 7.009 (AOAC, 1984). The dried apple pomace samples were ashed in a Muffle Furnace (Thermolyne Corp., Dubuque, IO) at 525°C for 5 hours. Carbohydrate percentage was calculated by subtracting the percentages of moisture, soluble and insoluble fiber, crude protein, crude fat and ash from 100%.

pH

The pH of the 'as received,' oven-dried and drum-dried apple pomace samples was determined by AOAC Method 14.022 (AOAC, 1984), using a Fisher Accument pH meter, model 600, (Pittsburgh, PA). The meter was calibrated to pH 7. Ten g of sample were blended with 100 ml of freshly boiled and deionized water for 2 minutes. The pH was measured on this material.

Water Activity

Water Activity (a_w) was determined on the 'as received' and the drum-dried pomace, using the Beckman Hygroline Flat-Bed Recorder, model VFB (Beckman Instruments Inc., Cedar Grove, NJ) according to the manufacturer's instructions (Anon., 1981). The recorder was designed for continuous measurement of equilibrium moisture (a_w). The instrument was calibrated with salt standards that created a_w readings of 0.113, 0.328, 0.834 and 0.973 at 25°C.

Water Hydration Capacity

Water Hydration Capacity (WHC) was determined on the 1-mm standard mesh drum-dried pomace according to AACC Method 88-40 (AACC, 1983). WHC is defined as the maximum amount of water that 1 g of material will imbibe and retain under 2000 x 5 g centrifugation for 10 minutes.

Pectin Content

Pectin content was determined on the drum-dried apple pomace sample with the method described by McComb and McCready (1952). This method is a quantitative colormetric method based on determination of the anhydrouronic acid (AUA) content. Concentrations of galacturonic acid of 0 μg to 60 μg were measured to determine the values of the standard curve. The equation of standard curve was determined by plotting the log of transmittance by galacturonic acid (Appendix A). A 40 μg galacturonic acid hydrate standard (33.2 μg of anhydrouronic acid) was analyzed with each replication. The samples were measured for % transmission at 520 nm, using a Hitachi Spectrophotometer, model 100-60, (Hitachi, Ltd., Tokyo, Japan).

Caloric Content

The gross caloric value was determined with a Parr Adiabatic Oxygen Bomb Calorimeter, model 124 (Parr Instrument Co., Moline, IL). Samples of 0.8g drum-dried apple pomace, dried oatmeal cookie and dried apple tart filling sample were used in the gross energy determinations; values were reported in Kcal per gram. The Atwater method was used to calculate the caloric values of the samples (Watt and Merrill, 1963).

F. Physical Analysis

Color Analysis

Samples of 'as received', drum-dried apple pomace and all the treatments of oatmeal cookies and apple pie fillings (dried and ground) were measured for color, using the Hunter Color Difference Meter, model D25M-2 (Hunter Associates Laboratory, Inc., Reston, VA) (Anon., 1979). Values L, 'a' and 'b' were recorded for the samples. The samples were held in a cuvette with an optical glass bottom for measurement. The meter was standardized against a white tile No. C2-21125 with L = 91.03, 'a' = -1.3 and 'b' = 1.6.

Physical Composition

The physical composition of pomace from each 'as received' lot was determined by separating the apple flesh, peel, stems, seeds and rice hulls, drying the components separately and determining the composition on a dry matter basis. Four 15-g samples were separated physically by use of tweezers for each apple cultivar.

Cookie Spread Measurement

Spread of the cookies for all treatments was determined as described by AACC Method 10-50D (AACC, 1983). Four cookies were placed edge to edge and the width (W) was measured. The cookies were rotated 90° and remeasured to obtain an average width of the 4 cookies. The thickness (T) was measured by stacking the 4 cookies and measuring the thickness of the stack and restacking in a different order and remeasuring the thickness to obtain an average measurement of the 4 cookies. The cookie spread factor was calculated by W/T x 10 = cookie spread factor. Measurements of W and T were replicated.

Microbial Counts of Stored, Drum-dried Pomace

Microbiological examination was conducted on the drum-dried apple pomace, according to methods of the American Public Health Association (APHA, 1984). Initial counts were taken on the day of processing (day 0) and on 15, 30, 60 and 90 days of dry storage at room temperature. Sterile 0.1% peptone buffer (225 ml) was added to 25 g drum-dried apple pomace and homogenized in a Stomacher Lab-Blender, model STO-400 (Tekmar Co., Cincinnati, OH) for 2 minutes. Dilutions of 10^{-1} to 10^{-4} were used for spread plating for aerobic plate count on Standard Methods Agar (SMA) with 1% triphenyl tetrazolium chloride (TTC) and for molds and yeast on Rose Bengal and acidified Potato Dextrose Agar (PDA) with 10% tartaric acid. The SMA plates were incubated at 32°C for 48 hours and the PDA and Rose Bengal plates were incubated at 28°C for 96 hours. Counts are reported as the logarithimic ($_{\text{base } 10}$) of colony forming units (CFU) per g of sample. All media was purchased from Difco (Detroit, MI).

G. Sensory Evaluation

The apple tarts and oatmeal cookies were evaluated by an untrained sensory panel of 31 members, consisting of faculty, staff and students. Testing was conducted in a laboratory designed for sensory testing according to methods and conditions suggested by Kramer (1973) and Larmond (1977). Apple tarts and oatmeal cookies were evaluated on separate days on an 8-point hedonic scale for acceptability with 1='like extremely' and 8='dislike extremely' (Appendix B). Samples were served in random order, illuminated with cool white florescent light and evaluated between 10:00 a.m.- 12:30 p.m. Each panelist was presented one sample (1/2 tart or 1 cookie) at a time and instructed to evaluate the product and rinse the mouth between samples.

H. Experimental Design and Statistical Analysis.

The tests for chemical and physical analyses were performed following a Randomized Complete Block design. The determination of significant changes in analysis due to processing and apple cultivar was performed by Proc GLM (SAS, 1984). Significance of differences among the means of each component was determined by the Student-Newmen-Kuel (SNK) means separation technique. The sensory evaluation results were analyzed by Tukey's Test of significant difference (at $p < 0.05$) among the samples. The statistical analysis was performed using the Statistical Analysis System program available through the IBM-CMS main frame computer at The University of Tennessee.

CHAPTER IV

RESULTS AND DISCUSSION

A. Chemical Analysis

Proximate Composition

Moisture content of the 'as received' pomace was affected ($p < 0.01$) by cultivar (Table 5). 'Winesap' apple pomace had the highest moisture content at 80.31%, and 'Red Delicious' had the lowest content at 79.21% (Table 6). Factors other than the moisture content that could have affected pomace moisture content included 1) fruit quality, 2) roller pressure of the cider mill and 3) percentage of rice hulls added to the apple mash to facilitate the extraction process. The mean moisture content of drum-dried apple pomace for all cultivars was 1.38%.

The F-ratios for analysis of variance for solids components of vacuum oven-dried and drum-dried apple pomace prepared from the three cultivars are presented in Table 7. The amount of all solids components, except soluble dietary fiber, was affected by cultivar ($p < 0.01$). The drying process affected the amount of crude protein, ash and soluble dietary fiber ($p < 0.05$) and the amount of ether extract ($p < 0.01$). The interaction between cultivar and drying process was significant ($p < 0.01$) for the ash and carbohydrate contents. The 'Red Delicious' pomace of both drying methods had the highest crude protein content, 2.63%, and 'Golden Delicious' pomace had the lowest, 2.02% (Table 8). The mean crude protein content for the vacuum oven-dried pomace for all the cultivars was 2.40% and for the drum-dried pomace, 2.18%. The severe heat treatment of the drum drying process may have caused the significant loss of nitrogenous substances when compared to the milder drying process of the vacuum oven method. Goldstein (1979) and Smock and Neubert (1950) reported the protein content of apple pomace (DWB) as 1.25% and 4.45 - 5.67%, respectively. These reports did not specify the process used to prepare the pomace, indicate the use of pressing aids or any other processing chemicals or refer to the apple cultivar being processed; all of these items could have accounted for the the differences in protein content.

'Red Delicious' and 'Winesap' of both drying methods had higher ether extract contents than 'Golden Delicious.' The mean ether extract content for vacuum oven-dried pomace of all cultivars was 1.2 times higher than that of the drum-dried

Table 5 - F-ratios for analysis of variance for moisture content of 'as received' and drum-dried apple pomace

Source	d.f.	'As received'	Drum-dried
Cultivar	2	121.54**	1.50^{ns}
Mean square error	6	0.047	0.017

** Significant at $p < 0.01$ level.
ns Not significant at $p > 0.05$ level.

Table 6 - Moisture content of 'as received' and drum-dried apple pomace

Cultivar	'As received'[a]	Drum-dried[1]
	%	
Golden Delicious	79.21^{c}	1.48^{e}
Red Delicious	77.33^{d}	1.26^{e}
Winesap	80.31^{b}	1.36^{e}

a Mean of 3 observations.
b-d Means within a column followed by different superscripts are significantly different at $p < 0.01$.
e Means within a column followed by the same superscript are not significantly different at $p > 0.05$.

Table 7 - F-ratios for analysis of variance for solids components of vacuum oven-dried and drum-dried apple pomace

					Dietary fiber[b]		
Source	d.f.	Crude protein[a]	Ether extract[a]	Ash[a]	Insoluble	Soluble	Carbohydrate[a]
Cultivar (C)	2	19.63**	18.87**	97.00**	27.99**	3.30^{ns}	65.72**
Drying process (D)	1	9.08*	28.57**	9.09*	0.14^{ns}	18.50*	4.40^{ns}
C x D	2	0.48^{ns}	0.99^{ns}	156.53**	4.52^{ns}	1.75^{ns}	22.37**
Mean square error		0.025	0.006	0.009	1.973	0.565	1.151

* Significant at $p < 0.05$.
** Significant at $p < 0.01$.
ns Not Significant at $p > 0.05$.
a Error mean square d.f.= 12.
b Error mean square d.f. = 6.

Table 8 - Solids components of vacuum oven-dried and drum-dried apple pomace

Drying process	Cultivar	Crude[a] protein	Ether[a] extract	Ash[a]	Dietary fiber[b] Insoluble	Dietary fiber[b] Soluble	Carbohydrate[a]
		% (DWB)[c]					
Oven-dried	Golden Delicious	2.11[d]	1.08[d]	5.11[g]	29.60[d]	5.75[d]	56.33[d]
	Red Delicious	2.75[d]	1.35[d]	5.78[e]	36.24[d]	3.97[d]	49.93[e]
	Winesap	2.35[d]	1.36[d]	6.03[d]	32.46[d]	5.76[d]	52.04[e]
Drum-dried	Golden Delicious	1.92[d]	0.96[d]	5.50[f]	32.53[d]	3.03[d]	52.97[e]
	Red Delicious	2.46[d]	1.15[d]	6.23[d]	38.27[d]	3.06[d]	46.38[f]
	Winesap	2.24[d]	1.13[d]	4.79[h]	29.88[d]	3.48[d]	55.76[d]

a Mean of 3 observations.
b Mean of 2 observations.
c Dry weight basis.
d-g Means within a column followed by different superscripts are significantly different at $p < 0.01$.

pomace. The overall mean ether extract content for all the cultivars of both drying methods was 1.17% . Smock and Neubert (1950) reported the ether extract content of apple pomace as 3.75 - 4.65% (DWB). The rice hulls used in this experiment had 0.74% crude fat.

Oven-dried 'Winesap' and drum-dried 'Red Delicious' pomace had the highest individual ash contents. All the other interaction means were different ($p < 0.01$) from each other. These differences in ash content could have been caused by different levels of rice hulls added in the process of juice extraction and the severe heat treatment of the drum drying processing.

'Red Delicious' pomace from both drying methods contained a higher ($p < 0.01$) mean insoluble fiber content than 'Golden Delicious' and 'Winesap,' between which no difference was found. The mean insoluble dietary fiber content of both drying methods and the interaction of cultivar and drying method was 33.40%. The mean soluble dietary fiber content of all the cultivars from both drying processes and the interaction of cultivar and drying method was 4.16%. The mean soluble dietary fiber content for vacuum oven-dried pomace of all cultivars was 1.5 times higher than that of the drum-dried pomace of all cultivars. The insoluble fiber content was approximately 8 times larger than the soluble fiber content. Duxbury (1987) reported the insoluble and soluble dietary fiber contents of apple fiber powder manufactured by Tastee Apple Inc. as 31.72% and 11.13%, respectively. Wang and Thomas (1989) reported the total dietary fiber of apple pomace obtained from single pass metallic membrane ultrafiltration of apple puree as 35.29% for the freeze-dried and 33.24% for the drum-dried pomace. In this study the difference among the insoluble and soluble dietary fiber contents may be attributed in part to the presence of rice hulls which contained approximately 61.9% total dietary fiber. Rice hulls contributed to the increased insoluble fiber content of the pomace (Anon., 1990).

Specific for the cultivar and drying process interaction, oven-dried 'Golden Delicious' and drum-dried 'Winesap' had similar calculated carbohydrate contents that were higher ($p < 0.01$) than that of drum-dried 'Red Delicious'. The carbohydrate content of the both drying methods and the interaction of cultivar and drying method showed considerable variability which was due to the variation of the other solids components. Smock and Neubert (1950) reported the nitrogen-free-extract of dried apple pomace as 54.77% to 59.29%.

pH

The pH values of the 'as received' and both types of dried pomace are presented in Table 9. Differences occurred due to cultivar and drying method. 'Red Delicious' pomace had a lower pH than pomace of the other cultivars for each drying method. The pH of the vacuum oven-dried pomaces was greater than that of 'as received' and drum-dried pomaces. The final pH of the drum-dried apple pomace for all the cultivars was 4.33± 0.03. The pH of the rice hulls added in the juice extraction process had a pH of 5.95± 0.07. The primary acid in apples is malic acid, and the content of malic acid varies among cultivars and within cultivars, depending upon the climatic conditions and length of growing season (Lopez et al., 1958). Emerson reported that strains of 'Golden Delicious', 'Red Delicious' and 'Winesap' apples had a pH of 3.4-3.8, 3.7-4.0 and 3.4-3.5, respectively. The apple cultivar, climatic conditions, length of growing season and the presence of rice hulls could have affected the pH of the apple pomace in the present study.

Water Activity

There was a significant difference ($p< 0.01$) among the cultivars for a_w of the drum-dried pomace but not for the 'as received' pomace (Table 10). The mean a_w for the 'as received' pomace was 0.97 and the drum-dried was 0.13 (Table 11). Drum-dried 'Red Delicious' pomace had a higher a_w than 'Winesap,' and a_w of 'Golden Delicious' was intermediate. The minimum a_w values for the growth of most spoilage bacteria is 0.90, most yeast, 0.88 and most molds, 0.80. Considering a_w only, the 'as received' pomace could support the growth of most microorganisms while the drum-dried pomace would not; however, the effect of a_w on growth of microorganisms is influenced by other parameters such as pH, temperature and relative humidity (Jay, 1986).

Water Hydration Capacity

There was a significant difference ($p< 0.05$) in water hydration capacity (WHC) of the pomace among the cultivars (Table 10). 'Red Delicious' pomace had the higher WHC and 'Golden Delicious' and 'Winesap' had the lower (Table 11). Chen et al. (1988) reported the WHC of spray-dried apple fiber obtained from Tree Top Inc, (Selah, WA) as 9.36± 0.10 g of water per g. Approximately 72% of the spray-dried apple powder was reduced in particle size to pass through a 100-mesh

Table 9 - pH values for 'as received' and vacuum oven- and drum-dried apple pomace[a]

Cultivar	'As received'	Oven-dried	Drum-dried
Golden Delicious	4.40± 0.14	4.65± 0.21	4.35± 0.07
Red Delicious	4.00± 0.00	4.25± 0.07	4.30± 0.00
Winesap	4.50± 0.00	4.60± 0.00	4.35± 0.07

a Mean of 2 observations.

Table 10 - F-ratios for analysis of variance for water activity (a_w) and water hydration capacity (WHC) of 'as received' and drum-dried apple pomace

		'As received'	Drum-dried	
Source	d.f.	a_w	a_w	WHC
Cultivar	2	4.97^{ns}	38.22**	10.95*
Mean square error	3	0.202	0.083	0.020

* Significant at $p< 0.05$ level.
** Significant at $p< 0.01$ level.
ns Not significant at $p> 0.05$ level.

Table 11 - Water activity (a_w) and water hydration capacity (WHC) of 'as received' and drum-dried apple pomace

	'As received'[a]	Drum-dried[a]	
Cultivar	a_w	a_w	WHC
			mL/g
Golden Delicious	0.97^{b}	0.13^{de}	3.36^{c}
Red Delicious	0.98^{b}	0.15^{d}	3.96^{b}
Winesap	0.97^{b}	0.12^{e}	3.40^{c}

a Mean of 2 observations.
b-c Means within each column followed by different superscripts are significantly different at $p< 0.05$ level.
d-e Means within each column followed by different superscripts are significantly different at $p< 0.01$ level.

screen. Wheat bran and oat bran samples of 40-mesh particle size were also studied and found less hygroscopic than apple fiber and to exhibit a WHC of 5.03± 0.10 and 2.40± 0.20, respectively. These differences could be due to the structural differences of the cell wall material between grains and fruit fibers and the to lower fiber content of the grain brans, the drying process, the presence or absence of seeds and stems, rice hulls in the pomace, and/or to the particle or mesh size of the sample.

Pectin Content

There was a significant difference ($p < 0.01$) in pectin content among apple cultivars of drum-dried pomace (Table 12). 'Winesap' pomace had the highest pectin content and 'Golden Delicious' had the lowest (Table 13). Smock and Neubert (1950) reported the pectin content of apple pomace as 15.00-18.00% (DWB). Wang and Thomas (1989) determined pectin content of freeze-dried and drum-dried apple pomace obtained from a single pass metallic membrane ultrafiltration process as 6.09% and 3.71% (DWB), respectively. Pectin was determined indirectly by difference of TDF and neutral-detergent fiber contents. The published pectin content is thought to be lower than the value in the present study because of the method of determination. Chemically, pectins are pectinic substances which are water-soluble polymers of galacturonic acid connected by α 1-4 linkages in long chains, and the modification by esterification of pectinic substances alters the solubility of the pectins (McComb and McCready, 1952). Therefore, the less soluble the pectin, the more readily it is preciptiated when an electrolyte solution or organic solvent is present. In this experiment soluble fibers which include pectic substances, were precipitated with 95% ethanol, filtered through a bed of cellite and a fritted crucible with 40-60 µm pores. The purpose of the cellite was to facilitate filtration. The mean soluble fiber content of the drum-dried apple pomace was 3.19%, and in comparison to the percentage of pectin, soluble fiber content was a gross underestimation. This underestimation in soluble fiber content may be due to the inability of the method described by Prosky et al. (1988) to filter completely the soluble fiber components through the insoluble components and the cellite bed. Possibly, the soluble fiber was trapped physically in the crucible and was, therefore, expressed as insoluble dietary fiber.

Table 12 - F-ratios for analysis of variance for pectin content of drum-dried apple pomace

Source	d.f.	Pectin
Cultivar	2	32.65**
Mean square error	9	2.139

** Significant at $p < 0.01$ level.

Table 13 - Pectin content of drum-dried apple pomace

Cultivar	Pectin[a]
	%
Golden Delicious	11.85[d]
Red Delicious	15.70[c]
Winesap	20.20[b]

a Mean of 4 observations.
b-d Means followed by different superscripts are significantly different at $p < 0.01$ level.

Caloric Content

The caloric content of drum-dried apple pomace was affected by cultivar for the calculated ($p< 0.01$) and measured ($p< 0.05$) values (Table 14). 'Winesap' pomace at 217.81 Kcal per 100 g (DWB) had the highest calculated caloric content, and 'Red Delicious' pomace at 184.71 Kcal per 100 g had the lowest (Table 15). The mean caloric value measured by the calorimetric procedure was approximately 1.93 times greater than the calculated caloric content. This difference was due to the approximately 47.11 - 52.55% undigestible fiber content of the pomace.

B. Physical Analysis

Color Analysis

The Hunter color values L and 'b' for the 'as received' apple pomace were affected ($p< 0.01$) by cultivar, and all Hunter color values for the drum-dried pomace were affected ($p< 0.01$) by cultivar (Table 16). 'As received' 'Winesap' pomace was slightly darker (lower luminosity) and less yellow than the pomace of 'Golden Delicious' and 'Red Delicious' pomace (Table 17). The mean 'a' value of the 'as received' pomace for all cultivars was 8.65. Drum-dried 'Golden Delicious' was lighter (higher luminosity), less red than 'Red Delicious' or 'Winesap' and less yellow than 'Winesap' pomace. Drum-drying increased the L and 'b' value and decreased the 'a' value of the pomace. The drum-dried apple pomace may be described visually as grayish with a slight tint of red and a more obvious yellow appearance. The blend of pomace used in the apple tart filling and oatmeal cookies had L, 'a' and 'b' values of 51.78, 5.42 and 18.16, respectively.

Physical Composition

Apple cultivar was related significantly to the physical composition of the 'as received' pomace for percentage apple flesh ($p< 0.05$) and rice hulls ($p< 0.01$) but did not affect ($p> 0.05$) percentage of seeds or stems (Table 18). 'Golden Delicious' pomace had less apple flesh and more rice hulls than 'Red Delicious' or 'Winesap' pomace (Table 19). The mean percentages of seeds and stems of pomace of all the cultivars were 2.89% and 0.58%, respectively. The rate at which the rice hulls are fed into the pressing system can be controlled and will vary with the condition and quality of the apple being pressed. Generally, rice hulls are fed continuously at a rate

Table 14 - F-ratios for analysis of variance of caloric content of drum-dried apple pomace

Source	d.f.	Calculated	d.f.	Measured
Cultivar	2	116.96**	2	21.01*
Mean square error	6	7.173	3	1.495

* Significant at p< 0.05 level.
** Significant at p< 0.01 level.

Table 15 - Caloric content of drum-dried apple pomace

	Calculated[a]	Measured[b]
	Kcal per 100 g[c, d]	
Cultivar		
Golden Delicious	205.42[f]	388.38[i]
Red Delicious	184.71[g]	389.28[i]
Winesap	217.81[e]	395.65[h]

a Mean of 3 observations.
b Mean of 2 observations.
c Kcal x 4.184 = kJ.
d 'As received' basis.
e-g Means within a sample and column followed by different superscripts are significantly different at p< 0.01 level.
h-i Means within a sample and column followed by different superscripts are significantly different at p< 0.05 level.

Table 16 - F-ratios for analysis of variance for Hunter color values of 'as received' and drum-dried apple pomace

Source	d.f	L	'a'	'b'
			'As received'	
Cultivar	2	53.77**	0.10^{ns}	39.68**
Mean square error	3	0.110	0.048	0.068
			Drum-dried	
Cultivar	2	76.67**	109.00**	43.30**
Mean square error	3	0.157	0.002	0.017

** Significant at $p< 0.01$ level.
ns Not significant at $p> 0.05$ level.

Table 17 - Hunter color values[a] of 'as received' and drum-dried apple pomace

Cultivar	L	'a'	'b'
		'As received'[b]	
Golden Delicious	27.65[c]	8.60[c]	14.50[c]
Red Delicious	28.65[c]	8.70[c]	14.20[c]
Winesap	25.30[d]	8.65[c]	12.35[d]
		Drum-dried[b]	
Golden Delicious	54.25[c]	4.80[e]	18.75[c]
Red Delicious	51.70[d]	5.50[d]	18.20[cd]
Winesap	49.35[e]	6.00[c]	17.55[d]

a Hunter L (100 = white, 0 = black);
'a' (' a' = redness, '- a' = greenness);
'b' ('b' = yellowness, '- b' = blueness).

b Mean of 2 observations.

c-e Means within each column and drying process followed by different superscripts are significantly different at $p< 0.01$ level.

Table 18 - F-ratios for analysis of variance for physical composition of 'as received' apple pomace

Source	d.f.	Flesh	Rice hulls	Seeds	Stems
Cultivar	2	6.94*	20.91**	0.35^{ns}	0.52^{ns}
Mean square error	9	6.248	2.125	3.703	0.667

* Significant at $p< 0.05$ level.
** Significant at $p< 0.01$ level.
ns Not significant at $p> 0.05$ level.

Table 19 - Physical composition of 'as received' apple pomace

Cultivar	Flesh	Rice hulls	Seeds	Stems
	% (DWB)[a, b]			
Golden Delicious	70.01^{d}	26.45^{e}	3.15^{c}	0.38^{c}
Red Delicious	75.75^{c}	20.06^{f}	3.28^{c}	0.92^{c}
Winesap	75.68^{c}	21.63^{f}	2.23^{c}	0.46^{c}

a Dry weight basis.
b Mean of 4 replications.
c-d Means followed by different superscripts within a column are significantly different at $p< 0.05$ level.
e-f Means followed by different superscripts within a column are significantly different at $p< 0.01$ level.

of 2-6% on a weight basis of the apples; data indicated a calculation of components that the rice hulls were fed at a rate of approximately 10.66% on a weight basis of the apples.

Microbial Counts of Drum-dried Pomace

The microbial counts (CFU's) on the drum-dried apple pomace stored over desiccant at ambient room temperature are presented in Table 20. The aerobic plate count (APC) of all cultivars from 0 to 30 days and increased slightly from 30 to 90 days storage. Throughout the 90 day storage study, counts of all cultivars for PDA and Rose Bengal medias were less than or equal to log 2.7 CFU/g. The pH, severe heat treatment and low a_w created an unfavorable environment for microbial growth.

C. Measurements and Evaluation of Food Products Prepared with Apple Pomace

Caloric Content

The calculated and measured caloric contents of apple tart filling were affected ($p< 0.01$) by the percentage of pomace added to the total formula weight (Table 21). The apple tart filling with 20% pomace added to the total formula weight had a significantly higher calculated and significantly lower measured caloric content than the formula prepared with 10% pomace (Table 22). The amount of water added to the formula was based on the percentage of apple pomace. The formula with 20% apple pomace had more water than that of 10% pomace. This fact accounts for the lower measured caloric value found in the apple tart filling with 20% pomace.

The oatmeal cookie was not affected by percentage of pomace for the calculated caloric value but was affected ($p< 0.05$) by percentage of pomace for the measured caloric content (Table 21). The mean calculated caloric value for the oatmeal cookies prepared with all 3 levels of pomace was 380.32 Kcal per 100 g. The mean of the measured caloric contents of the cookies was approximately 1.14 times greater than the calculated caloric value. The undigestible solids content of the cookies which range from 11.44 - 12.75% and was supplied mainly by the pomace, oatmeal and raisins. Although it was expected that the calculated caloric content of 2-6% on a weight basis of the apples; data indicated a calculation of components that the rice hulls were fed at a rate of approximately 10.66% on a weight basis of the apples.

Table 20 - Microbial counts of drum-dried apple pomace stored over desiccant at ambient roon temperature

Media	Cultivar	Storage days[a] 0	15	30	60	90
		Log$_{10}$ CFU[d] per g				
SMA[b]	Golden Delicious	1.9	2.6	1.8	2.7	2.7
	Red Delicious	2.1	2.3	1.2	2.7	2.5
	Winesap	2.2	2.5	1.4	2.7	2.8
PDA[c]	Golden Delicious	1.0	1.6	1.6	1.5	1.0
	Red Delicious	1.0	2.7	1.4	1.3	0.7
	Winesap	2.2	2.7	1.4	1.2	0.7
Rose Bengal	Golden Delicious	1.0	1.2	1.0	1.0	0.7
	Red Delicious	1.0	1.0	1.2	0.7	1.2
	Winesap	1.0	1.0	0.7	1.2	1.0

a Mean of 2 observations.
b Standard Methods Agar with 1% TTC.
c Potato Dextrose Agar with 10% tartaric acid.
d Colony forming units.

Table 21 - F-ratios for analysis of variance of caloric content of apple tart filling and oatmeal cookies prepared with apple pomace

Source	d.f.	Calculated	d.f.	Measured
		Apple tart filling		
Pomace percentage	1	1333.40**	1	306.02**
Mean square error	4	0.059	2	0.439
		Oatmeal cookie		
Pomace percentage	2	0.70^{ns}	2	13.26*
Mean square error	6	1154.621	3	1.628

* Significant at $p < 0.05$ level.
** Significant at $p < 0.01$ level.
ns Not significant at $p > 0.05$ level.

Table 22 - Caloric content of apple tart filling and oatmeal cookies prepared with apple pomace

	Calculated[a]	Measured[b]
	----------------Kcal per 100 g[c]----------------	
	Apple tart filling	
% pomace[d]		
10	76.80[g]	101.34[f]
20	84.02[f]	89.75[g]
	Oatmeal cookie	
% pomace[e]		
30	361.65[j]	429.46[i]
40	392.24[j]	435.95[j]
50	387.07[j]	433.57[j]

a Mean of 3 observations.
b Mean of 2 observations.
c Kcal x 4.184 = kJ.
d Apple pomace was added at 10 and 20% of the total formula weight.
e Apple pomace was substituted for 30, 40 and 50% of the oatmeal in the formula.
f-h Means within a sample and column followed by different superscripts are significantly different at $p< 0.01$ level.
i-j Means within a sample and column followed by different superscripts are significantly different at $p< 0.05$ level.

Color Analysis

The Hunter color values of the apple tart filling and the oatmeal cookies prepared with apple pomace were not affected ($p > 0.05$) by the different levels of pomace (Table 23). The Hunter color values of apple tart filling and oatmeal cookies prepared with apple pomace is presented in Table 24. The mean L, 'a' and 'b' color values of the apple tart fillings containing both levels of pomace were 30.03, 5.75 and 11.80, respectively, and the mean values for the oatmeal cookies containing all levels of pomace were 38.93, 7.00 and 15.53, respectively. The absence of color change in the food systems with added pomace may be attributable to the inherent color of the food systems under investigation.

Cookie Spread Measurement

No significant difference ($p > 0.05$) was found in width (W), thickness (T) and W/T ratio for cookies of the oatmeal cookie formulas with 30, 40 and 50% pomace (Table 25). Table 26 presents the W, T and cookie spread factor of the oatmeal cookies prepared with apple pomace. Because of the strong WHC of the apple pomace the cookies did not spread and tended to be small and slightly thick. Similar results were reported by Chen et al. (1988).

Sensory Evaluation

The level of pomace had no effect ($p > 0.05$) on the acceptability of any of the sensory characteristics of the apple tart filling (Table 27). There was a difference among panelist scores for acceptability of texture ($p < 0.05$) and overall acceptability ($p < 0.01$) but not for appearance and flavor. A small percentage of the panelists scored texture and overall acceptability of the apple tart filling either as very high ("dislike extremely") or very low ("like extremely"), thus producing a greater degree of variability among the individual scores. All mean scores were between the categories of "like moderately" (score = 3) and "like slightly" (score = 4) (Table 28).

The percentage of pomace did not affect ($p > 0.05$) the characteristics evaluated for acceptability for flavor, texture, appearance and overall acceptability of the oatmeal cookies, but differences in sensory values were found among panelists scores for flavor and texture ($p < 0.05$), appearance and overall acceptability ($p < 0.01$) (Table 29). A small percentage of the panelists scored flavor, texture, appearance and overall acceptability of the apple tart filling either as very high

Table 23 - F-ratios for analysis of variance for Hunter color values of apple tart filling and oatmeal cookies prepared with apple pomace

Source	d.f	L	'a'	'b'
			Apple tart filling	
Percentage pomace	1	6.53^{ns}	1.60^{ns}	0.47^{ns}
Mean square error	2	0.583	0.025	0.340
			Oatmeal cookie	
Percentage pomace	2	0.71^{ns}	0.17^{ns}	5.64^{ns}
Mean square error	3	0.663	0.030	0.023

^{ns} Not significant at p> 0.05 level.

Table 24 - Hunter color values[a] of apple tart filling and oatmeal cookies prepared with apple pomace

% pomace	L	'a'	'b'
		Apple tart filling[b]	
10[c]	31.00[e]	5.65[e]	11.60[e]
20	29.05[e]	5.85[e]	12.00[e]
		Oatmeal cookie[b]	
30[d]	38.40[e]	6.95[e]	15.25[e]
40	39.05[e]	7.05[e]	15.60[e]
50	39.35[e]	7.00[e]	15.75[e]

a Hunter L (100 = white, 0 = black);
'a' ('a' = redness, '- a' = greenness);
'b' ('b' = yellowness, '- b' = blueness).

b Mean of 2 observations.

c Apple pomace was added at 10 and 20% of the total formula weight.

d Apple pomace was substituted for 30, 40 and 50% of the oatmeal in the formula.

e Means within each product and column followed by like superscripts are not significantly different at $p > 0.05$ level.

Table 25 - F-ratios for spread measurement of oatmeal cookies prepared with apple pomace

Source	d.f.	Width (W)	Thickness (T)	Cookie spread factor
Percentage pomace	2	1.16^{ns}	1.77^{ns}	1.51^{ns}
Mean square error	9	0.109	0.005	3.173

ns Not significant at p> 0.05 level.

Table 26 - Spread measurements of oatmeal cookies prepared with apple pomace

% pomace[a]	Width (W)[b]	Thickness (T)[b]	Cookie spread factor
	----------------	cm	----------------
30	5.1^{c}	2.2^{c}	23.1^{c}
40	5.2^{c}	2.3^{c}	23.1^{c}
50	4.9^{c}	2.3^{c}	21.2^{c}

a Apple pomace was substituted for 30, 40 and 50% of the oatmeal in the formula.

b Mean of 4 observations.

c Means followed by the same superscript not significantly different at p> 0.05 level.

Table 27 - F-ratios for analysis of variance for sensory values of acceptability of apple tart filling prepared with apple pomace

Source	d.f.	Appearance	Flavor	Texture	Overall acceptability
Percentage pomace	1	0.01^{ns}	3.84^{ns}	0.10^{ns}	3.77^{ns}
Panelist	30	1.31^{ns}	1.47^{ns}	2.02*	2.43**
Mean square error	30	1.65	1.36	1.45	1.10

* Significant at $p< 0.05$ level.
** Significant at $p< 0.01$ level.
ns Not significant at $p> 0.05$ level.

Table 28 - Sensory values[a] for acceptability of apple tart filling prepared with apple pomace

% pomace[b]	Appearance[c]	Flavor[c]	Texture[c]	Overall[c] acceptability
10	3.6[d]	2.8[d]	3.5[d]	3.0[d]
20	3.6[d]	3.4[d]	3.6[d]	3.6[d]

a Hedonic scale: 1= like extremely, 8 = dislike extremely.
b Apple pomace was added at 10 and 20% of the total formula weight.
c Mean of 31 panelists.
d Means followed by the same superscript not significant at $p> 0.05$ level.

Table 29 - F-ratios for analysis of variance for sensory values of acceptability of oatmeal cookies prepared with apple pomace

Source	d.f.	Flavor	Texture	d.f.	Appearance	Overall acceptability
Percentage pomace	2	2.81^{ns}	0.59^{ns}	2	1.23^{ns}	1.46^{ns}
Panelist	30	1.85*	3.05**	29	4.39**	3.26**
Mean square error	60	0.701	0.785	58	0.510	0.543

* Significant at $p< 0.05$.
** Significant at $p< 0.01$.
ns Not significant at $p> 0.05$.

oatmeal cookies prepared with apple pomace. All the means occurred between the categories "like very much" (score = 2) and "like slightly" (score = 4) (Table 30). The panel did not indicate a difference in acceptability between the apple tart filling or among the oatmeal cookies prepared with pomace and scored the sensory characteristics of acceptability for the products as "like very much" to "like slightly."

Table 30 - Sensory values[a] for acceptability of oatmeal cookies prepared with apple pomace

% pomace[b]	Flavor[c]	Texture[c]	Appearance[d]	Overall[d] acceptability
30	2.7[e]	3.1[e]	3.2[e]	2.9[e]
40	3.1[e]	3.3[e]	3.0[e]	3.2[e]
50	3.1[e]	3.0[e]	3.3[e]	3.1[e]

a Hedonic scale: 1= like extremely, 8 = dislike extremely.
b Apple pomace was substituted at 30, 40 and 50% of the oatmeal in the formula.
c Mean of 31 panelists.
d Mean of 30 panelists.
e Means followed by the same superscript are not significant at $p > 0.05$ level.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to measure the proximate composition, pectin, color, pH, water activity, water hydration and caloric value of apple pomace obtained from 'Golden Delicious', 'Red Delicious' and 'Winesap' apples after the juice was extracted as unfiltered cider, to determine the effect of drum-drying on the pomace and to evaluate the acceptability values of the products prepared with apple pomace according to two food systems.

The moisture content of 'as received' pomace was highest in 'Winesap' at 80.31% and lowest in 'Red Delicious' at 77.33%. Drum-drying reduced the moisture content of all cultivars to a mean of 1.38%. The level of all solid components of pomace except soluble dietary fiber was related to cultivar of the fruit. The severe heat treatment of the drum drying process caused significant loss, when compared to the milder vacuum oven drying, of all solids components except insoluble dietary fiber and carbohydrate. The interaction of cultivar and drying method significantly affected ash and carbohydrate contents. Drum-dried pomace contained a relatively low amount of crude protein, 2.18%; ether extract, 1.08%; ash; 5.51% and soluble dietary fiber, 3.19% and a relatively high amount of insoluble dietary fiber , 33.56% and carbohydrate, 51.70% (DWB). The pectin content of drum-dried apple pomace ranged from 11.85 to 20.20%, depending upon cultivar.

pH of the pomace was related to cultivar and affected by drying; the mean pH of vacuum oven-dried pomace was 4.50 and of drum-dried, 4.33. The water hydration capacity of drum-dried pomace was 3.36-3.96 mL per g, depending upon the cultivar. This property may be advantageous during baking to bind and hold the moisture, to minimize product drying during baking and to prevent the loss of moisture of fruit filled type products. Width (W), thickness (T), and cookie spread factor of oatmeal cookies did not differ.

The low pH and water activity, 0.13, of drum-dried pomace created unfavorable conditions for microbial growth. The aerobic plate count (APC) of all cultivars of drum-dried apple pomace storage over desiccant at ambient room temperature decreased from 0 to 30 days and increased slightly from 30 to 90 days storage. Counts on PDA and Rose Bengal medias remained consistently low throughout the 90 days of storage. The range of all counts was log 0.7-2.8 CFU per g pomace.

The apple pomace contained approximately 73.8% apple flesh, 23.7% rice hulls, 2.9% seeds and 0.58% stems, and the proportion of these substances varied among cultivars. Rice hulls contribute to the insoluble fiber content and could have limiting effects on the level of apple pomace added to a product because of graininess and residual mouth feel of the rice hulls.

The measured caloric (Bomb Calorimeter) value of apple pomace was 1.93 times greater than the calculated value (Atwater method), reflecting the presence of the 47.11-52.55% undigestible fiber content. Calculated values ranged from 184.74 to 217.81 Kcal per 100 g. Pomace was added at 10 and 20% of the total formula weight of the apple tart filling, and the calculated calorie content at 76.80 and 84.02 Kcal per 100 g, respectively, was increased with the percentage of pomace. The calculated caloric value of the oatmeal cookie, 380.32 Kcal per 100 g, was not affected by level of pomace.

The drum-dried pomace blend used in the apple tart filling and the oatmeal cookies had L, 'a' and 'b' values of 51.48, 5.42 and 18.16, respectively. The pomace may be described visually as grayish with a slight tint of red and with a more obvious yellow appearance. There were no differences in Hunter color values of the apple tart filling and oatmeal cookies prepared with pomace.

Level of pomace had no effect on acceptability of apple tart filling and oatmeal cookies. The panelists scored the characteristics of the products as "like slightly" to "like very much." Apple pomace was added satisfactorily to apple tart filling at 10 and 20% of the formula weight and at 30, 40 and 50% of the oatmeal weight in oatmeal cookies.

There is potential for great variation in composition and characteristics of the pomace because it is a by-product of an industry which gives priority to its major product and adjusts its process accordingly. Variation in the composition of apple pomace may be attributed to the cultivar of fruit and drying method and to other factors such as climatic and regional growth conditions, storage period and conditions, processing techniques and handling methods.

This study showed that drum-dried apple pomace is shelf stable and has potential as an ingredient of apple tart filling and oatmeal cookies. Further research should address the cost effectiveness of processing apple pomace as a food ingredient, the levels and types of chemical residues found, the limitation of application and the optimum levels of apple pomace in food products.

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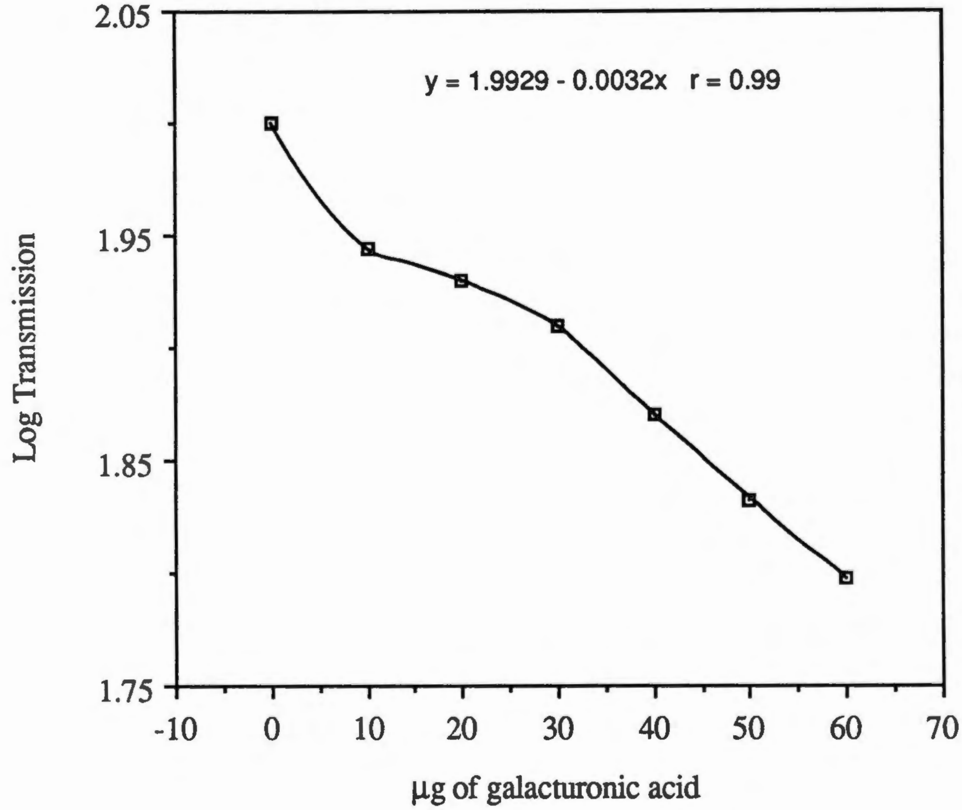
APPENDICES

Appendix A. Standard curve of galacturonic acid.



Appendix B. Sensory score sheets.

You will receive two tarts. Please taste each sample and indicate how well you like each characteristic of the <u>FILLING</u> on the scales below. Take a sip of water between samples to rinse your mouth.

Appearance

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Flavor

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Texture

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Overall acceptability

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

COMMENTS:____

____
____
____
____

You will receive three cookies. Please taste each sample and indicate how well you like each characteristic on the scales below. Take a sip of water between samples to rinse your mouth.

Appearance

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Flavor

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Texture

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

Overall acceptability

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Disklike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

COMMENTS:____
____
____
____
____

VITA

Kimberlee J. Carson was born on October 12, 1965 in Cincinnati, Ohio. She is the daughter of Mr. Donald and Jane Carson. Kim attended Sycamore High School in Cincinnati and later enrolled at Eastern Kentucky University. In May 1988 she earned a Bachelor of Science Degree in General Dietetics. During her undergraduate studies, Kim was an active member and Vice-President of Alpha Omicron Pi and a member of the Women's Varsity Tennis Team. In the fall of 1988 she entered the graduate program of The University of Tennessee and will graduate in December of 1990 with a Master of Science Degree in Food Technology and Science. She is a member of the Institute of Food Technologists (IFT) and a Volunteer Section member of IFT.