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OIL ABSORPTION CAPACITY, OIL ABSORPTION SELECTIVITY, AND MICROSTRUCTURAL CHARACTERISTICS OF CALENDERED MELTBLOWN POLYESTER, CALENDERED MELTBLOWN POLYPROPYLENE, AND PAPER TOWELS

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ABSTRACT

Calendered meltblown polypropylene and polyester and paper towels were examined for oil absorption capacity by a weight difference method. Six different oils, coconut, corn, cottonseed, olive, safflower, and sunflower oils, were used to yield a range of fatty acid compositions. The oil remaining in the pool in which the material was dipped was analyzed by gas chromatography to note fatty acid composition. The materials were examined by scanning electron microscopy to note physical characteristics that relate to absorption, i.e. surface detail and surface area. Pore size was measured to note inter-fiber spaces and oil viscosity measurements were made to determine viscosity impact on absorption capacity. Polypropylene was found to be the best performer with the highest capacity and a preference for low chain length, saturated fatty acids. This was affected by the large pore size and small diameter fibers of the polypropylene material yielding millions of small pockets in which the oil could reside.

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1. INTRODUCTION

Meltblown fabric was developed from a process of making micro-fine fibers invented in 1951 by the Naval Research Laboratory to collect radioactive particles in the upper atmosphere (Anonymous, 1989). The process was improved over the years and scaled to manufacturing size by Exxon Chemical Company. A variety of applications have been developed including insulating lining for clothes, medical drapes, masks, and gowns, battery separators, diapers, and feminine hygiene products, artificial suede and leather, and filters. Most recently, the 3M Company marketed a microwavable bacon package made partially from meltblown material. The applications are quite varied and continually expanding.

The introduction of meltblown fabric into the food packaging area presented an exciting possibility for dietary fat reduction. However, many unanswered questions about the fundamental abilities of the material and material interactions with food components are not known or quantified. Meltblown materials can absorb several times their weight in oil. What type of fat and exactly how much fat of a given type will the material hold? This is an area of concern for food and nutrition researchers alike. This information can help in the selection of certain materials for specific food applications.

It was the purpose of this research to determine the characteristics of

meltblown polypropylene, meltblown polyester and paper towels as they relate to lipid absorption capacity and selectivity of primarily saturated, short and long chain fatty acids. A secondary objective was to determine the relationship of the materials' microstructure to the differences of absorptive capacity and absorptive selectivity in lipid-material combinations.

2. REVIEW OF LITERATURE

2.1 Health and Diet

The prevalence of obesity, coronary disease, and cancer in America has made fat reduction an important issue for consumers and a profitable objective for the market-wise food industry. Scientists, doctors and the general public are taking a look at the contributing dietary factors and singling out fat, particularly saturated fat, as a common threat (Byrne, 1988; Schucker et al., 1987). Fat intake has been proven to affect many different metabolic changes in the human body including cholesterol levels. In fact, the type of fat consumed has been shown to affect the type of cholesterol transport proteins present in the blood and theoretically affect the onset of a disease state (Anderson 1988; Carroll et al., 1986; Etherton et al., 1988; Lewis et al., 1981; Roberts, 1988; Schaefer et al., 1981; Stein et al., 1982; Törnberg et al., 1986).

The scientific community and food processors are attempting to make use of this information to better the health of the population and increase corporate profits. Many methods for lowering fat consumption have been introduced including diet modification (Stevens, 1989), genetic engineering of food animals (Pursel, 1989), fat substitutions (Anonymous,1990; Kantor, 1990), and improved product packaging (Costello et al., 1990).

One new food packaging material specifically geared to fat reduction is

meltblown polypropylene and meltblown polyethylene fabric. This material has been incorporated into microwavable pouches and used to cook bacon and reheat sausage patties. Costello et. al. (1990) reported an additional 3.3-3.5 grams of fat could be removed from these meats with meltblown pouches as compared to paper towels. However, little is known about the properties of meltblown material. How much oil will it hold? Is there a preferred type of oil/fat that is absorbed more readily? The applications of this material are purely speculative because the properties of the material that relate to food chemistry are unknown or not yet quantified.

2.2 Polymers and Properties

Melt-blown materials made from polypropylene and polyester (polyethylene terephthalate) polymers possess very special properties due to their chemical structures. Both materials are hydrophobic and oleophilic, though their chemical structures are quite different. The fabrics look very similar to the eye but possess different chemical characteristics that make each very special on a molecular level and yield different tactile and behavioral properties.

Polypropylene is one of the the simplest polymers in current use (Kresser, 1960). The structure of polypropylene is generally isotactic. This arrangement is illustrated in Figure 2.1 (Scales, 1990). The isotactic structure allows for easy crystallization. The polymer chain forms in a helix with three monomer units comprising a single twist as is depicted in Figure 2.2 (Frank, 1968). This helical arrangement and the isotactic alignment allow the polypropylene to orient in a

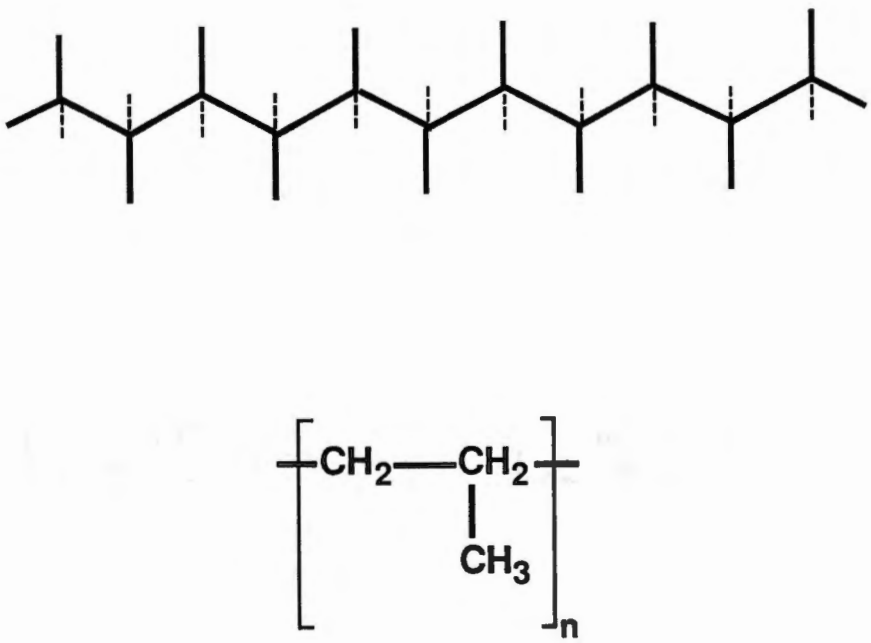

Figure 2.1 – Isotactic structure of polypropylene (Scales, 1990).

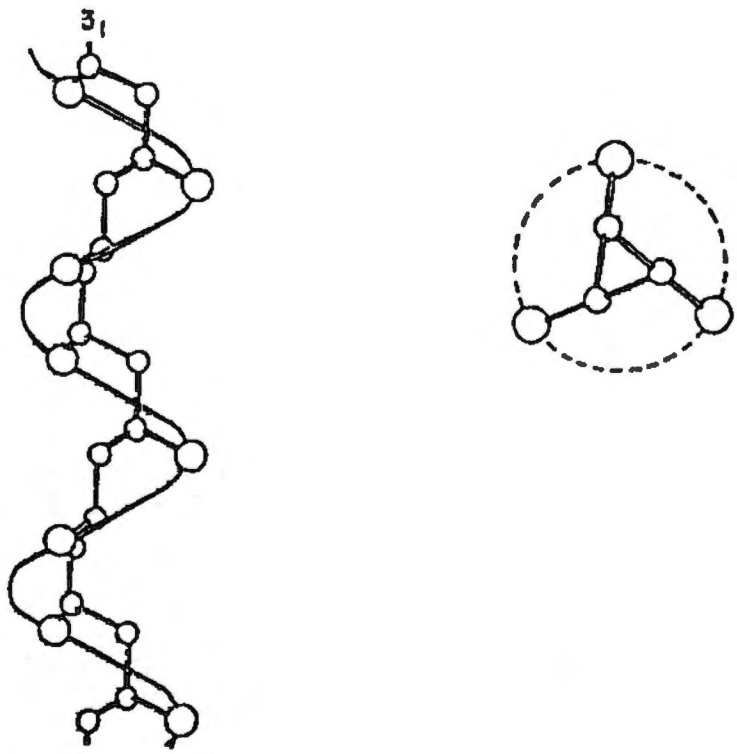

Figure 2.2 – Helical arrangement of isotactic polypropylene polymer chains (Frank, 1968).

crystalline structure. This crystalline structure affects hardness, density and softening temperature positively while decreasing solubility (Miller, 1966).

The most reactive portion of the monomer is the tertiary carbon's hydrogen atom (Kresser, 1960). This reactive site is susceptible to halogenation with chlorine, bromine or other negative monovalent ions at high temperatures or at ambient temperatures with ultraviolet radiation (Frank, 1968). Oxidation also occurs under these conditions with the presence of moisture (Frank, 1968).

Polypropylene is soluble in xylene, tetralin, and aliphatic, aromatic, and halogenated hydrocarbons at 80°C (Frank, 1968). Many aliphatic and aromatic hydrocarbon compounds are found in foods in minute amounts as functional flavor and color elements (Heath, 1986). In addition, different chemicals cause swelling and dissolution of polymer fibers at higher temperatures. This is illustrated in Table 2.1 (Mark et al., 1985). Polypropylene is resistant to strong acids and other oxidizing agents though they do slowly attack the chains. In some cases, polypropylene gained weight when exposed to various compounds by absorptive swelling (Mark et al., 1985). In other instances the polymer lost weight due to the dissolving action of chemicals (Mark et al., 1985). In practice, stabilizers are added to commercial resins to retard chemical breakdown (Scales, 1990).

While polypropylene has one reactive site to protect, the much more complex polyethylene terephthalate (polyester) has four main reactive sites. The structure of polyester is shown in Figure 2.3 (Woodward, 1989). Polyester is

Table 2.1 – Chemical stability of polypropylene in the presence of various inorganic and organic reagents as reported by Mark et al. (1985).

Compound	Temperature (°C)	Change in Time (days)	Weight Change (%)	Effect
Inorganic compounds				
ammonia, 30%	22	180	-0.5	unaltered
boric acid	100	30	-0.028	unaltered
calcium carbonate, saturated solution	100	30	-0.052	unaltered
calcium chloride, 50%	22	30	0	unaltered
chlorosulfonic acid	22	10	ND	decomposed
chromic acid, 2 N	22	30	- 0.2	unaltered
copper nitrate, saturated solution	100	10	- 0.174	NE, yellow
hydrochloric acid, 30%	22	90	- 0.5	NE, brown
hydrofluoric acid	22	90	- 0.5	NE
hydroperoxide 30%	22	90	0	NE, yellow
iodine, 50% solution	22	30	0	NE, brown
iron trichloride	100	30	- 0.005	NE, yellow
magnesium chloride, saturated solution	100	30	- 0.032	NE, yellow
nitric acid, 50%	80	10	ND	decomposed
phosphoric acid, 60%	100	30	-0.126	unaltered
potassium dichromate, 10% in H_2S0_4 1:1	22	90	+0.6	NE, brown
potassium bromate, saturated solution	100	30	-0.05	NE, yellow
potassium chlorate, saturated solution	100	30	-0.10	NE, yellow
potassium chromate, 40% solution	100	30	0.113	NE. yellow
potassium hydroxide, 54% solution	20	30	0	unaltered
silver nitrate, 20% solution	22	30	0	unaltered
sodium bicarbonate, saturated solution	100	30	-0.288	unaltered
sodium bichromate, saturated solution	100	30	+0.10	brown
sodium carbonate, saturated solution	22	30	0	unaltered
sodium chloride, saturated solution	22	90	0	unaltered
sodium hydroxide, 30% solution	80	30	+0.2	NE, yellow
sodium hypochlorite, 13%	22	90	+0.75	NE, yellow
sodium phosphate, saturated solution	100	30	-0.375	NE, yellow
sodium sulfite, 40%	22	30	0	unaltered
sulfuric acid, 50%	22	90	0	unaltered
sulfuric acid, 98%	100	20	-3.5	cracks
water, distilled	100	30	+0.055	unaltered
zinc chloride, 20% solution	100	30	+0.19	unaltered
H_2S0_4 + HCl, 1:1	22	30	+0.18	NE
H_2S0_4 + HF, 1:1	22	30	+0.17	NE, yellow
H_2S0_4 + $HN0_3$, 1:1	22	30	+0.74	NE, yellow
HCl + HF, 1:1	22	30	+0.24	NE, yellow
HCl + $HN0_3$, 1:1	22	30	+1.39	NE, yellow
HF + $HN0_3$, 1:1	22	30	+0.24	NE, yellow
Organic Compounds				
acetic acid, 50%	80	30	+0.5	NE
acetone	22	90	+ 8	swollen
acetophenone	60	30	+ 1.8	swollen
alkylbenzene	50	50	+ 2.3	swollen
aniline	22	30	+ 0.5	unaltered
benzene	22	90	+ 12	swollen
benzoyl chloride	22	30	+ 5.8	swollen
butyl alcohol	22	90	+ 0.35	unaltered
butyl acetate	22	30	+ 3.9	swollen
butyl phthalate	80	90	+ 4.7	swollen
carbon disulfide	22	30	+ 7.6	swollen
carbon tetrachloride	22	30	+35	swollen
chloroform	22	30	+ 5.5	swollen
cyclohexanol	60	10	+ 6	swollen
decahydronaphthalene	60	30	- 3.4	swollen
dioxane	22	30	+ 3.3	swollen
ethyl acetate	22	90	+ 4 9	swollen
ethyl alcohol	22	30	- 0.2	unaltered
ethyl chloride	0	2	-10.1	swollen
ethyl ether	22	30	- 8 5	swollen
ethylene glycol	22	10	0	unaltered
formic acid, 85~o	22	30	0	unaltered
formaldehyde, 35%	22	30	+ 0.16	unaltered
freon	0	90	- 0.09	unaltered

Table 1.2 (Continued)

Compound	Temperature (°C)	Change in Time (days)	Weight Change (%)	Effect
glycerin	22	30	+ 0.2	unaltered
n-heptane	22	30	+ 11	swollen
hydrazine sulfate, 10%	80	180	0	unaltered
isopropyl alcohol	22	30	+ 0.2	unaltered
lactic acid, 20%	60	30	+ 0.4	unaltered
linseed oil	60	30	0	unaltered
malic acid	60	180	- 0.4	unaltered
methyl alcohol	22	30	+ 0.2	unaltered
methylene chloride	60	60	+ 1.6	swollen
nitrobenzene	60	30	+ 2.0	unaltered
oleic acid	80	30	+ 5	swollen
oxalic acid, 50%	60	30	+ 0.5	unaltered
petroleum ether, bp 100-140°C	60	30	+ 2.3	swollen
phenol	22	90	+ 2	swollen
pyridine	22	10	+ 3.8	swollen
sodium acetate, saturated solution	100	30	- 0.13	unaltered
succinic acid	60	30	- 0.1	unaltered
tetrahydrofuran	22	30	+ 3.7	swollen
tetrahydronaphthalene	60	30	+ 3.8	swollen
thiophene	60	30	+ 0.1	unaltered
toluene	22	10	+ 11	swollen
trichloroacetic acid	22	30	+ 0.5	unaltered
turpentine	60	30	+ 10.5	swollen
vaseline oil	80	30	+ 8	swollen
p-xylene	22	1	+ 11	swollen

ND = not determined
NE = negligible effect.

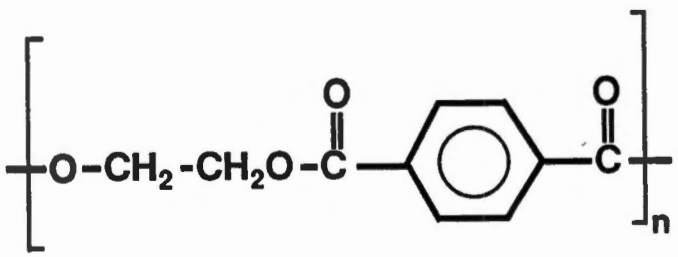

Figure 2.3 – Structure of polyester, polyethylene terephthalate (Woodward, 1989).

hydrophobic and resistant to most organic solvents, most acids, and photodegredation (Goodman et al., 1965). Polyesters have a high melting point due to the rigidity of the aromatic ring (Mark et al., 1969). The main reactive sites (4) of polyester are located on the aromatic ring (Goodman et al., 1965). The hydrogen atoms not connected to the chain carbons of the phenolic ring are readily substituted by various reaction schemes. The bond energy of the carbonyl groups are generally too high for substitution to occur at that point in the polymer (Mark et al., 1985).

The reactive sites can undergo typical phenolic reactions. Generally, this means halogenation with bromine or chlorine or substitution with a methyl group or esterification of a methyl group (Goodman et al., 1965). Cross-linking also occurs at this point between chains. Because of the bulk, even amorphous regions can connect to form interchain bonds yielding a stronger structure with a higher melting point.

Polyester is extremely resistant to strong acids. For example 10% sulfuric acid has a similar effect to that of water on the polymer chain; 50% sulfuric acid takes six months to half the tenacity of polyester fibers (Goodman et al., 1965). However, oxidative hydrolysis does occur above 70°C in the presence of moisture (Goodman et al., 1965). Several ionic bases have been found to remove the outer surface of polyester fibers while non-ionic bases will penetrate and degrade fibers by cleaving the internal ester linkages (Goodman et al., 1965). Chloroform was found to dissolve polyester at sub-zero temperatures

(Goodman et al., 1965). Upon warming of the extractant liquid, the dissolved amorphous regions crystallize out of solution (Goodman et al., 1965). The reactiveness of chloroform with polyester makes the standard chloroform-methanol extraction methods unusable. Photodegradation occurs in polyester at wavelengths of <315nm (Mark et al., 1969). This range is Gamma radiation, a wavelength present in sterilizing irradiation energy.

Degradation of polymeric material always proceeds from the amorphous regions to the non-oriented crystalline regions to the oriented crystalline regions (Goodman et al., 1965). Crystallinity only occurs partially in polymer fibers - especially in melt-blown fibers. The melting temperature is defined as the temperature where crystalline and amorphous phases are in equilibrium (Mark et al., 1985). Melting temperature is affected by degree of crystallinity, the size and uniformity of the crystallites, the polymer length, the prominence of side chains and the types of side chains present.

Various side groups are added to modify the properties of polymers for fire retardation, color changes, stability to photodegredation, oxidative stability and other qualities. All these chemical components are available to react with food ingredients under conditions of heat and light.

The mechanism by which meltblown fabrics absorb oil has not been published in generally available literature. Perhaps this information is proprietary where it has been examined. Nevertheless it is evident physical phenomena could be responsible for most absorption. The most likely explanation would be

a physical capillary type action between the material's fiber surfaces. Coating of the individual fibers possibly is caused by the surface tension of the oils. Surface tension and capillary action can allow oil to fill spaces spanning between two or more fibers. There appear to be no possible chemical reactions between the fibers and oils (Wonderlick, 1990).

2.3 The Meltblown Process

The meltblown process allows petroleum-based polymers to be formed into porous sheets of highly entangled small diameter fibers. This process involves extruding melted polymer chips through a small orifice die into an air stream which draws and directs the fibers to collect in sheets on a rotating wire screen cylinder. A schematic diagram of a meltblown line similar to the University of Tennessee's meltblown line is located in Figure 2.4. The process involves placing polymer pellets into the hopper which feeds an extruder. The polymer chips enter the extruder and are melted as they travel along the screw to the die. The die contains a linear, horizontal row of extremely small diameter holes through which the molten polymer is forced by the high pressure inside the extruder. The molten polymer is drawn and directed onto the collector by hot, high velocity air blown from air manifold above and below the die. The resulting material is composed of highly entangled continuous fibers often referred to as a web. The web produced will typically not have fibers oriented in any particular direction.

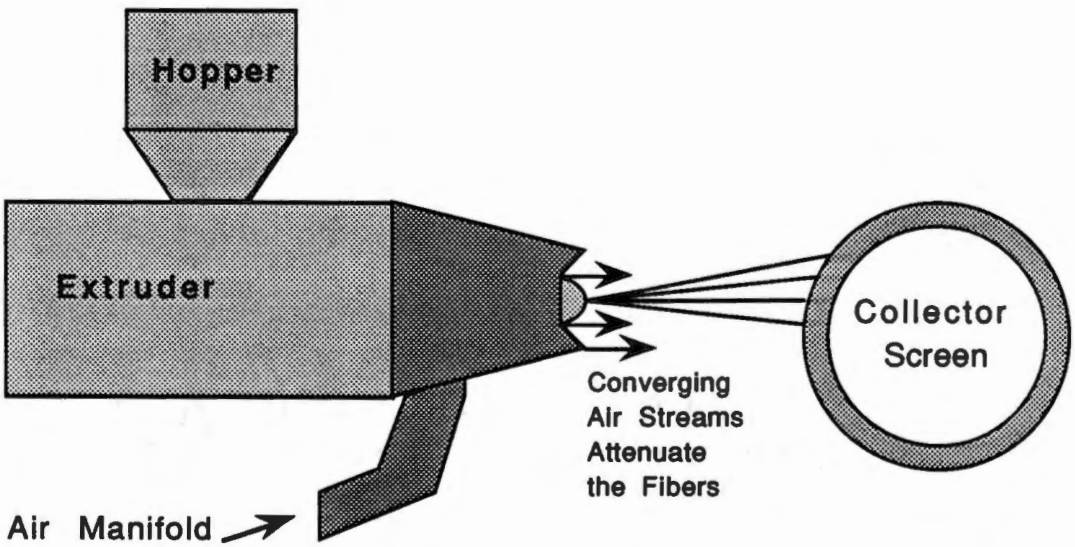

Figure 2.4 – Diagram of a meltblowing line. Polymer pellets are placed into the hopper and extruded through the die tip into two converging streams of hot, high velocity air onto the collector.

2.4 Oils Chemistry and Function

Edible oils are primarily composed of tri-acyl-glycerols with a small fraction of free fatty acids. The properties of fats are due to the type of fatty acid on the glycerol backbone and the placement of the fatty acids on the glycerol backbone. Some fats are solid and some are liquid at room temperature. This wide assortment of fat types is composed of relatively few different types of fatty acids. Fatty acids are composed of hydrocarbon chains and a carboxyl group. The most common fatty acids have between 4 and 22 carbon atoms. Some of these are caprylic acid (8 carbons), capric acid (10 carbons), lauric acid (12 carbons), myristics acid (14 carbons), palmitic acid (16 carbons), stearic, oleic, linoleic, and linolenic acids (18 carbons), and arachidic acid (20 carbons). The degree of saturation affects the melting temperature of fatty acids. For example the four 18 carbon fatty acids, stearic acid (saturated), oleic acid (1 unsaturated bond), linoleic acid (2 unsaturated bonds), and linolenic acid (three unsaturated bonds) have vastly different melting points: 70°C, 14°C, -5°C, and -11°C, respectively (Lawson,1985). The melting point of the constituent fatty acids affects the viscosity of the fat at any given temperature.

Fats and the polyester and polypropylene polymers are attracted because of their chemical similarity. Both are hydrophobic. Physical requirements for surface coating dictate that the coating liquid molecules must be more attracted to the object being coated than to each other (Adam, 1941). If this tenet is met, a film like coating will slightly spread over the object with droplets forming in

random spots (Adam, 1941). The other major requirement is wettability. Oil does wet the meltblown surface while water does not. Wettability is a description of the minicus angle of a fluid around a solid (Adam, 1941). If the angle is greater than 90°, the surface is considered unwettable. Such combinations imply all the capillaries or pits in a solid will be filled with the wetting fluid (Adam, 1941). This is the case with meltblown fibers and oils.

3. MATERIALS AND METHODS

3.1 Production of Meltblown Material

The three materials used in this study were calendered meltblown polypropylene, calendered meltblown polyester, and paper towels. The meltblown materials were produced at the University of Tennessee Textiles and Nonwovens Laboratory. The calendered polypropylene was produced from Exxon PP3505G, 400 MFR resin with a 0.4 g/hole/minute throughput and a die to collector distance of 12 inches. These conditions produced a web of 1.0 oz/yd which was calendered at a later date. The calendered polyester was produced from Eastman Kodak PET12270 with a 0.4g/hole/minute throughput and a die to collector distance of 8 inches. This 1.0 oz/yd fabric was calendered the same day as the polypropylene under identical conditions.

Two lengths of 1.0 oz/yd material were calendered together at 85°C between a patterned roller and a smooth steel roller with 20-24 lbs of pressure. This yielded 2.0 oz/yd fabrics of calendered polypropylene and calendered polyester. These fabrics were cut into 10-cm diameter circles. Paper towels were obtained from Scott Paper Company (Mobile, AL) and cut into 10-cm diameter circles. The cut circles of all three materials (discs) were stored in separate petri dishes to minimize contamination until needed.

3.2 Composition of Oils

The oils were chosen to give a diverse selection of fatty acid concentrations. The six oils included coconut oil (Anderson Clayton/Humko Products Inc., Memphis, TN), corn oil (CPC International Inc., Englewood Cliffs, NJ), cottonseed oil (Anderson Clayton/Humko Products Inc., Memphis, TN), olive oil (Cento Fine Foods Inc., Thorofare, NJ), safflower oil (Hollywood Foods, Los Angeles, CA), and sunflower oil (SVO Enterprises, Eastlake, OH). These oils were stored under nitrogen at ambient temperature throughout the research. Viscosities of the oils used were determined with the Brookfield Viscometer over a range of temperatures. Typical oil compositions for the native oils used are presented in Table 3.1. These values were determined with the gas chromatograph methodology mentioned below.

The methodology has been divided into the following sections: absorption capacity determination, absorption selectivity determination, and mechanism description. Absorption capacity determination involved treating each of the material disc types with each of the six oil types and determining the weight transfer of oil to material. Absorption selectivity analysis involved gas chromatograph analysis of fatty acids remaining compared to original fatty acid content of the oils. In addition the fatty acid concentration for each material was analyzed and compared to the original fatty acid content to note any differences in fatty acid selectivity. Absorption mechanism description involved material description through the use of scanning electron microscopy, pore size and

Table 3.1 – Percentage fatty acid composition of oils used in this study as determined by gas chromatography[a].

Oil	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0
Coconut	15.24	11.85	10.33	3.66	2.14	7.29	31.68	25.81	1.04	1.28
Corn	–	–	0.82	0.25	1.07	2.25	27.02	68.09	–	1.32
Cottonseed	–	–	0.92	0.33	2.03	2.21	24.60	69.89	–	0.94
Olive	–	–	0.84	0.26	1.13	3.31	61.73	25.01	5.95	2.62
Safflower	–	–	–	0.25	0.69	2.62	18.58	77.27	–	0.59
Sunflower	–	–	0.83	0.26	0.55	4.07	72.84	21.07	0.44	0.77

– below detectable limits

[a] number of carbons: number of unsaturated bonds such that:

C8:0 = Caprylic acid = ($C_7H_{15}COOH$)

C10:0 = Capric acid = ($C_9H_{19}COOH$)

C12:0 = Lauric acid = ($C_{11}H_{23}COOH$)

C14:0 = Myristic acid = ($C_{13}H_{27}COOH$)

C16:0 = Palmitic acid = ($C_{15}H_{31}COOH$)

C18:0 = Stearic acid = ($C_{17}H_{35}COOH$)

C18:1 = Oleic acid = ($C_{17}H_{33}COOH$)

C18:2 = Linoleic acid = ($C_{17}H_{31}COOH$)

C18:3 = Linolenic acid = ($C_{17}H_{29}COOH$)

C20:0 = Arachidic acid = ($C_{19}H_{43}COOH$)

distribution measurements, image analysis of fiber surfaces, and oil viscosity measurements.

3.3 Absorption Capacity Determination

Glass petri dishes with lids were cleaned, rinsed, and dried in an oven (110°C) and cooled in a desiccator. Initial weight was taken to 0.001g and recorded. Pasturer pipets with bulbs were used to add approximately 3.5g of the specified oil to the petri dish bottom. The petri dish cover was labeled and the exact oil weight recorded to 0.001 g from a Metler balance. Tongs were used to set the petri dish bottoms into the labeled, upside down covers on a tray.

Once completed, a set of nine dishes containing the oil were placed into a Lab Line L-C Incubator set at 47°C. The material discs were weighed individually on weighing paper utilizing forceps to minimize contamination. The weighed discs were removed from the scale with forceps and were pierced with a sewing needle to run a length of thread through each disc. The needle was removed, the thread was tied, and the discs were hung above a raised shelf.

When the oils had been heated for 30 minutes, the petri dishes with oil were removed individually and matched with the corresponding material disc. Each material disc was added carefully to the petri dish by holding the disc at an angle and manipulating the petri dish to make direct contact between the oil and the disc. Each disc was turned over using the thread so contact was made with the oil on both sides. The petri dish was lowered and placed on the raised shelf

directly below its corresponding disc for 30 minutes. Each material disc was weighed again on the tared, weighing-paper-covered balance. The weight was recorded for all material discs. The petri dish bottoms were weighed with the use of tongs and recorded. The residual oil, that which remained in the petri dish bottoms, was saved for absorption selectivity analysis.

Calculations preceding statistical analysis were performed to obtain meaningful data. The initial material disc weight was subtracted from the final disc weight and that new value called Δdisc; Δdisc represents the change in disc weight caused by oil absorption. The initial petri dish weight and the initial fat weight were subtracted from the final petri dish weight and that new value called Δfat; Δfat represents the loss of oil from the petri dish reservoir due to absorption by the test material. These two values, which differed by less than 0.01 g, were averaged to obtain the weight change between the fat reservoir and the absorptive material, denoted as Δchange. This value was used to correct for differences in initial disc weight variation and for initial fat weight variation as follows:

$$\% \text{ Disc Gain} = \frac{\Delta\text{Change}(100)}{\text{Initial Disc Weight}}$$

$$\% \text{ Residual Loss} = \frac{\Delta\text{Change}(100)}{\text{Initial Fat Weight}}$$

These values were computed for each material/fat combination and used for statistical analysis.

3.4 Absorption Selectivity Analysis

A modified version of A.O.C.S. Official Method Ce2-66 (1988) was used to convert approximately 0.200 g of each residual oil sample to methyl esters within one hour of absorption capacity determination completion. The modification substituted hexane for pentane as the dilution solvent. Methyl esters were analyzed on a Shimadzu GC-9AM gas chromatograph equipped with a Shimadzu FDD-1A floppy disc drive and a Shimadzu AOC-9 autosampler, hereafter referred to as GC. The GC temperature program was arrived at through an experimental stepwise procedure to resolve and optimize peak separation and included the following rates and holding periods:

PERIOD	RATE	TARGET TEMPERATURE	HOLDING TIME
Initial	none	118°C	2 minutes
1st Rate	4°C/minute	till 125°C	none
2nd Rate	7°C/minute	till 150°C	none
3rd Rate	3°C/minute	till 168°C	none
4th Rate	1°C/minute	till 170°C	1 minute
5th Rate	5°C/minute	till 210°C	none

Nitrogen carrier gas was used at a flow rate of 0.20 ml/minute. A flame ionization detector (FID) was used to detect elution of compounds from the 6' long, 1/8" diameter, stainless steel, factory packed, Supeleco fatty acid column (Bellefonte,PA). The Supeleco column was packed with 10% SP2340 and 60/80 Chromosorb WHP. The FID was fueled with hydrogen and compressed air both fed with a pressure of 0.5 kg/cm. The autosampler was programmed to analyze

four separate analysis for each methyl ester sample vial.

All methyl ester analyses were performed within 36 hours of methyl ester preparation with storage at -70°C during extended waiting periods. All data were stored on floppy discs for reprocessing with a composite standard after all analyses were completed. The RM-1 and RM-5 fatty acid standards were obtained from Supeleco,Inc (Bellefonte,PA) and included C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1, C18:2, C18:3, and C20:0. A composite calibration was made utilizing 10 injections of standard to calibrate the GC integrator. All sample chromatograms were reprocessed with the same calibration curve to yield standardized results. Oils that had not been treated with the materials were converted to methyl esters and analyzed under the same conditions for comparison purposes, here after referred to as native oils.

3.5 Absorption Mechanism Description

Pore size and distribution of all three materials were evaluated using a Colter Porometer II (Colter Electronics Limited, England). This involved cutting a circle of each material to fit the sample chamber and immersing that sample in a special viscous liquid- Porofil (Colter Electronics Limited, England). The thickness of the sample was measured and entered into the porometer. The instrument determined the bubble point and calculated the mean, minimum, maximum pore sizes and the relative distribution of each size pore.

Scanning electron microscopy was utilized to ascertain average fiber diameter, to estimate the percentage of the area melted in the calendering

process, and to discover surface characteristics that might affect absorption. The samples were taken from pre-cut disc and mounted onto SEM stubs, coated with gold-palladium and examined in a Hitachi S-800 FEG-SEM at the High Temperature Materials Analysis User Center at Oak Ridge National Laboratory. Four random 500x micrographs were taken of different areas to determine fiber diameter of calendered polyester and calendered polypropylene materials. Micrography was performed with a beam current of 5kV. The micrographs were scanned into a Macintosh computer and measurements were taken along two perpendicular lines until 20 fibers had been measured from each photograph. Ultimage™ 1.3.4 (GTFS, Santa Rosa, CA) was used to compute fiber diameters and these measurements were plotted and averaged with Cricket Graph™ (Cricket Software, Maluern, PA).

Pressed area quantitation was accomplished by similar methods utilizing the same Hitachi S-800 FEG-SEM and software on the computer at the High Temperature Materials Analysis User Center at Oak Ridge National Laboratory. The micrographs were taken at 40x magnification to include a unit cell (a complete repeating unit in the pattern). This unit cell contained two distinct areas: the pressed and native areas. The pressed area and the total area were quantitated by image analysis on a computer. The pressed area was divided by the total area and multiplied by 100 to determine the percentage of the total area compressed/melted. Four unit cells were measured and averaged from calendered polyester and calendered polypropylene materials.

Surface characteristics of all three materials were examined at 30,000x magnification. Notes were made on fiber arrangement and other noticeable characteristics as determined by significance and prominence of particular characteristics. Analysis was carried out on a Hitachi S-800 Field Emission Gun Scanning Electron Microscope at the High Temperature Materials Analysis User Center at Oak Ridge National Laboratory. Samples were coated with gold and palladium in a Bio-Rad Polaron Division SEM Coating System at 20 mAmps for 30 seconds before imaging on the Hitachi S-800.

Viscosity measurements were taken on the six oils over time from 47°C to 20°C with a Brookfield Viscometer (LV Model) equipped with a number 1 spindle turning at 30 and 60 RPMs. Six 250 ml flask were filled with 200 ml of each oil and heated to 47°C in the incubator oven. Viscosity measurements (in centipoise or mPa/s) were taken one at a time and plotted to note the change in viscosity during cooling and to note room temperature viscosity.

3.6 Statistical Analysis

Three sample materials and six oils were matched by a generated incomplete block design for a total of 18 treatments. Nine samples per work time were analyzed for absorption capacity and selectivity. Analyses were not completed until all material and oil matches were replicated five times.

All statistical analysis were performed with the use of Statistical Analysis System (SAS, 1989). Analysis of variances were conducted to note significant differences attributable to the main effects and/or interactions. When there were

no differences that could be attributed to fat type or interactions, these factors were removed as main effects in the model. Scheffe's Mean Separation Test was utilized to note differences between means.

4. RESULTS AND DISCUSSION

4.1 Absorption Capacity Determination

Absorption capacity was determined by two simultaneous methods; the discs of each material were dipped into individual reservoirs containing a known amount of oil and the weight gain of the disc and the weight loss of the reservoir were recorded. A percentage was calculated for weight loss from the reservoir by dividing the change in weight by the original reservoir weight and multiplying by 100. Thus the data in Table 4.1 were obtained. Mean initial reservoir content weight varied from 3.72±0.25 g, 3.66±0.23 g, and 3.64±0.22 g for polyester, polypropylene, and paper towel discs, respectively; the mean initial weights of the reservoirs used for all three materials were similar. Coconut oil polypropylene disc reservoirs lost a greater percentage oil than paper towel disc reservoirs and polyester disc reservoirs. Polyester and paper towel reservoirs lost a lower percentage of oil than polypropylene reservoirs when corn oil, cottonseed oil, and sunflower oil were used. With olive oil, polyester reservoirs lost a similar percentage as the other materials, however, polypropylene reservoirs lost significantly more than paper towel reservoirs. The polyester reservoir percent loss for safflower oil was significantly less than the percent loss from polypropylene and paper towel reservoirs for safflower oil. The combined average reservoir loss percent for polyester was 25.119%. For paper towels this

Table 4.1 – Percentage weight loss* of polyester (PET), polypropylene (PP), and paper towel (PT) disc reservoirs of selected oils during absorption capacity testing.

Fat Type	PET	PP	PT
Coconut oil	23.165[a]	32.709[b]	23.105[a]
Corn oil	23.730[a]	31.593[b]	24.273[a]
Cottonseed oil	25.181[a]	34.598[b]	25.368[a]
Olive oil	27.577[ab]	33.290[a]	25.177[b]
Safflower oil	25.523[a]	32.898[b]	24.195[a]
Sunflower oil	25.540[a]	35.584[b]	23.399[a]
Combined average	25.119[a]	33.445[b]	24.253[a]

* $\frac{\text{(Total combined initial reservoir weight- total weight after absorption testing)(100)}}{\text{total combined initial reservoir weight}}$

[abc] Means on the same row followed by different letters are significantly different ($p<0.05$)

average was 24.253% and for polypropylene it was 33.445%. The polypropylene reservoir lost a significantly greater percentage of oil overall than the other reservoirs. It is apparent that for most oils, polypropylene discs are most effective in absorbing oil when compared to both the polyester and paper towel discs. This trend is especially evident in the shorter chain saturated oils used. Using this polypropylene material to absorb fat tends to remove larger quantities of saturated fat than can be removed using the other materials. Polypropylene food packaging applications should allow consumers to increase reduction of saturated fat in the diet.

A percentage was calculated for weight gain of material discs by dividing the change in weight by the original disc weight and multiplying by 100. Thus the percentage of the average polyester, polypropylene, and paper towel discs weight added to the discs by the average absorption of all types of oil were obtained (Table 4.2). The average weight of 10-cm circular discs of polyester material was 0.335 g. The average weight of 10-cm circular discs of polypropylene material was 0.327 g and the average weight of 10-cm circular discs of paper towel material was 0.225 g. The polyester disc gained an average of only 278.94% of its initial disc weight in coconut oil which was significantly less than polypropylene or paper towel materials with gains of 368.59% and 381.31%, respectively. This trend was followed for corn, cottonseed, olive, and sunflower oils as is indicated in Table 4.2. For safflower oil all three materials were different with paper towel absorbing the most oil as a

Table 4.2 – Percentage weight gain* of polyester (PET), polypropylene (PP), and paper towel (PT) disc from absorption of selected oils during absorption capacity testing.

Fat Type	PET	PP	PT
Coconut oil	278.94[a]	368.59[b]	381.31[b]
Corn oil	264.88[a]	363.75[b]	389.59[b]
Cottonseed oil	275.70[a]	375.98[b]	385.27[b]
Olive oil	294.33[a]	379.39[b]	402.67[b]
Safflower oil	271.01[a]	364.20[b]	396.75[c]
Sunflower oil	279.74[a]	380.50[b]	384.60[b]
Combined average	277.94[a]	372.07[b]	390.03[c]

* $\frac{\text{(Total initial disc weight before absorption testing)(100)}}{\text{total combined initial disc weight}}$

[abc] Means on the same row followed by different letters are significantly different ($p<0.05$)

percentage of its weight followed by polypropylene and polyester respectively. The combined average weight gain for each material yielded significant differences between all three materials. The paper towel discs absorbed 390.03% of their initial disc weight in oil. On the average, the polypropylene discs absorbed 372.07% of their initial disc weight in oil while the polyester discs absorbed 277.94% of their initial disc weight in oil. The paper towel discs weighed significantly less than the other materials although similar amounts of oil are being picked up by the paper towels than are absorbed by the more bulky polypropylene discs (Table 4.2). The percentage of oil lost from the reservoir is a better indication of oil absorption capacity due to the larger differences in disc weight than differences in reservoir weight.

4.2 Absorption Selectivity Determination

The results from each material–fat interaction are located in Tables 4.3-4.8. These results show significant differences between selectivity of the materials for certain fatty acids and a discrepancy from the concentration of fatty acids found in the native oil.

The fatty acid concentrations in residual coconut oil were significantly different for C8:0 and C18:3 between the three materials but not different from the fatty acid concentrations in the native oil (Table 4.4). The concentration of C8:0 was significantly lower and the concentration of C18:3 was significantly higher for polypropylene material than for the paper towels or the polyester material. This indicates that polypropylene material absorbed more C8:0 and

Table 4.3 – Percentage of specific fatty acids remaining in coconut oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	15.36[a]	11.34[b]	15.44[ac]	15.24[abc]
C10:0	12.20	12.30	12.10	11.85
C12:0	10.25	10.55	10.25	10.33
C14:0	3.56	3.72	3.59	3.66
C16:0	2.05	2.18	2.10	2.14
C18:0	7.00	7.45	7.17	7.29
C18:1	31.81	32.69	31.65	31.68
C18:2	26.37	27.75	26.03	25.81
C18:3	0.23[a]	1.11[b]	0.52[a]	1.04[ab]
C20:0	1.43	1.47	1.39	1.28

[abc] Means on the same row followed by different letters are significantly different ($p<0.05$)

Table 4.4 – Percentage of specific fatty acids remaining in corn oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	–	–	–	–
C10:0	0.19	–	–	–
C12:0	0.86	0.88	0.93	0.82
C14:0	0.28	0.27	0.29	0.25
C16:0	1.07	1.06	1.07	1.07
C18:0	2.16	1.99	2.25	2.25
C18:1	27.56	27.33	27.67	27.02
C18:2	67.36	67.07	67.32	68.09
C18:3	–	–	–	–
C20:0	1.38	2.28	1.40	1.32

– Below detectable limits of the gas chromatograph

Table 4.5 – Percentage of specific fatty acids remaining in cottonseed oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil

Fatty Acid	PET	PP	PT	Native Oil
C8:0	0.28	–	0.09	–
C10:0	0.48	0.23	0.25	–
C12:0	1.02	1.04	1.08	0.92
C14:0	0.36[ab]	0.36[ab]	0.38[a]	0.33[b]
C16:0	2.00	1.85	2.02	2.03
C18:0	1.81	1.97	2.09	2.21
C18:1	25.14[a]	25.81[b]	25.48[ab]	24.60[a]
C18:2	68.91[a]	68.69[a]	68.65[a]	69.89[b]
C18:3	–	–	–	–
C20:0	1.00[a]	1.09[b]	1.04[ab]	0.94[a]

[ab] Means on the same row followed by different letters are significantly different ($p<0.05$)
– Below detectable limits of the gas chromatograph

Table 4.6– Percentage of specific fatty acids remaining in olive oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	–	–	–	–
C10:0	–	–	0.45	–
C12:0	1.01[a]	1.06[a]	1.02[a]	0.84[b]
C14:0	0.32[a]	0.33[a]	0.32[a]	0.26[b]
C16:0	1.19[a]	1.19[a]	1.18[a]	1.13[b]
C18:0	3.49	3.45	3.43	3.31
C18:1	64.21	64.14	63.99	61.73
C18:2	27.05[a]	27.29[a]	26.93[a]	25.01[b]
C18:3	1.11[a]	1.05[a]	1.08[a]	5.95[b]
C20:0	2.64	2.56	2.62	2.62

[ab] Means on the same row followed by different letters are significantly different ($p<0.05$)
– Below detectable limits of the gas chromatograph

Table 4.7 – Percentage of specific fatty acids remaining in safflower oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	0.15	–	–	–
C10:0	0.10	–	0.09	–
C12:0	0.70[a]	0.97[b]	0.97[b]	–
C14:0	0.26	0.29	0.28	0.25
C16:0	0.69	0.68	0.67	0.69
C18:0	2.55	2.92	2.98	2.62
C18:1	18.78	29.99	30.12	18.58
C18:2	76.85	65.34	65.08	77.27
C18:3	–	0.10	0.12	–
C20:0	0.61	0.69	0.67	0.59

[ab] Means on the same row followed by different letters are significantly different ($p<0.05$)
– Below detectable limits of the gas chromatograph

Table 4.8 – Percentage of specific fatty acids remaining in sunflower oil after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the native oil.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	0.18	0.07	0.40	–
C10:0	0.33	0.33	0.28	–
C12:0	0.95[ab]	1.01[a]	0.97[ab]	0.83[b]
C14:0	0.30[ab]	0.32[a]	0.30[ab]	0.26[b]
C16:0	0.58[ab]	0.63[a]	0.58[ab]	0.55[b]
C18:0	3.82	3.85	4.00	4.07
C18:1	72.28	60.98	71.97	72.84
C18:2	21.55	32.47	20.91	21.07
C18:3	0.02[a]	0.25[b]	0.50[b]	0.44[b]
C20:0	0.95	1.10	1.05	0.77

[ab] Means on the same row followed by different letters are significantly different ($p<0.05$)
– Below detectable limits of the gas chromatograph

less C18:3 than the other materials. This supports the assertion that polypropylene is somewhat selective for shorter chain fatty acids.

No differences were found among the three materials or native corn oil compositions (Table 4.4). Corn oil is primarily composed of C18:1 and C18:2, both considered unsaturated fatty acids. There appeared to be no selectivity for these fatty acids among the different materials.

The mean distribution of specific fatty acids in residual cottonseed oil were found to vary between the material types (Table 4.5). No significant differences were found among the three materials for C10:0, C12:0, C14:0, C16:0, C18:0,or C18:2. The concentration of C14:0 found in the residual pools of the synthetic materials was significantly different from the native cottonseed oil concentration. The polypropylene disc absorbed a lower percentage of the oleic (C18:1) and arachidic acids (C20:0) than were absorbed by the polyester disc. The polyester and paper towel reservoirs contained similar concentrations of C18:1 and C20:0. All materials absorbed a significant amount of linoleic acid (C18:2).

Significantly higher amounts of C12:0, C14:0, C16:0, and C18:2, and significantly lower amounts of C18:3 were left remaining in the residual olive oil after treatment by all three materials as compared to the native oil fatty acid concentrations as indicated in Table 4.6. No significant differences were noted among the different materials absorption. The C10:0 fatty acid was only found in detectable levels for the paper towel reservoir.

In the residual safflower oil samples, only C12:0 demonstrated a significant difference among the sample treatments (Table 4.7). Polyester absorbed more C12:0 than polypropylene or paper towels though none of the materials absorbed much C12:0. The concentration in the native oil was so low it did not register in the gas chromatograph detector. Safflower oil, a highly unsaturated oil, did not experience selective absorption between the three materials.

The polypropylene residual contained significantly more C12:0, C14:0 and C16:0 than the native sunflower oil (Table 4.8). The difference in recorded amounts of C8:0 could account for the small difference found in these values becoming significant; shifts in the amount of one constituent fatty acid alters the values of all others in this percentage based analysis. Polyester material absorbed more C18:3 than either of the two other materials; significantly less C18:3 remained in the residual oil after treatment with polyester than was found in the native oil.

The oils were combined to note trends in selectivity. Overall polyester and paper towels absorbed less C8:0 than polypropylene. This data is summarized in Table 4.9. Paper towels absorbed significantly less caprylic (C8:0), capric (C10:0), and myristic acids (C14:0) than both meltblown materials. Polyester absorbed less C10:0 and C14:0 than polypropylene from which the residual oil contained more C10:0 and C14:0 than the native oil. Paper towels and polyester absorbed less lauric acid (C12:0) than polypropylene from which the residual oil

Table 4.9 - Total percentage of specific fatty acids remaining after absorption test of polyester (PET), polypropylene (PP), and paper towels (PT) as compared to the average percentage of specific fatty acids in all native oils.

Fatty Acid	PET	PP	PT	Native Oil
C8:0	2.62[a]	1.25[b]	3.16[c]	1.45[b]
C10:0	2.18[a]	1.45[b]	2.62[c]	1.13[d]
C12:0	3.15[a]	2.38[b]	3.23[a]	1.97[c]
C14:0	0.84[a]	0.69[b]	0.98[c]	0.60[d]
C16:0	1.25[a]	1.22[a]	1.36[b]	1.22[a]
C18:0	3.46[a]	3.28[b]	3.70[c]	3.25[ab]
C18:1	40.14	39.25	38.57	38.55
C18:2	47.95	51.04	47.82	51.23
C18:3	0.22[a]	0.34[a]	0.38[a]	1.29[b]
C20:0	1.33	1.49	1.42	1.27

[abcd] Means on the same row followed by different letters are significantly different ($p<0.05$)

contained more C12:0 than the native oil. Paper towels absorbed less palmitic (C16:0) and stearic acids (C18:0) than the other two materials. Polyester absorbed less C18:0 than polypropylene though neither of these concentrations were significantly different from the concentration found in the native oil. All three materials absorbed significant amounts of linolenic acid (C18:3); the concentration for each residual from the material treatments was lower than the concentration found in the native oil. As a general rule, the polypropylene material absorbed more of the shorter chain fatty acids; this is exposed by the fact that for the three materials, polypropylene reservoirs lost more C8:0, C10:0, C12:0, and C14:0 than the other two materials. Similarly, the paper towel reservoir lost significantly less of these saturated short chain fatty acids to the paper towel disc. This data indicates an inability of paper towels to pick up these type fats that is not indicated by the polypropylene data and implies specific health benefits for those wishing to reduce dietary saturated fat.

Selective behavior was shown with the shorter chain fatty acids, namely C8:0 through C14:0 for polypropylene. This was found in the coconut oil for C8:0 and in the total picture for the other fatty acids. Thus polypropylene was found to absorb more of the shorter chain saturated fatty acids than the other materials. Overall, most fat-material combinations did not show selective behavior. This may be due to the fats being primarily unsaturated and unaffected by the materials used. Another possible reason for not finding significance might be the overall low volume of both oil and material used. With

such small volumes of fat, the shift in fatty acid concentration due to the percentage calculation obscures slight changes in fatty acid concentrations with initially low concentrations.

4.3 Fiber Diameter and Surface Characteristics

Material samples were examined by scanning electron microscope to note individual characteristics. The polyester and polypropylene materials were analyzed to determine average fiber diameter and percent of area melted in the calendering process. Fiber diameter analysis was not performed for paper towels due to the incompatibility of the fiber structure with the measuring techniques used. All three materials were examined to note surface detail of individual fibers.

Calendered polyester and calendered polypropylene materials were composed of continuous small diameter fibers of each respective material arranged in a random web-like structure. Polyester material micrographs taken at 500x magnification and 5kV for fiber diameter determination are located in Figure 4.1. Polypropylene material micrographs taken at 500x magnification and 5kV for fiber diameter determination are located in Figure 4.2. Fiber diameters were found to be greater on average for polypropylene at 3.7μm than for polyester at 2.7μm. Plots of observed data with averages and upper and lower 95% confidence limits are located in Figures 4.3 and 4.4 for polyester and polypropylene, respectively. The polyester material, having lower average fiber diameter, had greater surface area than polypropylene material. Absorption has

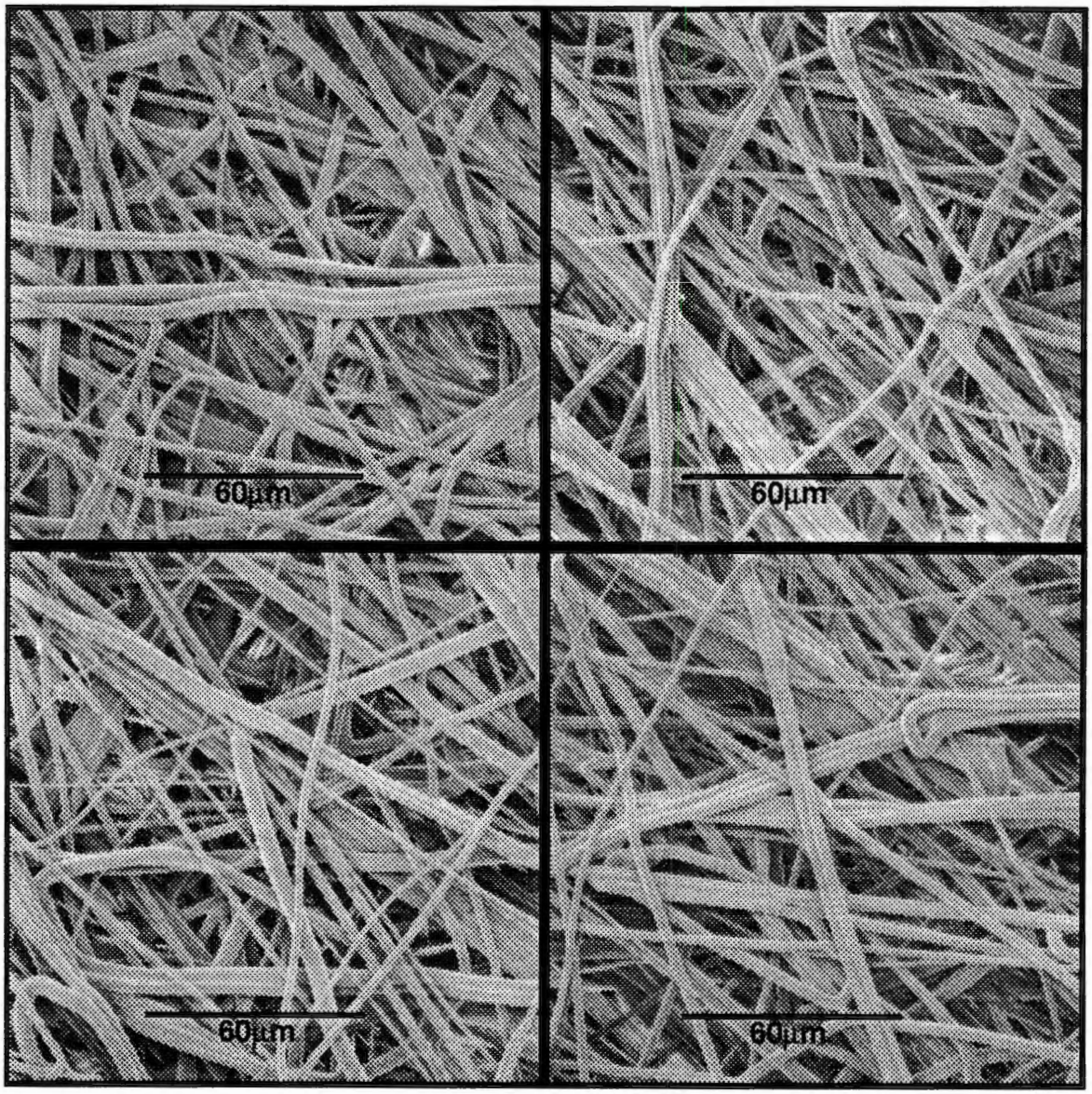

Figure 4.1 – Size and microstructural arrangement of meltblown polyester fibers. Scanning electron micrographs taken at 500x magnification and 5kV voltage.

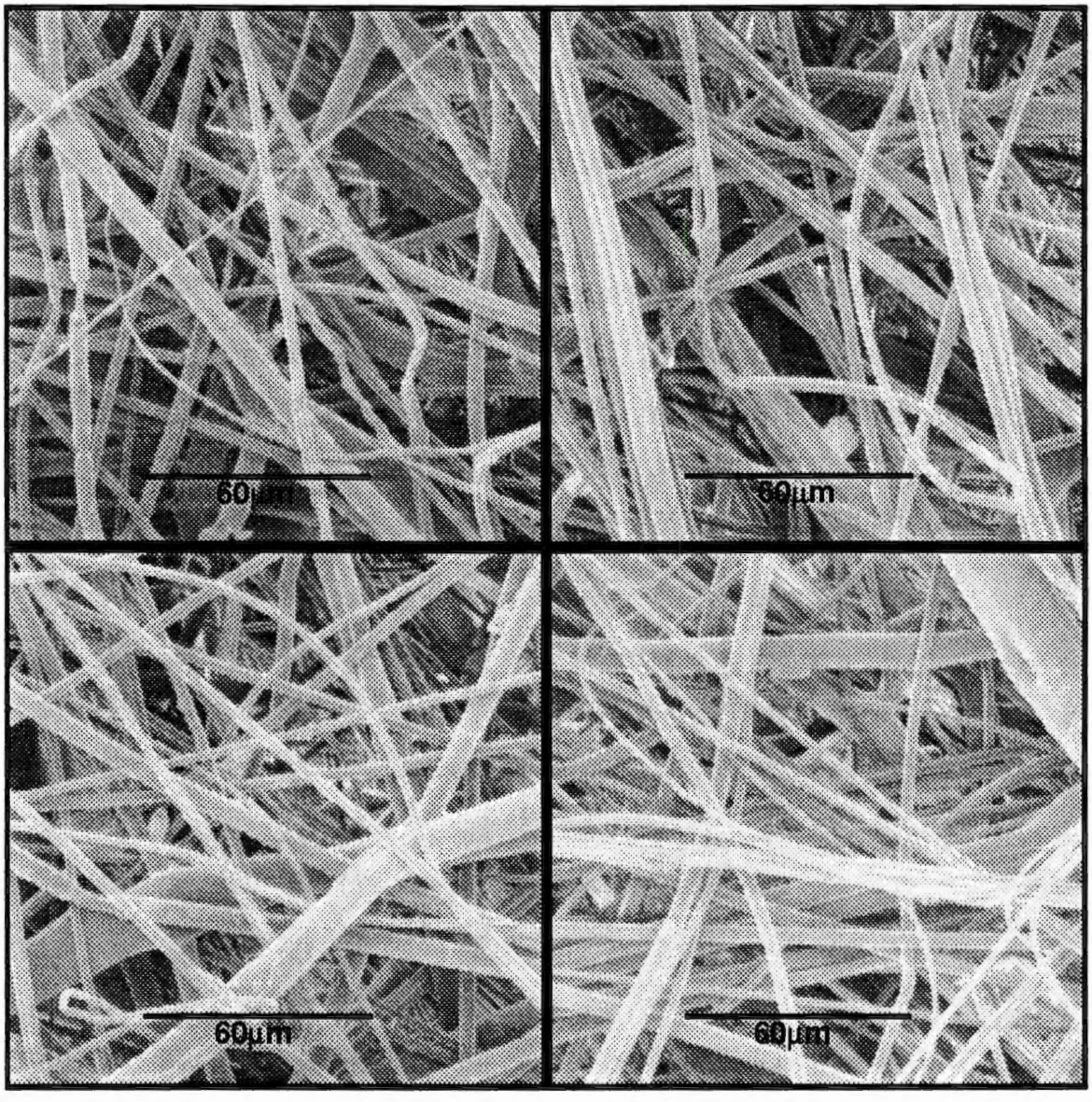

Figure 4.2 – Size and microstructural arrangement of meltblown polypropylene fibers. Scanning electron micrographs taken at 500x magnification and 5kV voltage.

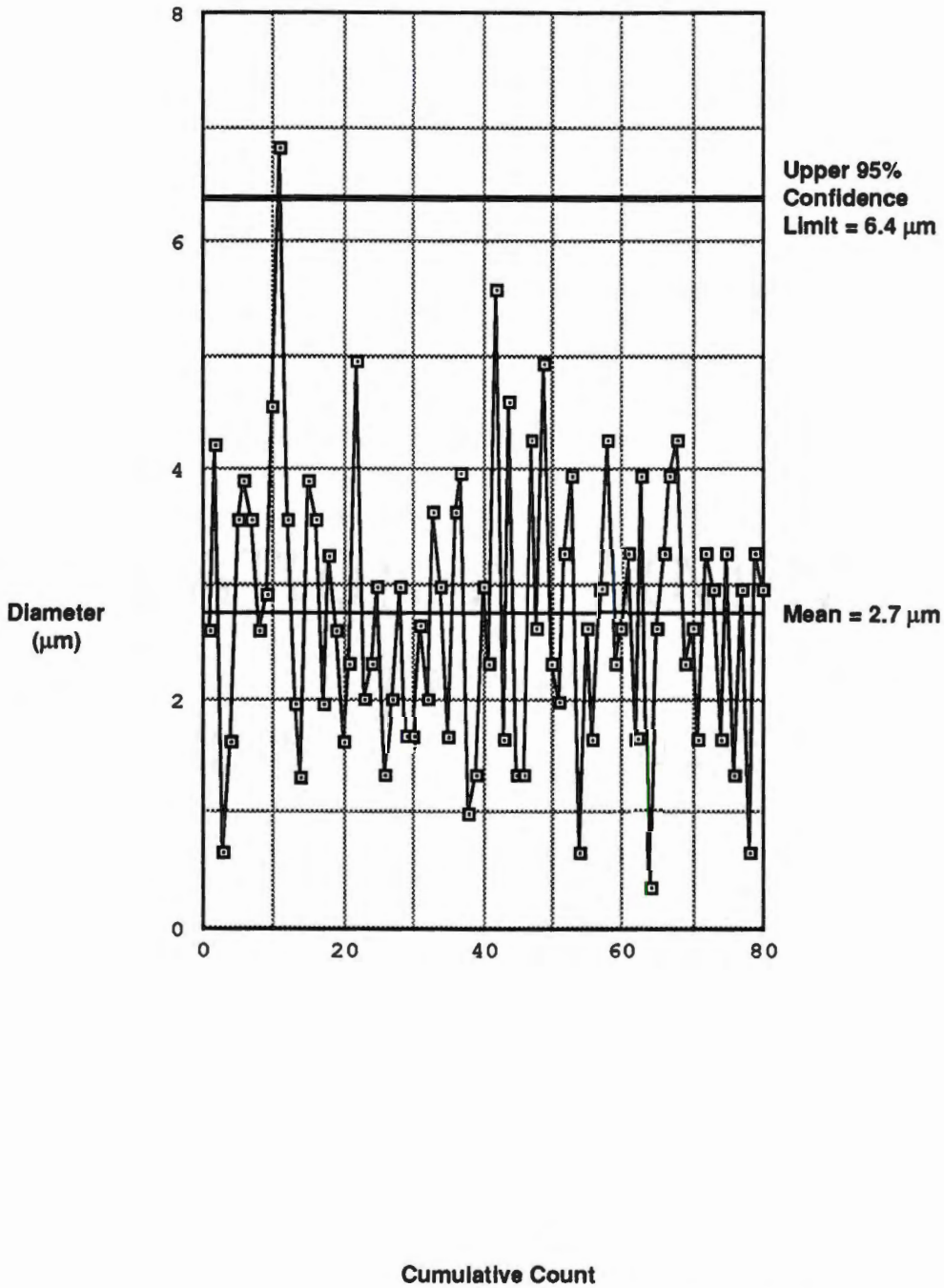

Figure 4.3 – Polyester fiber diameter plot. Plot of 2.0 oz/yd2 calendered polyester material fiber diameters from four scanning electron micrographs (20 measurements from each).

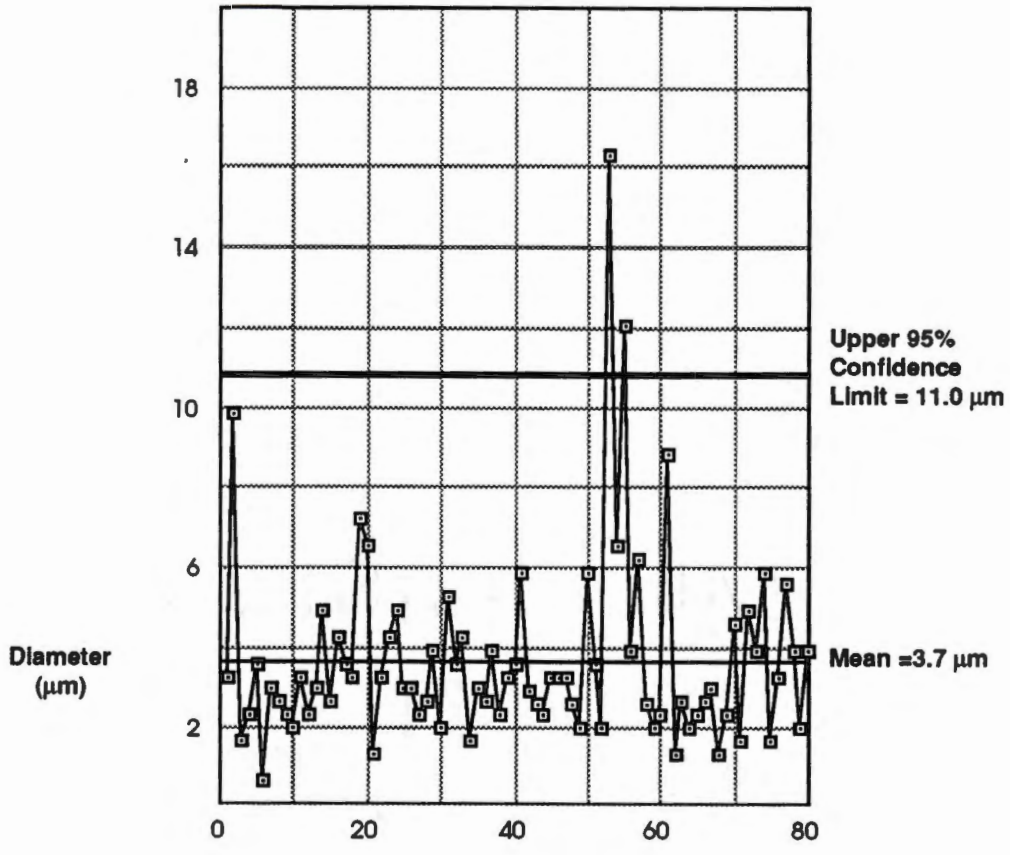

Figure 4.4 - Polypropylene fiber diameter plot. Plot of 2.0 oz/yd2 calendered polypropylene material fiber diameters from four scanning electron micrographs (20 measurements from each).

been believed to be an entirely surface activity whereby an increased surface area would allow greater absorption (Wonderlick, 1990). However, data obtained from the absorption and selectivity portion of this study indicated more oil is being absorbed by the polypropylene material. This may have been due to the similarity of polypropylene structure to the structure of the fatty acids allowing better packing onto the surface. Polyester contains a bulky phenolic ring which may have prevented such close packing as was allowed by the polypropylene. The paper towel material is hydrophilic and less similar to generic fatty acid structure.

Paper towels were composed of fibrous mass containing fibers of indeterminable size (due to the nature of the structure) as can be seen in Figure 4.5. These micrographs show representative structures of paper towel. This fibrous mass was densely populated with ridges and crevices which indicates a tremendous surface area is available for absorptive coating.

Surface examination at 30,000x magnification and 5kV delineated differences in structure between the three materials. The synthetic materials had very smooth surfaces with ridges and surface defects predominately in stressed areas. Representative micrographs of the synthetic materials are located in Figures 4.6 and 4.7. More surface features indicates that paper towels had more surface area per fiber than the synthetic materials. Because the absorption capacity of polypropylene was higher it is likely that the increased number of fibers are making up for the surface area of the paper towel crevices and ridges.

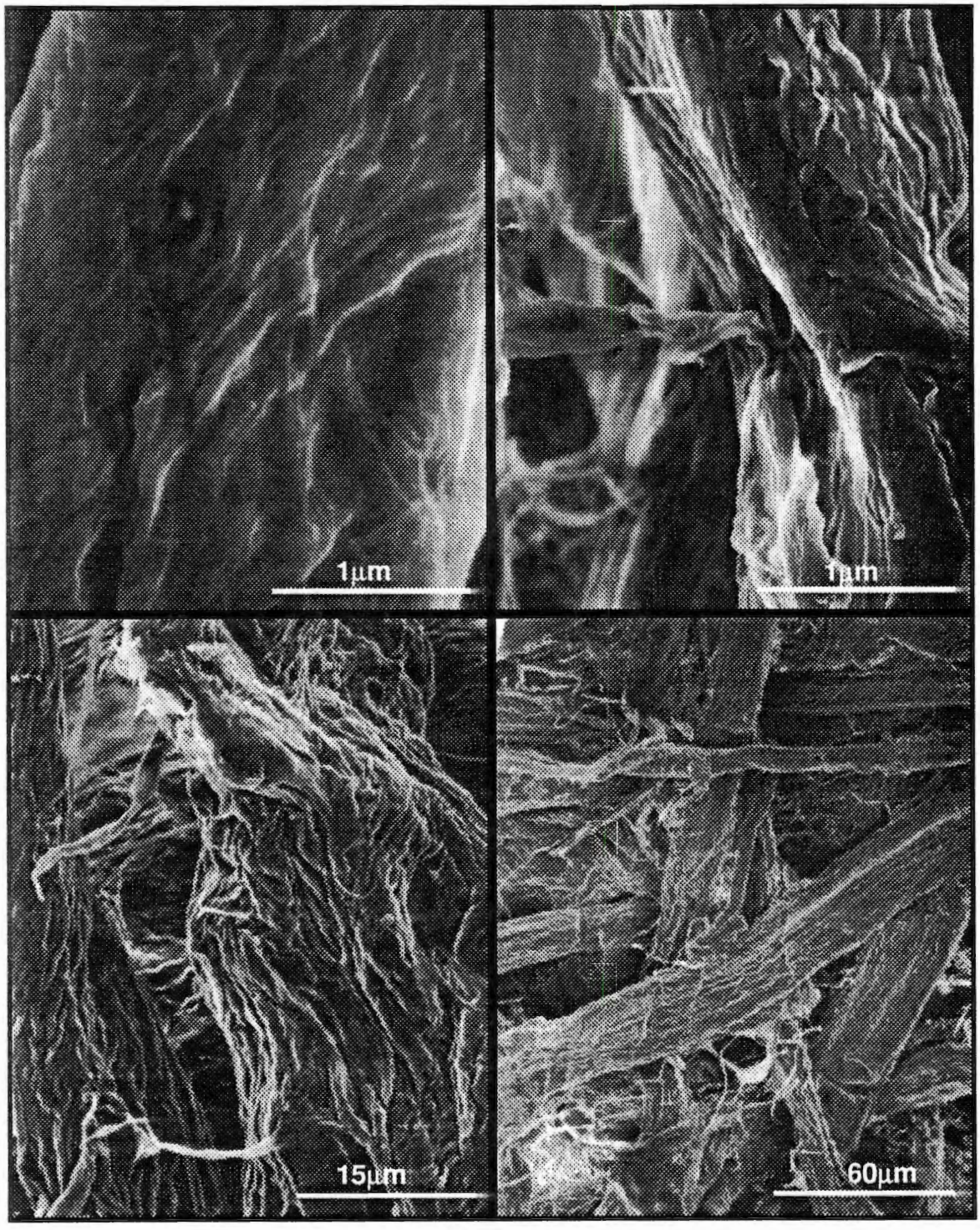

Figure 4.5 – Paper towel microstructure as resolved by SEM. Micrographs were taken at 30,000x(top), 2,000x(bottom right), and 500x (bottom left) and 5kV to show the surface structure of paper towels.

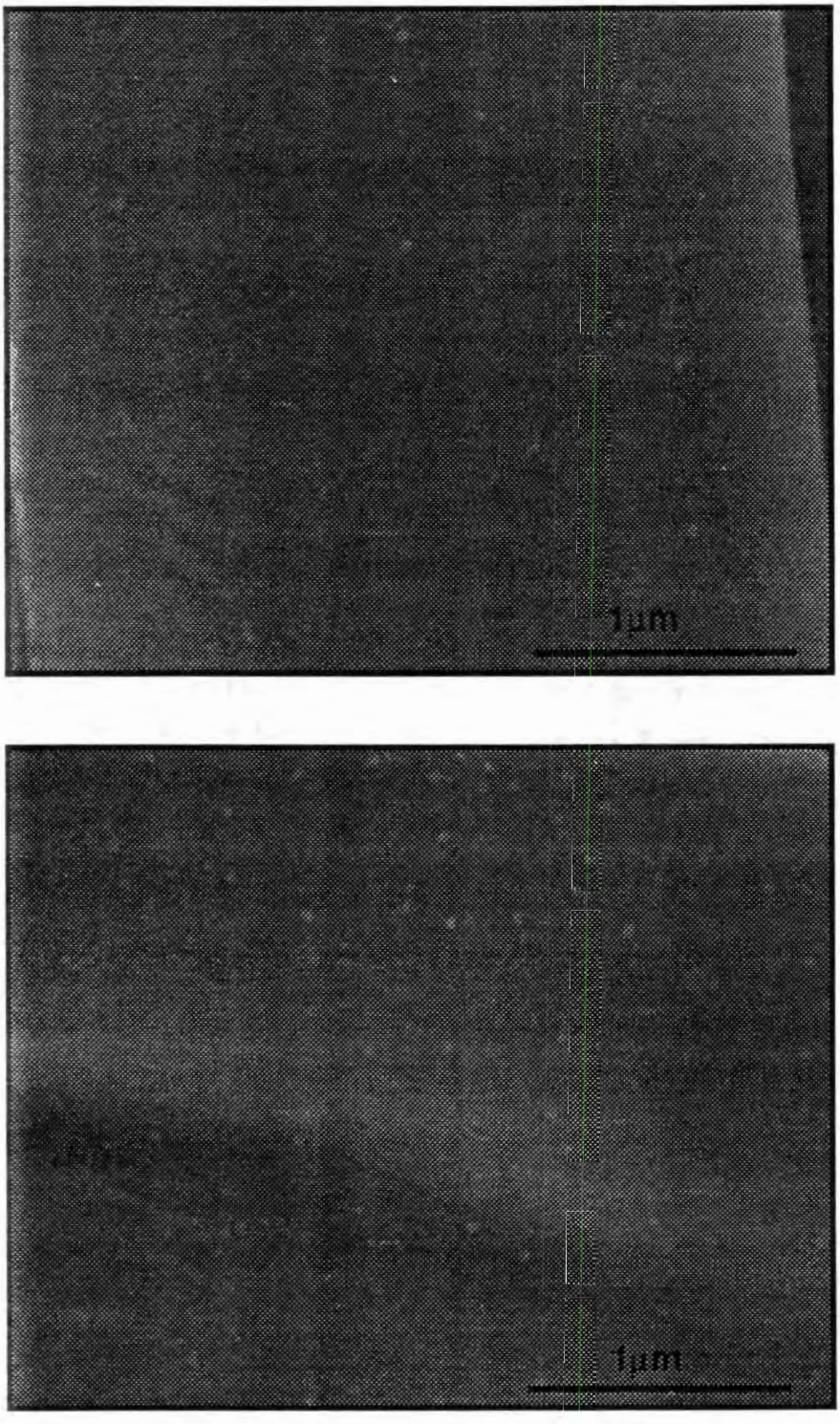

Figure 4.6 – Nonwoven polyester fiber microstructure as resolved by SEM. Micrographs taken at 30,000x and 5kV to note surface characteristics.

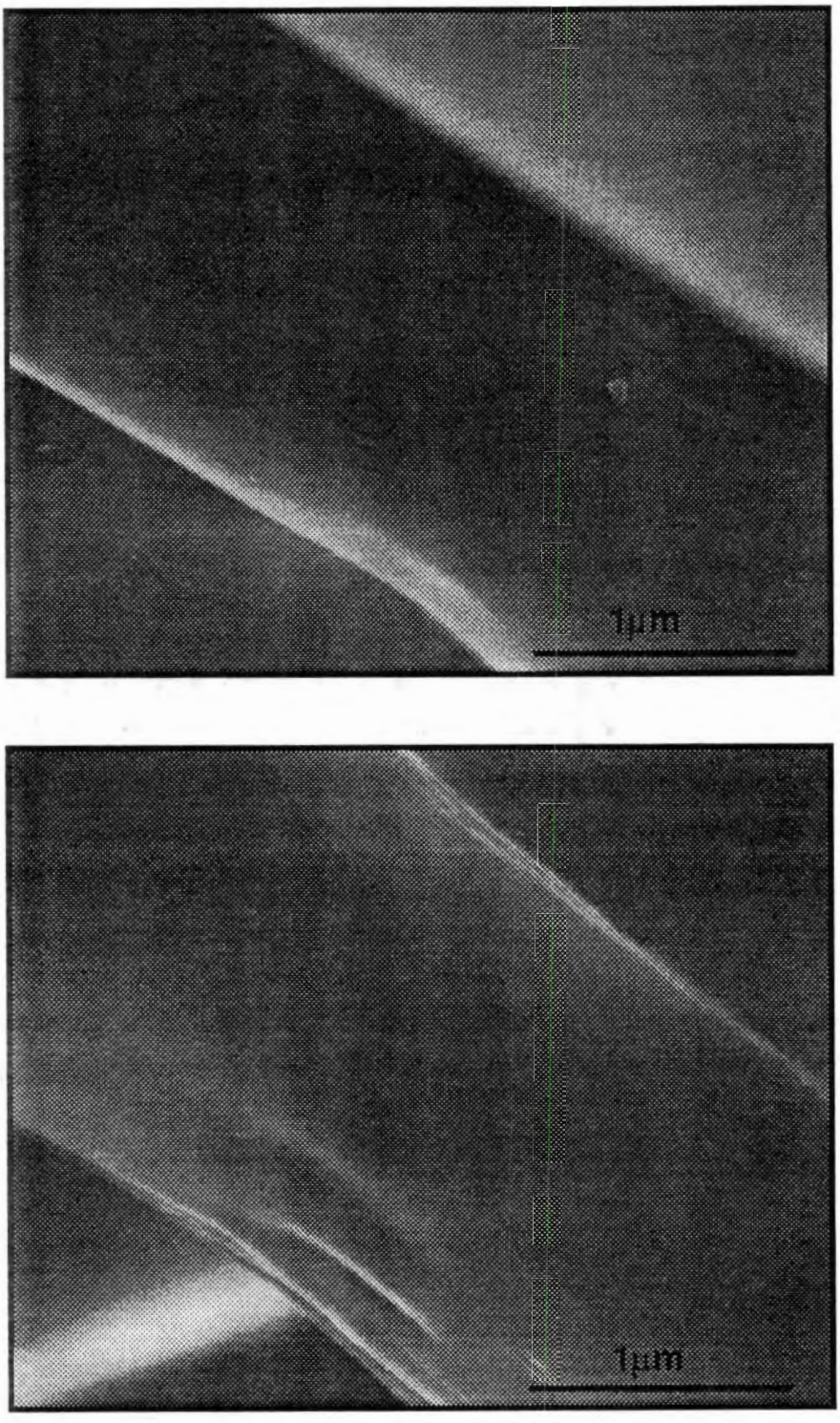

Figure 4.7 – Nonwoven polypropylene fiber microstructure as resolved by SEM. Micrographs taken at 30,000x and 5kV to note surface characteristics.

The area heat pressed by the calendering process averaged 19.95±1.53% for both materials. The same calender roll setup and temperature were used for both synthetic materials though the results were quite different. Micrographs used to calculate the percent melted are located in Figures 4.8 and 4.9. Polyester has a melting temperature between 258 to 263°C (Mark et al., 1969) and had an average pressed area of 19.80±1.52% of total area. Polypropylene has a melting temperature of 185.3°C (Mark, et al., 1985) and had an average pressed area of 20.10±0.20% of total area.. The influence of heat on fiber structure produced more fiber fusing in the polypropylene material than in the polyester material as is indicated in Figures 4.10 and 4.11. This increased the accuracy of the measurements made on the polypropylene material; the edges of the pressed areas were clearly defined on the more highly fused material areas allowing better measurement. The polypropylene heat pressed areas resembled a film; almost no fiber definition remained. The polyester heat pressed areas were fused and smoothed over though individual fibers were distinguishable. The surface area was reduced more in the polypropylene material than in the polyester material though the polyester material absorbed less oil. The structural similarities of fatty acids and polypropylene could be overriding the greater calendering related surface area reduction in the polypropylene material to allow the polypropylene to pack more oil on the surface of that material's fibers.

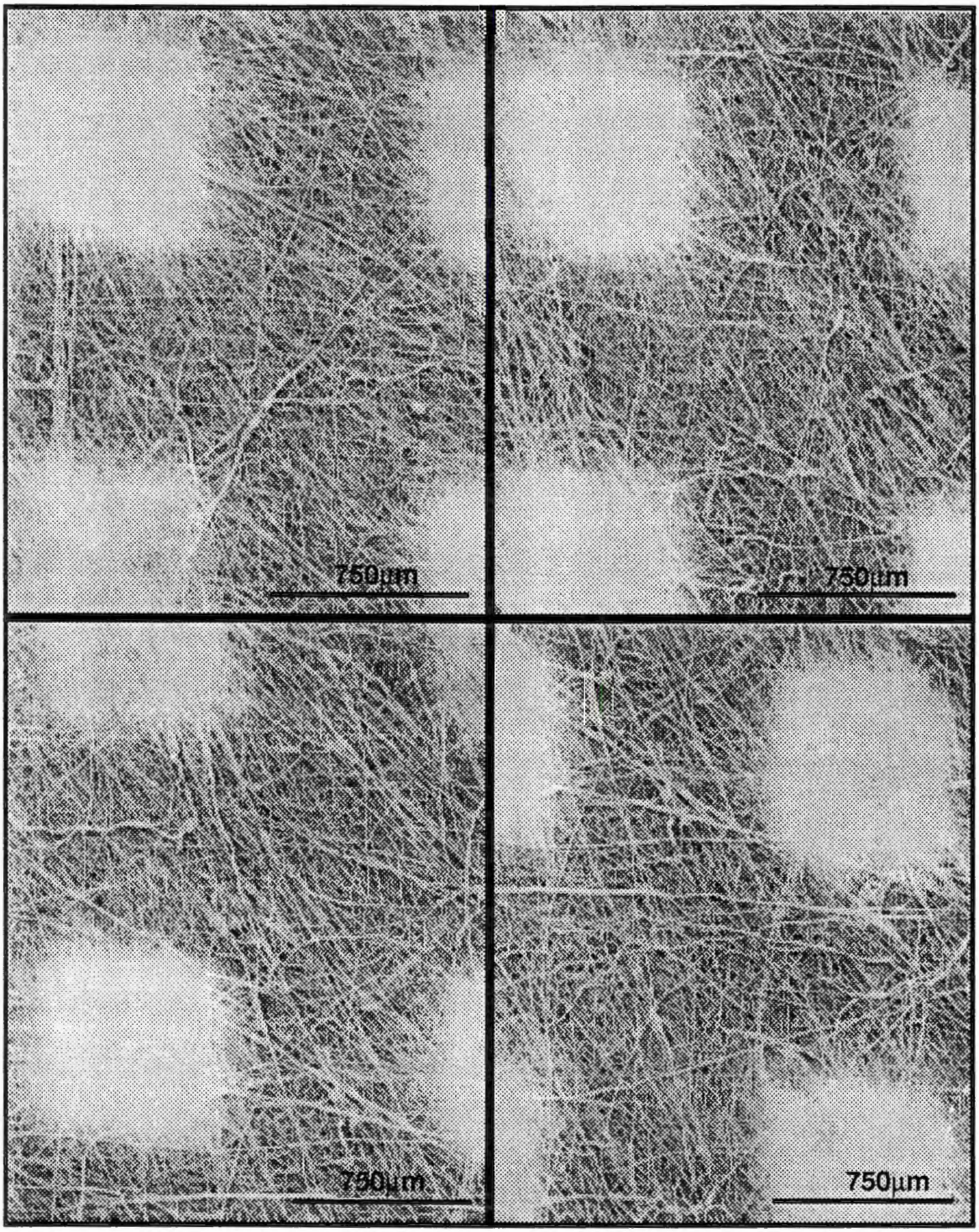

Figure 4.8 – Heat fused spots in calendered meltblown polyester material. Scanning electron micrographs taken at 40x magnification and 5kV voltage show the area compressed by the calendering process. These micrographs were used to calculate the area melted by the calendering process and to note differences in structure.

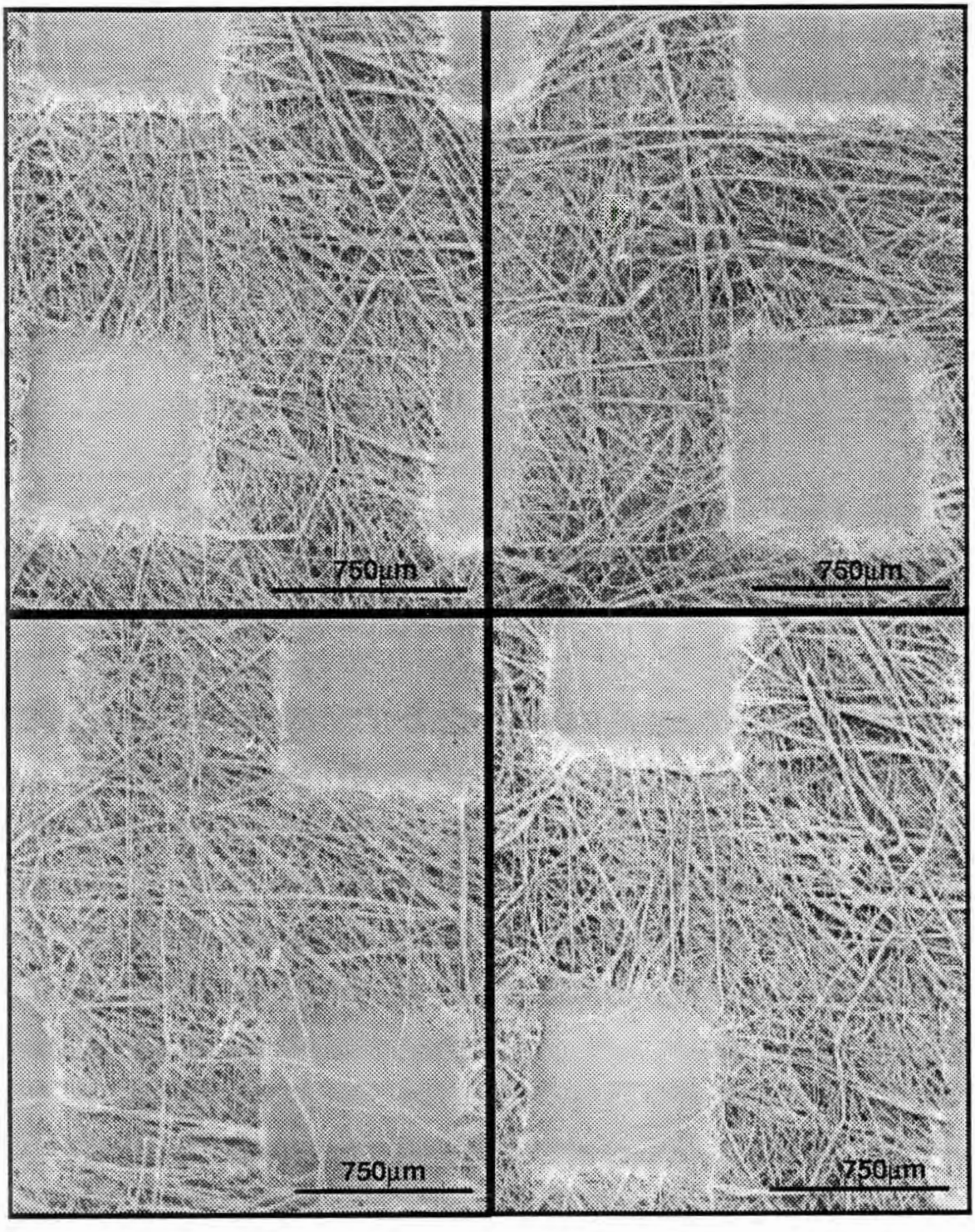

Figure 4.9 – Heat fused spots in calendered meltblown polypropylene material. Scanning electron micrographs taken at 40x magnification and 5kV voltage show the area compressed by the calendering process. These micrographs were used to calculate the area melted by the calendering process and to note differences in structure.

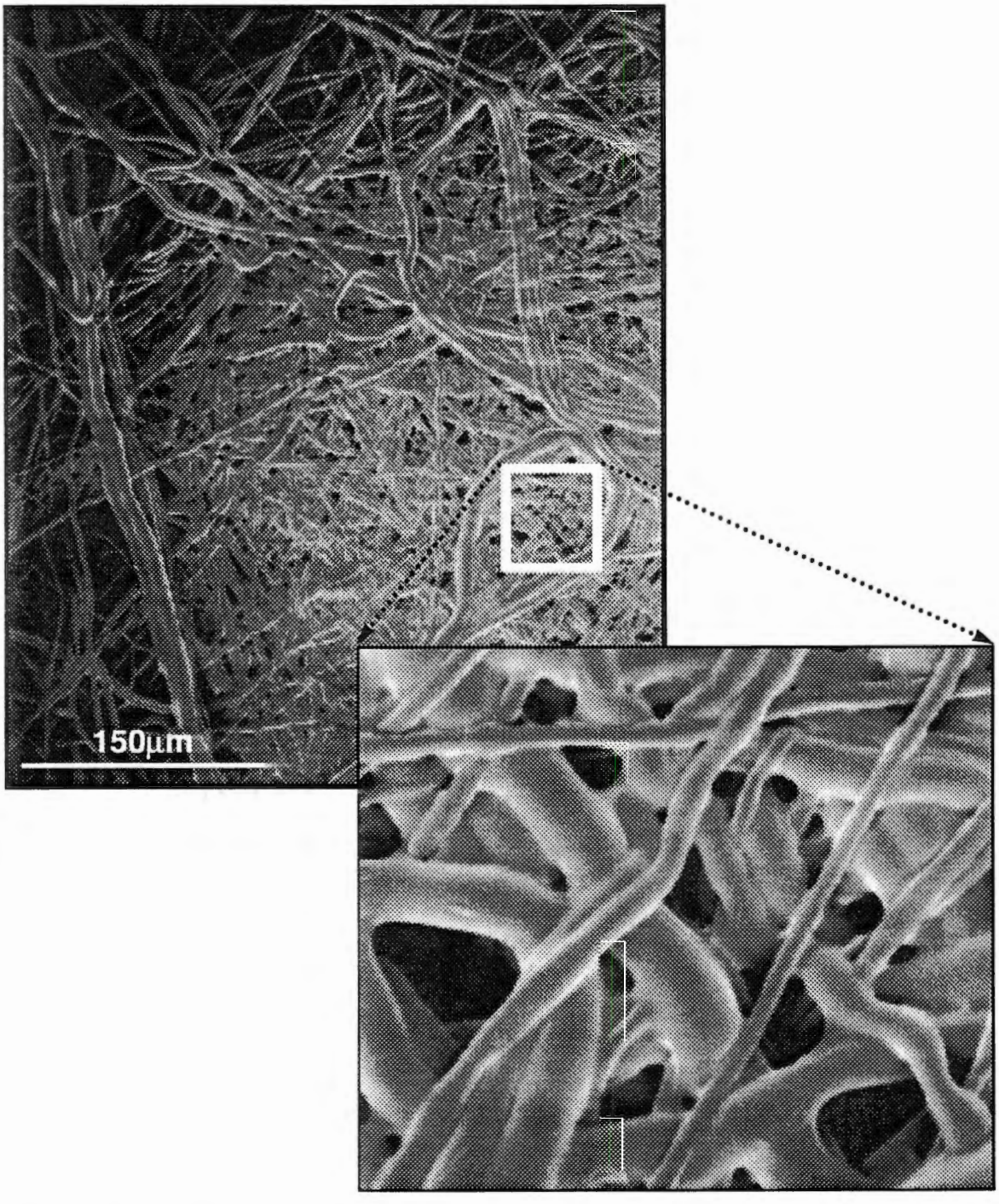

Figure 4.10 – Microstructure of calendered area on polyester meltblown web. Micrographs taken at 1.5kV and 200x magnification with high magnification (1000x) inset.

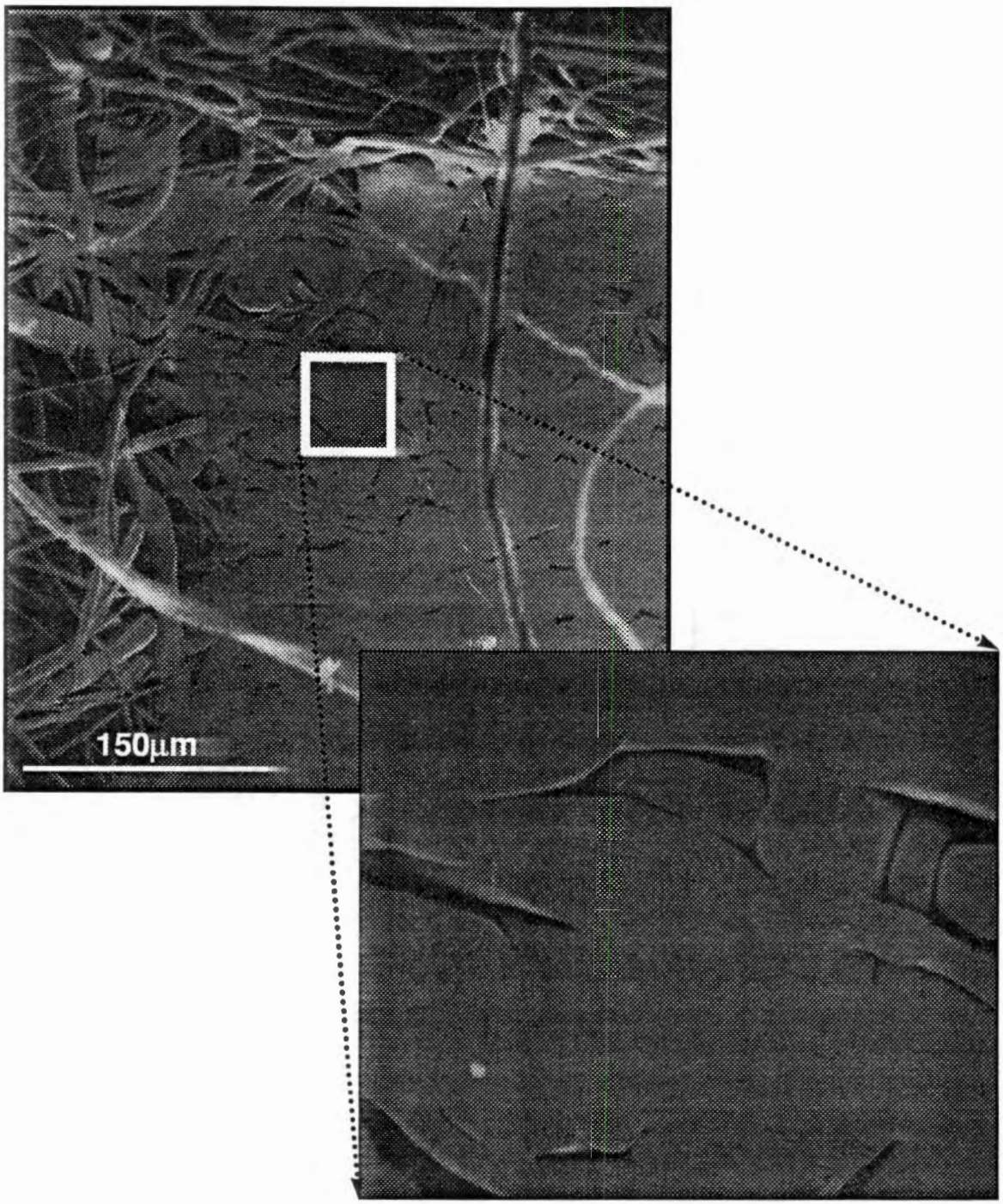

Figure 4.11 – Microstructure of calendered area on polypropylene meltblown web. Micrographs taken at 1.5kV and 200x magnification with high magnification (1000x) inset.

4.4 Pore Size Analysis

The pore size analysis revealed more differences in the microstructure of the materials. The polyester sample distribution of pore sizes is in Figure 4.12. Polyester material had a mean pore size of 6.9μm. Polypropylene material had a mean pore size of 14.02μm as is evident in Figure 4.13. This data indicated that the spaces between fibers were larger in the polypropylene than in the polyester material. This could explain where the added absorption ability of the polypropylene material is originating; oil could have filled the spaces between fibers by a capillary type action. Because polypropylene material has so many small diameter fibers with large numbers of tiny spaces to fill, the capacity to hold oil is greater than the capacity of the polyester material. Paper towels had a much larger mean pore size of 40.05μm (Figure 4.14). This data was misleading because the paper towel surface was slit in the manufacturing process in a uniform pattern. From microstructural examination it was clear that no observable pores existed within the paper towel outside of these slits. Paper towels achieved a comparable level of absorption due to the tremendous surface area rather than the existence of pores. Many of the ridges and crevices in the paper towel no doubt work similarly to the pores in the synthetic material by providing places to collect oils that then adhere together from surface adhesion forces.

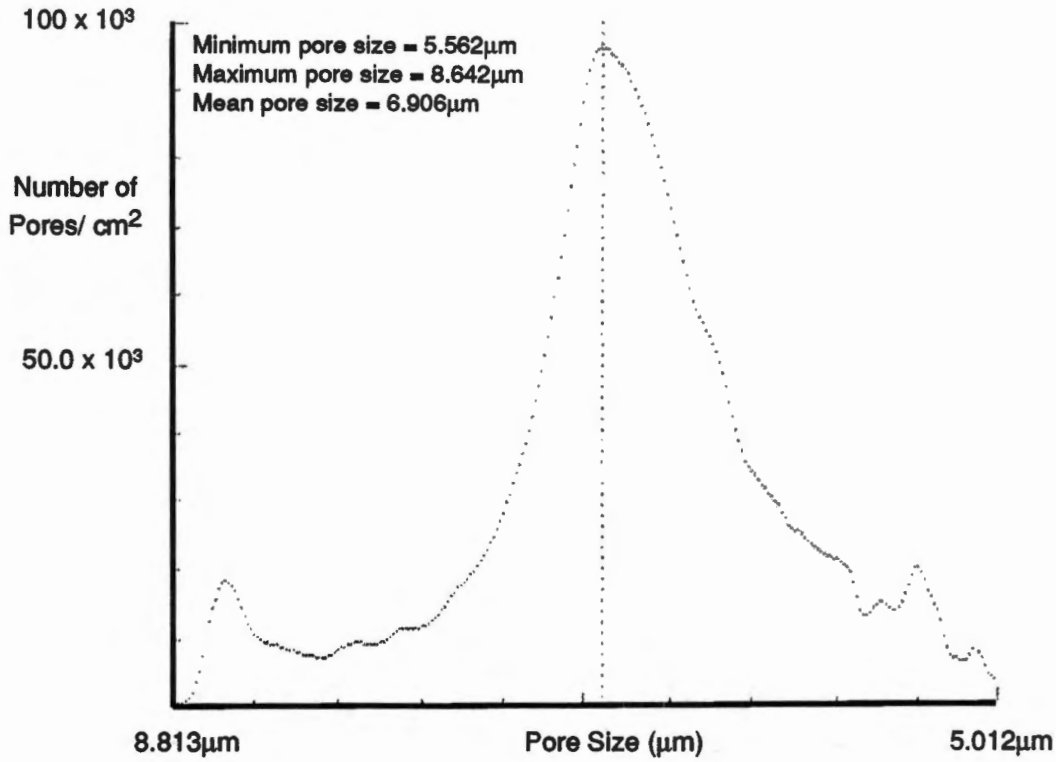

Figure 4.12 – Distribution of porous tunnels in calendered polyester material by size. Data plotted by a Colter Porometer baised on the bubble point of the material and the difference in resistance to air flow from wet to dry.

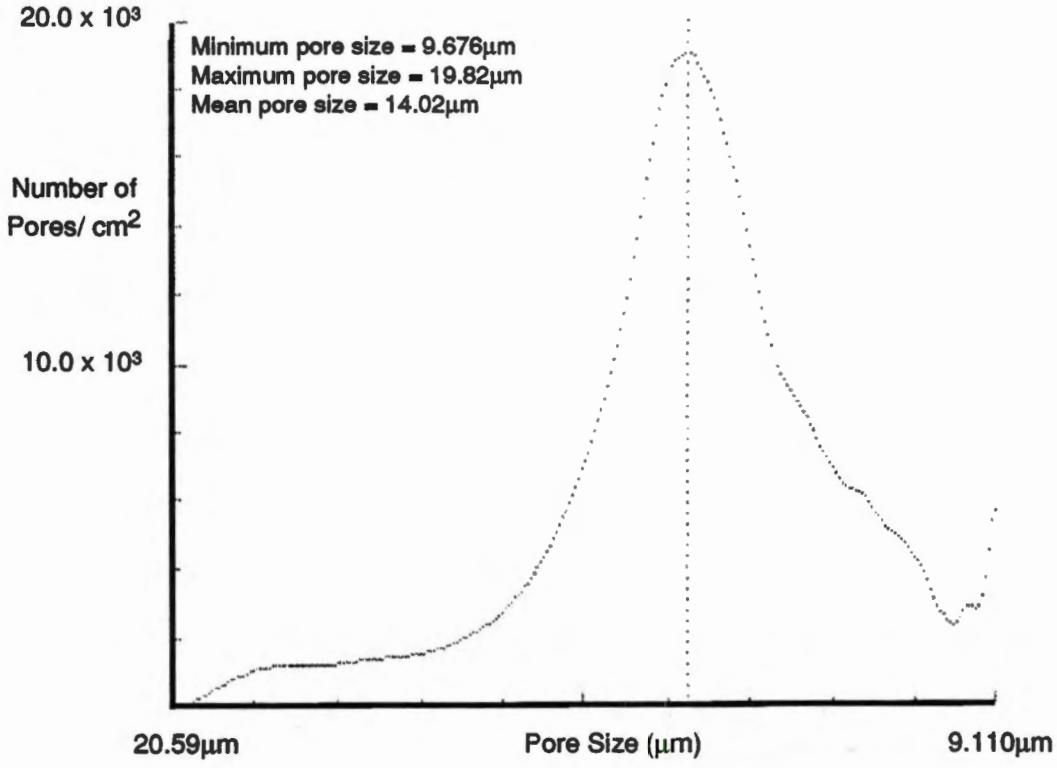

Figure 4.13 – Distribution of porous tunnels in calendered polypropylene material by size. Data plotted by a Colter Porometer baised on the bubble point of the material and the difference in resistance to air flow from wet to dry.

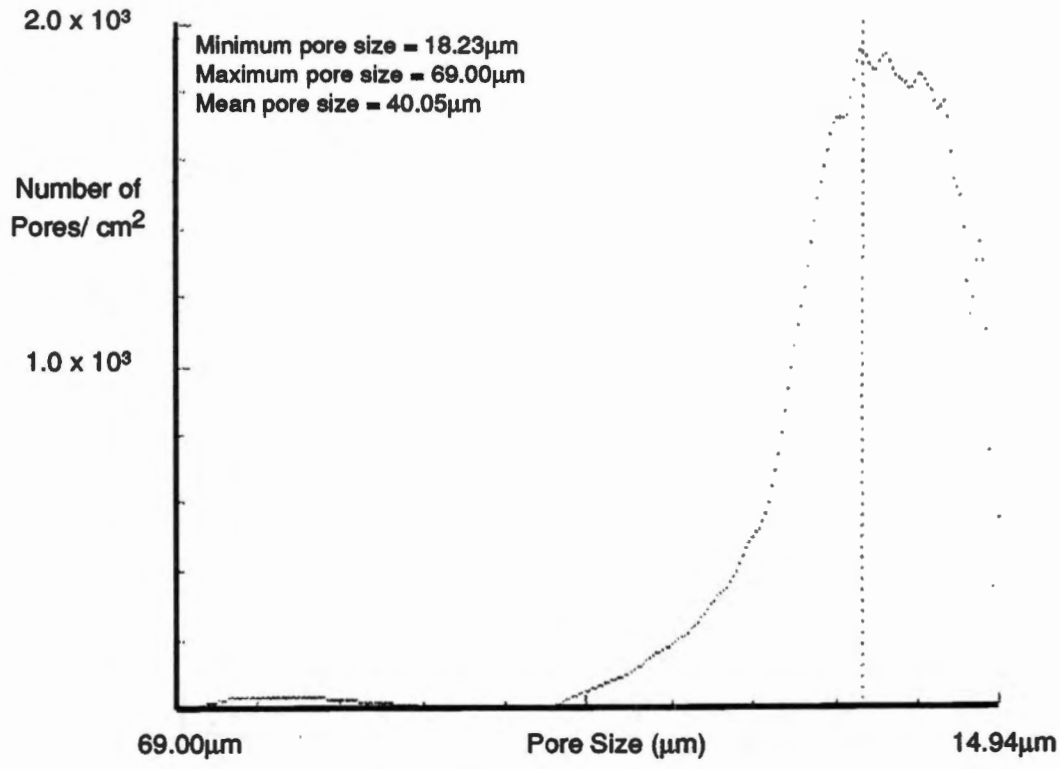

Figure 4.14 – Distribution of porous tunnels in paper towels by size. Data plotted by a Colter Porometer baised on the bubble point of the material and the difference in resistance to air flow from wet to dry.

4.5 Oil Viscosity

Viscosity measurements of the oils are plotted in Figures 4.15-4.20. As expected viscosity increased as temperature decreased for all oils. The lowest temperature measurement (around 20-23°C) will be used in discussion because the oils reached room temperature very quickly after exposure to the material disc. Functionally the flow of the oils slowed as the viscosity increased on the material disc. The coconut oil had a viscosity of 38 mPa(s) at 20°C, slightly above room temperature. The cottonseed oil viscosity (Figure 4.16) was around 38.5 mPa(s) at 21°C. Corn oil, Figure 4.17, had a centipoise reading of approximately 32 mPa(s) at 22°C. Olive oil viscosity (Figure 4.18) at 21.5°C was 54 mPa(s). Viscosity of safflower oil at 21°C was 41 mPa(s) as indicated in Figure 4.19. Sunflower oil viscosity (Figure 4.20) was 53.5 mPa(s) at 20°C. Increased viscosity should have played a role in increasing the surface tension available to adhere oils onto the fabrics. Theoretically it was suspected that the higher the viscosity of the oil, the more oil would hold onto any given fabric. Thus coconut oil, having the greatest thickness, should have deposited a larger amount on all disc types than the other oils. This was not supported by the data. The capacities of most of the oils were similar among each material type.

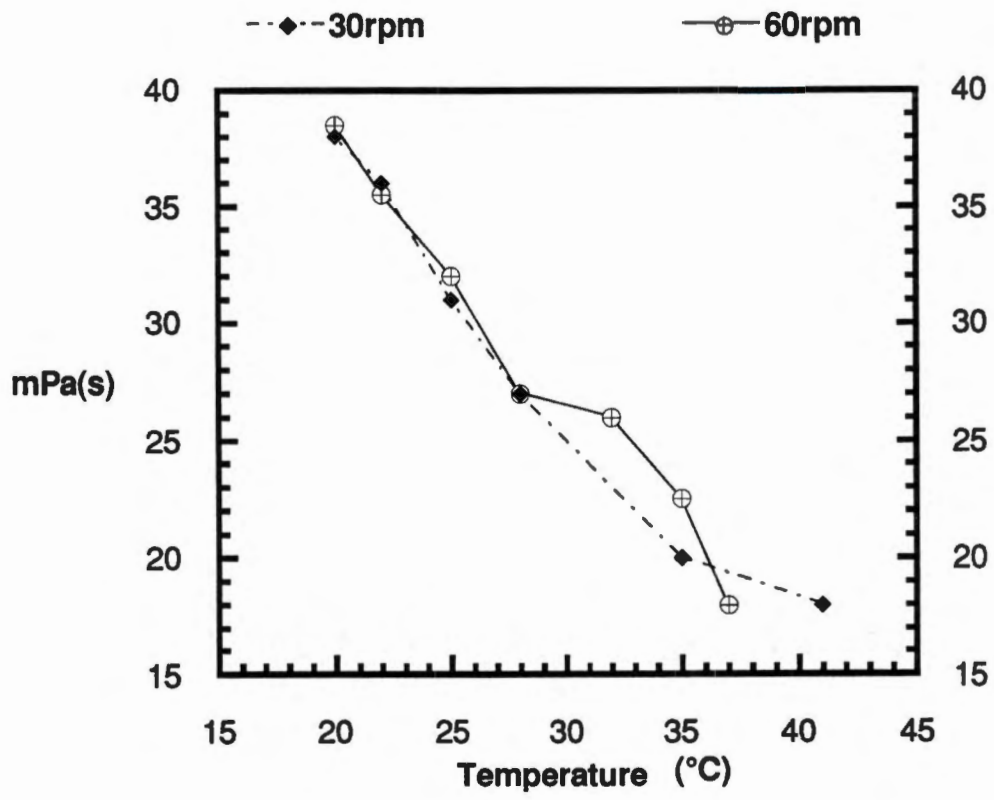

Figure 4.15 – Viscosity of coconut oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

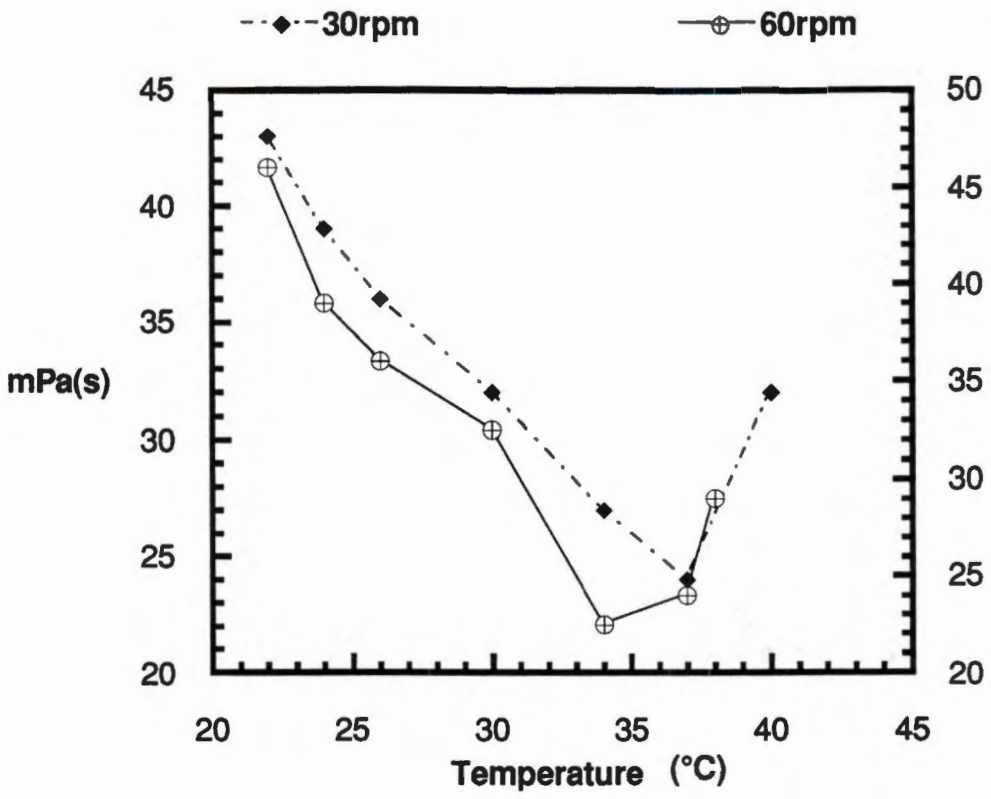

Figure 4.16 – Viscosity of corn oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

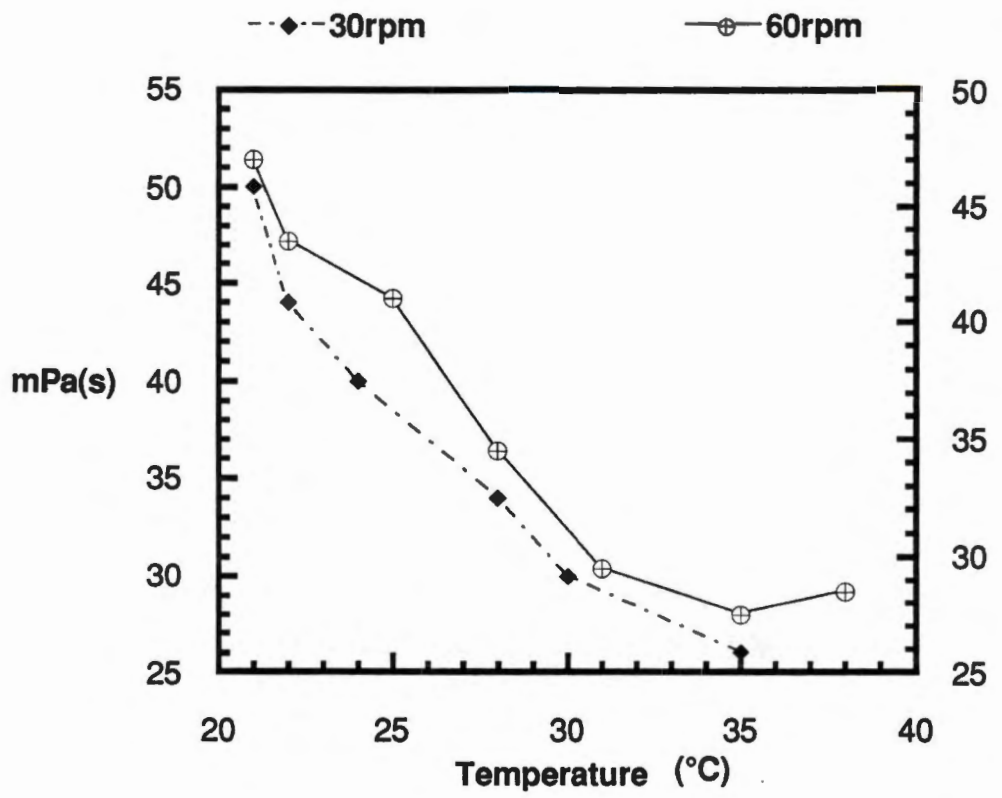

Figure 4.17 – Viscosity of cottonseed oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

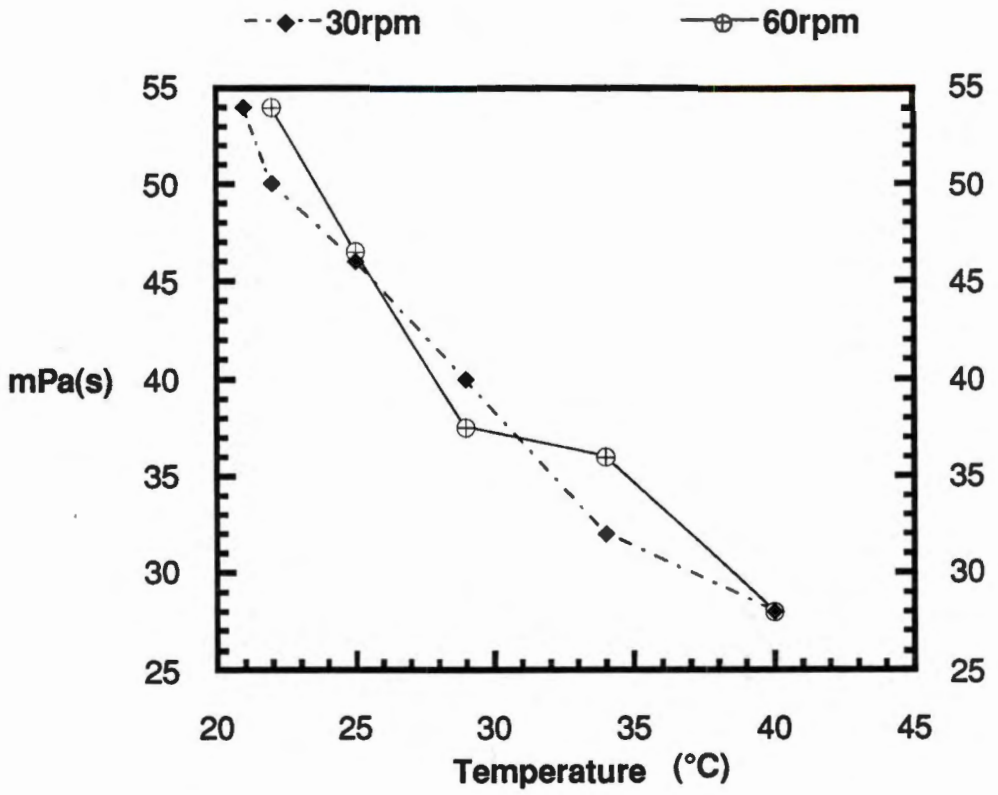

Figure 4.18 – Viscosity of olive oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

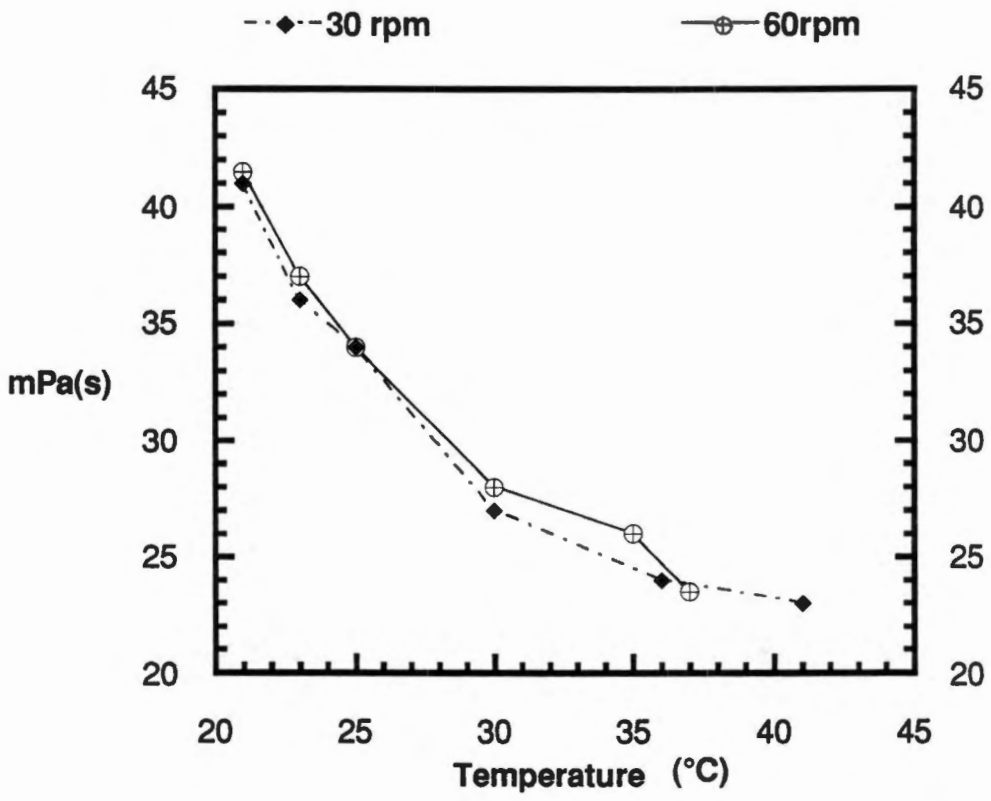

Figure 4.19 – Viscosity of safflower oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

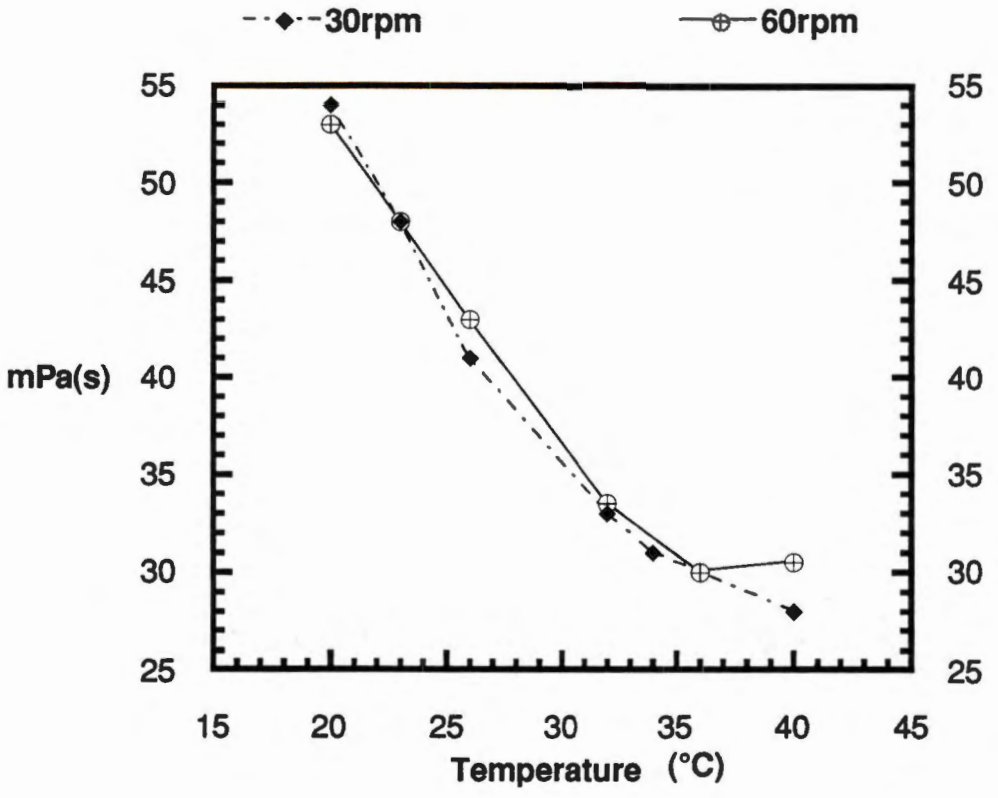

Figure 4.20 – Viscosity of sunflower oil in centipoise over a range of temperatures. Viscosity was determined with a Brookfield LV Viscometer utilizing a no.1 spindle and two speed settings, 30rpm and 60rpm.

5. CONCLUSIONS

The calendered polypropylene meltblown material absorbed a greater amount of the more saturated oils investigated. This indicates that polypropylene is a better choice of material for dietary fat reduction. The paper towel and the polypropylene absorbed more fat as a percentage of initial material weight than the calendered polyester.

The fact that the surface area of the polypropylene was reduced by calendering suggests that a different calender roll might increase or decrease absorption depending on the area compressed and melted together. The relationship of area reduction by calendering to the absorptive capacity should be determined to substantiate the claim that surface factors are completely responsible for absorptive capacity. In addition, surface area measurement needs to be performed on materials before and after calendering to note the actual reduction in surface area rather than just the linear area. These preliminary findings suggest that a strong relationship should exist between surface area and absorptive capacity.

Selectivity was only observed for the shorter chain fatty acids with the polypropylene absorbing the most C8:0, C10:0, C12:0, and C14:0. The polyester absorbed more C8:0, C10:0, C14:0, and C16:0 than the paper towel. No selective behavior was noted for the higher chain fatty acids. Clearly the

polypropylene material absorbs more saturated short chain fatty acids.

The surface area of the paper towels was repleat with folds, crevices, and other surface features. The synthetic materials had distinct smooth fibers. The fiber size was quite different between the meltblown fabrics. The polypropylene had fibers with an average diameter of approximately 3.7 μm while the polyester fibers were approximately 2.7 μm in diameter. The size of the space between fibers was greater in the polypropylene than in the polyester. This partially accounted for the differences in absorptive capacity. More oil was able to collect in the larger pores of the polypropylene. The paper towel did not have appreciable numbers of pores but most likely compensated with greater surface detail. Overall, the meltblown polypropylene material proved superior for food applications that require saturated fat reduction.

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REFERENCES

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VITA

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Daniel went to school at Glen Oaks Elementary School and Forest Hills Middle School. He attended Fairfield High School, Birmingham, Alabama for two years, transferred to the York School, Monterey, California, for half a year, and finished in 1984 at Homewood High School, Birmingham, Alabama.

Daniel's received a freshman scholarship at the University of South Alabama, Mobile, Alabama where he attended for two years. He transferred to Auburn University where in 1988 he received a Bachelors of Science Degree in Nutrition and Food Science. In 1988, Daniel accepted an assistantship at the University of Tennessee, Knoxville to pursue the Master of Science Degree in Food Science. This Degree was awarded in December of 1990.