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Forensic Characterization and Discrimination of Manila Envelopes

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FORENSIC CHARACTERIZATION AND DISCRIMINATION OF MANILA ENVELOPES

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ABSTRACT

Envelopes can be found at crime scenes when ransom, threat letters or potentially harmful substances are sent to victims. Therefore, they are important probative items of evidence analyzed by forensic document examiners. Manila envelopes are commonly used in the United States to transport or send documents as they are made of thick and durable paper. Although there are many studies on the forensic analysis of office paper and paper-based banknotes, and only a few on white envelopes, there does not exist previously published research on the physical or chemical characterization of manila envelopes. The goal of this research was to analyze manila envelopes using analytical methods normally applied for the analysis of paper with the purpose of characterizing and comparing those sold by different manufacturers as well as the envelopes included in the same and different boxes from the same manufacturer.

Samples from five manila envelopes, size 9x12", from each of the three boxes purchased from ten different brands were examined in order to evaluate whether there are significant differences that can be used for forensic discrimination and/or identification of the manufacturer. The analytical methods were also evaluated to determine the discriminating potential of each when applied to manila envelopes. The analytical methods considered in this research consisted of visual examination to determine physical features, as well as physical measurements of the envelopes and its folds, color examination, the use of Alternate Light Sources (ALS), and chemical analysis using Attenuated Total Reflection Fourier-Transform Infrared (ATR FT-IR) Spectroscopy, Raman Spectroscopy, X-ray Fluorescence (XRF) Spectroscopy, and X-ray Powder Diffraction (XRD). An analytical protocol for the forensic analysis of manila envelopes was developed, beginning with the non-destructive ones, using the most discriminating techniques previously mentioned.

Results indicate that brand discrimination is possible using a combination of the study of physical features and color values. ATR FT-IR spectroscopy Raman spectroscopy, XRF, ALS, as well as physical measurements have value for inclusions and exclusions. There were no differences observed in the XRD data from different envelopes because the diffractograms were dominated by the calcium carbonate peaks, indicating that this method does not have value for discrimination. Finally, differences between boxes within a brand indicate intra-brand variation, which can increase the evidentiary significance of questioned manila envelopes.

It was concluded that detectable chemical and physical differences in the paper of manila envelopes can be used for their characterization and discrimination.

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1. INTRODUCTION

Envelopes can be found at a crime scene when threat or ransom notes or potentially harmful substances are sent to a victim, therefore being common evidence items analyzed by document examiners, such as scientists at the US Secret Service.

The use of manila envelopes in the United States is common because they are made of thick and durable Manila paper or craft paper, thus they are frequently used to transport documents. Therefore, manila envelopes are likely to be probative items of evidence examined by forensic document analysts.

There does not exist previously published research articles on the physical or chemical characterization of manila envelopes. There are, however, studies on the forensic analysis of office paper and paper-based banknotes, and only two published studies have been found on white envelopes.

This research analyzed manila envelopes using traditional techniques for paper analysis. These techniques consisted of visual examination, physical measurements, color analysis, Alternate Light Sources (ALS), Attenuated Total Reflection (ATR) Fourier-Transform Infrared (FT-IR) Spectroscopy, Raman Microspectroscopy, X-ray Fluorescence (XRF) Spectroscopy, and X-ray Powder Diffraction (XRD).

For the analysis of the components of paper, ATR FT-IR spectroscopy, which is able to analyze many of them in greater detail, can be used to for their identification (1). Additionally, XRF is a fast and accurate non-destructive method that allows multi-element analysis, while XRD provides

qualitative and quantitative information on the compounds that are present in a solid sample (1). However, Raman spectroscopy is a technique that has not been published for the analysis of paper, but has been applied to the qualitative and quantitative analysis of organic and inorganic compounds of samples (1).

The purpose of this research was to analyze manila envelopes using the previously mentioned techniques in order to be able to characterize and compare those sold by different manufacturers as well as the envelopes included in the same and different boxes from the same manufacturer. Thus, it was investigated if there were meaningful differences among them, and if these can be used for forensic discrimination and/or identification of the manufacturer. Additionally, it was determined which technique(s) provided the most discriminating results, thus developing an analytical protocol for the forensic analysis of manila envelopes. Consequently, the most appropriate and useful technique(s) could then be used by forensic scientists to associate a manila envelope found at a crime scene with an envelope found at the suspect's home or workplace, which could add value with regard to a criminal investigation. Additionally, if a technique was determined to not provide any discriminating information, that technique could be excluded from an analytical protocol of the examination of manila envelopes, thus preventing a waste of valuable resources (time, equipment, etc.).

2. LITERATURE REVIEW

In the paper-making process, cellulose fibers are the mainly used substance, where the production is based on wood pulp or other fibers that come from bast fibers (such as hemp or jute), grasses (e.g., hemp, esparto or bamboo), leaf fibers (manila or sisal), and seed hairs (e.g., cotton). The cellulose fibers are exposed to a processing treatment before they become paper (2).

Besides cellulose fibers, paper manufacturers introduce other materials, such as sizing materials, which offer resistance to water and ink penetration, fillers or inorganic white pigments for the loading of paper, and the use of synthetic dyes or colored pigments for the coloring of paper. Additionally, coatings, which are generally constituted of a pigment and a component known as a binder, can be applied to increase its smoothness, printing quality, opacity or resistance to water, vapors, and oils (2).

Due to the enormous diversity of sizing, loading, coloring and other materials mixed with papers, a variety of analytical methods can be used for the analysis of paper.

Research has been published on some traditional techniques for the differentiation of office paper and paper-based banknote samples. Only two published studies regarding white envelopes have been found. The first was from 1977, and detailed a case study completed by the California Department of Justice which involved the association of two questioned envelopes with envelopes found at a suspect's home (3). This research utilized manufacturing characteristics, which were examined macroscopically and with ultraviolet light, but no chemical instrumental methods. The second study from 2010 (4) characterized the printed text and images on 500,000 envelopes, with

a focus on printing defects or imperfections, and calculated the error rate of associating envelopes to a known source, but did not analyze the envelope's physical or chemical properties.

The importance of envelopes as questioned documents was stated in a 2005 published case report by Mazzella and Taroni (5), where the authors demonstrated the usefulness of examining envelopes and made use of the Bayes' theorem to evaluate their probability of interest. They evaluated this by determining differences in brand by their size, printed details and paper type, but no chemical characterization was carried out. Thus, it would be of real interest to chemically analyze the envelopes.

Trace elemental analysis has been shown to have value in differentiating paper. According to McGaw et al. (6), depending on these concentrations, it is possible to distinguish between papers from two different vendors using Inductively Coupled Plasma-Mass Spectrometry. In this research, although the vendors were different, the authors failed to indicate if the paper manufacturers are the same or not. In this supply chain, one paper manufacturer can provide their paper products to several vendors. Thus two different vendors may be selling paper from the same manufacturer. It would be useful to differentiate between papers sold by different brands from the same or different manufacturers. The small number of vendors in this research limits the implications of the conclusions that were made.

Laser-induced breakdown spectroscopy (LIBS) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) were used by Lennard, El-Deftar, and Robertson for the elemental analysis of questioned documents, specifically office papers, writing inks, inkjet inks and laser printer toners. Both LIBS and LA-ICP-MS were able to differentiate different batches of the same brand of paper, in addition to different brands of paper. The authors used Principal

Component Analysis (PCA) to discriminate between batches of the same brand, with greater than 99% discrimination, but had less successful results when the batches were from a different brand from the same manufacturer (7).

In another study, portable XRF was used to non-destructively measure trace elemental concentrations on banknotes (8). The technique proved to be useful in very specific paper-based banknotes. This warrants additional analysis on a larger and more diverse sample set, especially in the case of the same currency being printed in different countries, such as the Euro. Two other studies (9,10) proved that trace elements can also help characterize papers, but was limited to paper sheets from early and middle 20th century books.

Another non-destructive technique, XRD, was studied by Marabello et al. (11) and Causin et al. (12), where large sample sets wer capable of differentiation. The first study by Marabello et al. analyzed 20-Euro banknotes from different issuing countries and different printing locations, which led to the observation that currency produced with the same raw materials can be differentiated depending on the issuance country. The Causin et al. study proved that XRD, along with FT-IR spectroscopy, was able to discriminate similar types of office papers from different manufacturers. Additionally, in a personal communication on November 27, 2017, with Dr. Virginia Maxwell, from the University of New Haven, she described her research on business cards using XRD while at the Connecticut State Forensic Laboratory, which led to important discrimination results.

FT-IR spectroscopy, a non-destructive method for chemical identification, has also been used in the discrimination of paper samples (13), and to identify forged banknotes (14), although both studies had limited sample sizes. FT-IR is also used to identify chemical components of the paper

or its coatings. Sonnex et al. viewed the ease of use and low cost of the FT-IR instrument as the major advantages of this method for questioned document analysis.

Alternate Light Sources (ALSs), which are considered by ASTM Standards (15) as equipment to be used for non-destructive examination of paper, is able to help identify particular features in paper, such as indentations, scratches, roughness or reflectivity (16). ALS can also be used in the comparison of the color of dyes or other components in the paper samples. According to Green (17), who studied the reliability of multipurpose paper's brightness using an ultraviolet light source, the examiner must be cautious in his or her statement, as it was observed that there can be differences in papers from the same batch due to errors on the manufacturing process.

Raman spectroscopy is a technique used for chemical identification that has been applied to the qualitative and quantitative analysis of organic and inorganic compounds of samples (1). It is a complementary method of analysis to FT-IR spectroscopy. Regarding the forensic examination of documents, this method has only been published in papers involving the examination of inks (18–20) and paper coatings (21).

In this research, the previously mentioned techniques (ALS, ATR FT-IR, XRF, XRD, and Raman Spectroscopy) were used in the examination of manila envelopes to evaluate their brand and box discrimination power. Finally, an analytical protocol for the forensic analysis of manila envelopes was developed.

3. MATERIALS AND METHODS

The physical and chemical analysis of manila envelopes consisted of several different traditional paper analysis techniques in order to evaluate commonalities and differences between manufacturers and determine the best methods for discrimination.

3.1 Sample Collection

150 manila envelopes (samples), size 9x12", were collected for analysis. These derived from five envelopes of each of the three batches purchased from ten different brands. There were selected randomly through an online randomization program (22).

Each brand and envelope was coded alphanumerically, with the ten brands corresponding to the letters A through J (Table 1).

Envelope #	Brand Name and Type
A	Staples®, Extra-Heavyweight Clasp Manila
B	W.B. Mason® Clasp Envelopes Brown Kraft
C	Office Depot®, Clasp, Brown
D	Quality Park®, Gummed Clasp, Brown
E	Columbian®, Clasp Gummed, Brown Kraft
F	Business Source® Heavy Duty 28lb., Gummed Seal with Clasp, Kraft
G	Amazon Basics®, Catalog Envelopes, Peel & Seal, Brown Kraft
H	Check O Matic®, Reusable Brown Kraft Catalog Document Mailer with Clasp Closure & Gummed Seal – 28lb Heavyweight Paper
I	Mead®, Press-It Seal-It
J	Jam®, Open End Catalog Envelopes, Brown Kraft

Table 1. List of brands purchased and their classification from A to J

Each of the three boxes purchased were numbered as 1, 2, and 3, whereas the five randomly chosen envelopes selected from each batch were numbered as 1, 2, 3, 4, and 5. Therefore, envelopes were

classified from A-1-1 through J-3-5. Within each of these envelopes, several spots were selected for each of the measurements, which will be specified for each measurement and analytical method.

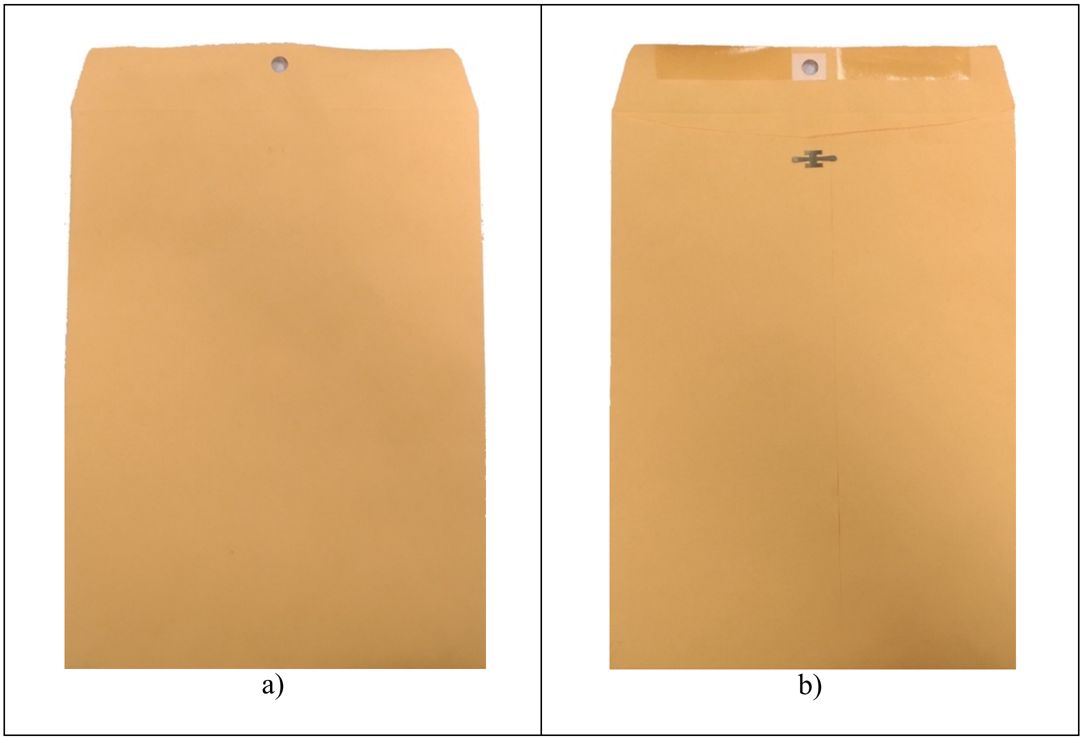


Figure 1. a) Front and b) back of a manila envelope

3.2 Physical and Chemical Analysis

The following measurements and analytical methods were employed:

1. Physical features: type of clasp, number of adhesive strips, and brand imprint.
2. Color analysis with a colorimeter.
3. ALS.
4. Physical measurements: dimensions, weight, thickness and color of every envelope were measured.

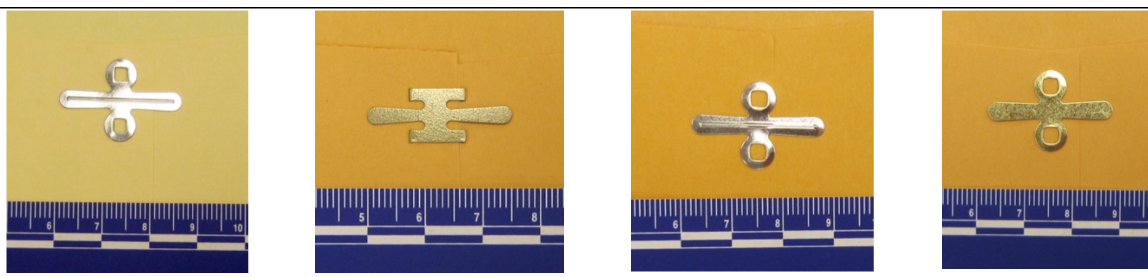
5. ATR FT-IR spectroscopy.
6. XRF spectroscopy.
7. Raman spectroscopy.
8. XRD.

3.2.1 Physical Examination

3.2.1.1 Physical features

The 150 envelopes were evaluated in regards to:

a. Clasp: the absence or presence of clasp was determined and, if present, the clasps were compared to the ones classified as Type I, II, III, and IV. Figure 2 shows the visual characteristics of the different types of clasps.



Clasp Type I | Clasp Type II | Clasp Type III | Clasp Type IV

Figure 2. Types of clasps present in the different brands

b. Adhesive: the number of adhesive strips, if present, were visually examined in every envelope.
c. Brand imprint: envelopes were examined in the front and in the back in order to determine if there was any visible imprints or ink stamp of the brand.

3.2.1.2 Color analysis

The color of the samples was evaluated using a colorimeter (Color Meter PCE-RGB2) for an objective determination and comparison of color values. The red, green, and blue channels (RGB) were measured with the colorimeter on three different spots on each of the 150 envelopes, with a total of 450 measurements. Figure 3 shows the location of the spots, which were selected from areas located where the length of the envelope was divided into three thirds of 10.2 cm each from its bottom. As it can be seen, these spots were located in the up-left, middle-right, and bottom-left of the front of the envelope. The color analyzer was calibrated with a white color calibration card before the measurements were taken, according to the user manual. The specifications of the instrument can be found in Appendix I. No sample preparation was required.

Figure 3. Areas in the front of the envelope where color was analyzed using the colorimeter

3.2.1.3 Alternate Light Sources

Ninety envelopes, three from each of the three boxes purchased from the ten brands, were analyzed with ALS (Ultralite ALS Ultra One) in order to identify any particular features on the samples, such as indentation, scratches, roughness or reflectivity, as well as any other feature the samples may show. Different illumination angles were utilized in this investigation, from perpendicular to the surface of the sample to various oblique low angles of side lighting.

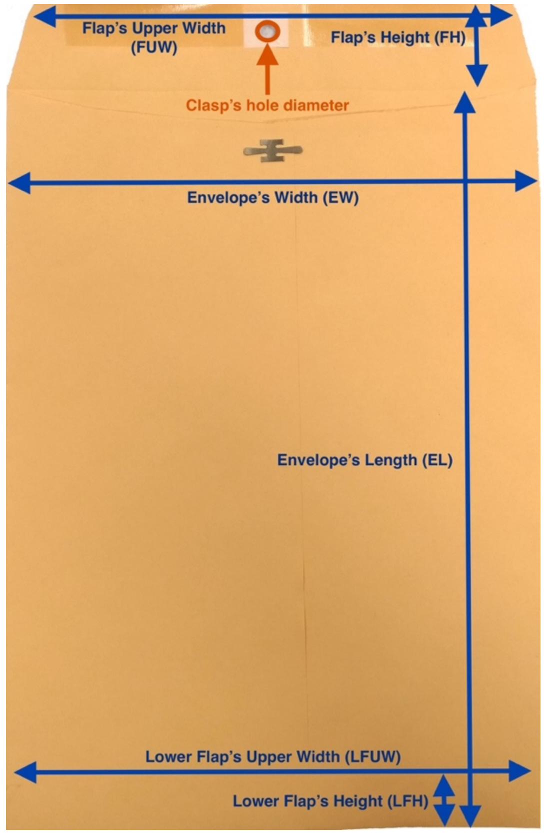
3.2.1.4 Physical measurements

The envelopes were examined and measured to determine the following physical characteristics:

Dimensions of the envelopes

The dimensions of 90 envelopes (three from the three boxes from each brand) were measured three times with a scale ruler. This includes the length and width of the rectangular part of the envelope, in addition to the flap, the adhesive strip or strips and the diameter of the clasp hole. An average was calculated for every value obtained from the three measurements taken from each section. Figure 4 shows where each of the measurements were taken.

a)



b)

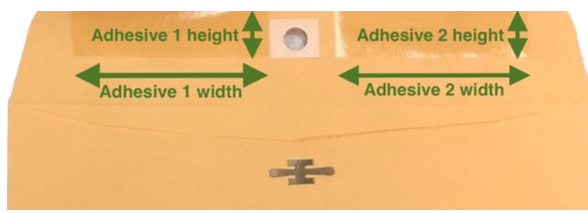


Figure 4. Physical measurements of a) the envelope and flaps and b) the adhesives' size

Thickness of the envelope paper

One hundred and fifty (150) envelopes, five from each of the three boxes from the ten brands purchased, were measured with a precision digital caliper (Mitutoyo Absolute Digimatic Caliper Coolant Proof IP67, resolution: 0.01mm, instrumental error: ±0.02mm (≤200mm)). The measurements were taken on a single layer of paper, in triplicate, of the three different spots

selected from every envelope and the average for each spot was calculated. Figure 5 shows the location of the areas where the caliper was placed and measurements were taken.

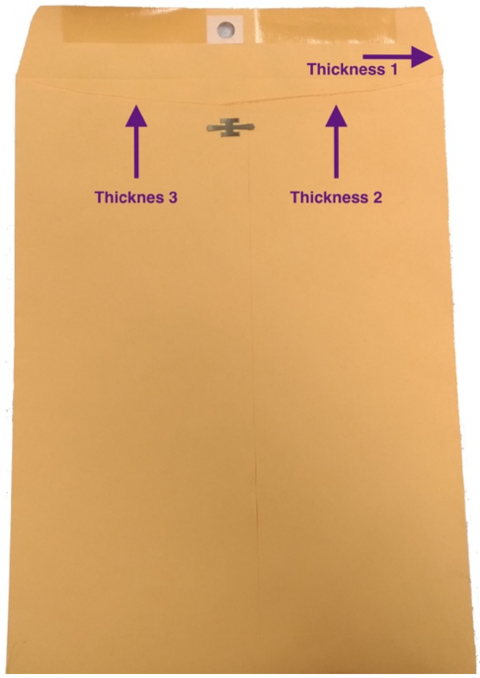


Figure 5. Areas measured with a caliper in the back of the envelope

Weight of the envelopes

The weight of each of the 150 envelopes was measured once using a digital scale (Kalorik XL Digital Kitchen Scale, Max: 10kg/22lb. d=1g/0.1oz, Resolution: 1g) and the average for each brand was calculated. A precision balance was not available for this experiment due to the overall weight of the envelope.

3.2.2 Chemical Examination

3.2.2.1 ATR FT-IR Spectroscopy

ATR FT-IR spectroscopy can be used for a qualitative and quantitative analysis of organic compounds in samples. An infrared beam passes through the sample, which absorbs energy, resulting in a spectrum to be obtained. Solids frequently show absorption bands in the mid-IR region (670 to 4000 cm^{-1}), where band intensities are proportional to their concentration. These bands are then used for the determination of the compounds (1).

Four designated locations on every envelope were examined. Figure 6 shows these locations. Three of them were selected from areas located in the up-left, middle-right, and bottom-left of the front of the envelope where the length of the envelope was divided into three thirds of 10.2 cm each from its bottom. The fourth spot analyzed was located in the front of the envelope in approximately the middle of the flap's width. No sample preparation was required for this technique. Samples were collected from the five random envelopes from each of the three boxes from the ten different brands purchased, which generated a total of 600 samples, An absorbance FT-IR spectrum was obtained for each sample.

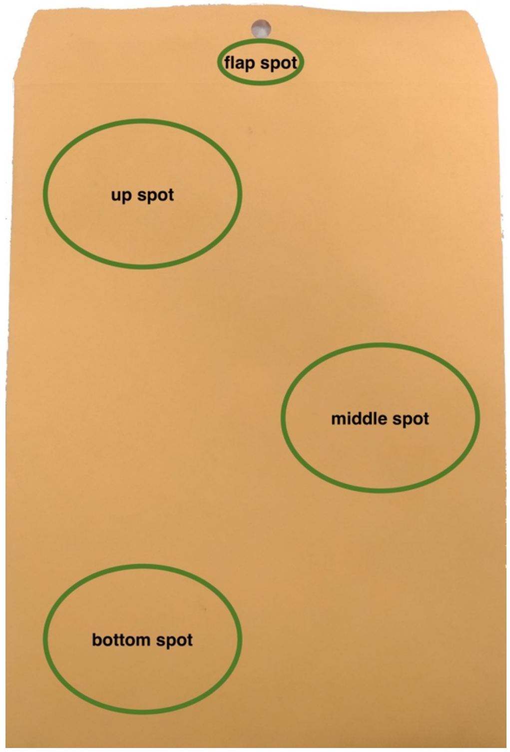


Figure 6. Areas in the front of the envelope where spots were measured for ATR FT-IR analysis

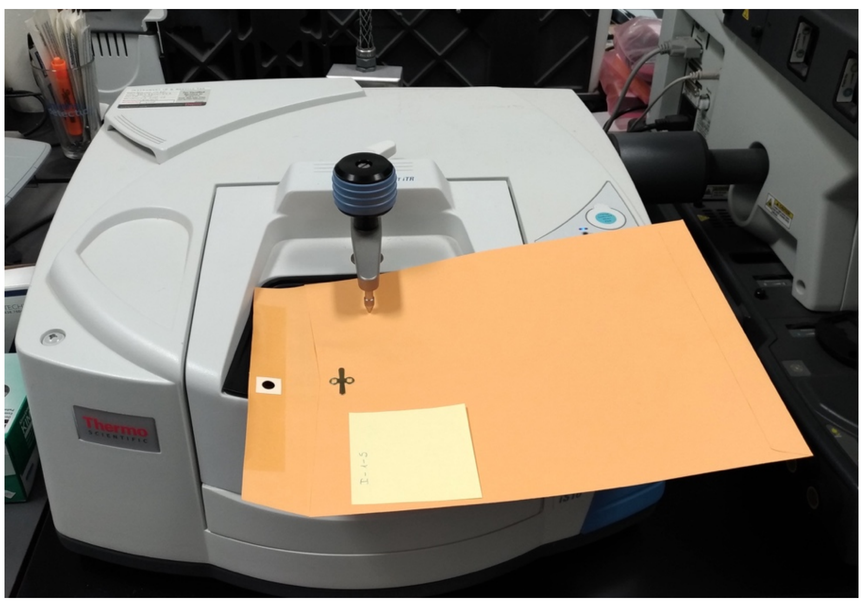


Figure 7. Sample collection of upper spot of the envelope with the Nicolet iS10 FT-IR Spectrometer

The instrument used for the analysis was the Nicolet iS10 FT-IR Spectrometer by ThermoFisher Scientific (see Figure 7). This instrument has a spectral range of 7800-350 cm^{-1}, mid-infrared KBr

beamsplitter, and 11000-375 cm^{-1} XT KBr extended range mid-infrared optics (23). The software used for the analysis was the Thermo Scientific™ OMNIC™ 9 software. Collection parameters were a 4 cm^{-1} resolution and 32 co-added sample and background scans. The experimental setup values were 650 to 4000 cm-1, with autogain, an optical velocity of 0.4747, a medium resolution aperture and open screen wheel. The instrument has also a DTGS KBr detector, a Smart iTR accessory and a diamond window. Polystyrene was analyzed daily to check the wavelength calibration of the instrument (24). A table of the polystyrene NIST Standard 1921a frequencies can be seen in Appendix II.

For spectral analysis, the identified peaks in each spectrum were compared to the peaks of components usually found in paper for filling and/or coating, such as calcite, talc, kaolinite and rutile. Table 2 shows the wavenumbers with the characteristic peaks for these components, obtained from the Rruff database (25).

Component	**Wavenumbers (cm^{-1})**
Calcite*	2514, 1795, 1394, 871, 711
Talc*	3669, 968, 667, 507, 410
Kaolinite (2)	3700, 920, 700, 475
Rutile*	3966, 501

Table 2. Components usually found on paper and their wavenumbers in the infrared spectrum.

**Data source: rruff.info*

3.2.2.2 Raman Spectroscopy

Raman spectroscopy can be used for the qualitative and quantitative analysis of organic and inorganic compounds. The sample is irradiated with a laser source of visible or near-IR

monochromatic beam and the spectra of the scattered radiation is then measured with a spectrometer (1).

Three designated locations on the paper were analyzed for each envelope and no sample preparation was required. Figure 8 shows the location where the samples were analyzed, which were selected from areas located in the up-left, middle-right, and bottom-left of the front of the envelope where the length of the envelope was divided into three thirds of 10.2 cm each from its bottom. Samples were collected from the five random envelopes from each of the three boxes from the ten different brands purchased, which makes it a total number of 450 samples. Figure 9 shows how the samples were placed in the instrument.

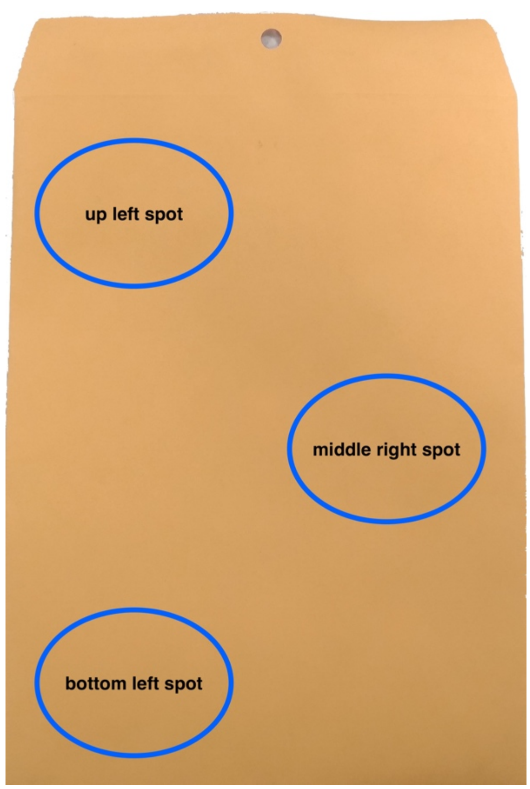


Figure 8. Locations of sample collection in the front of the envelope for Raman analysis

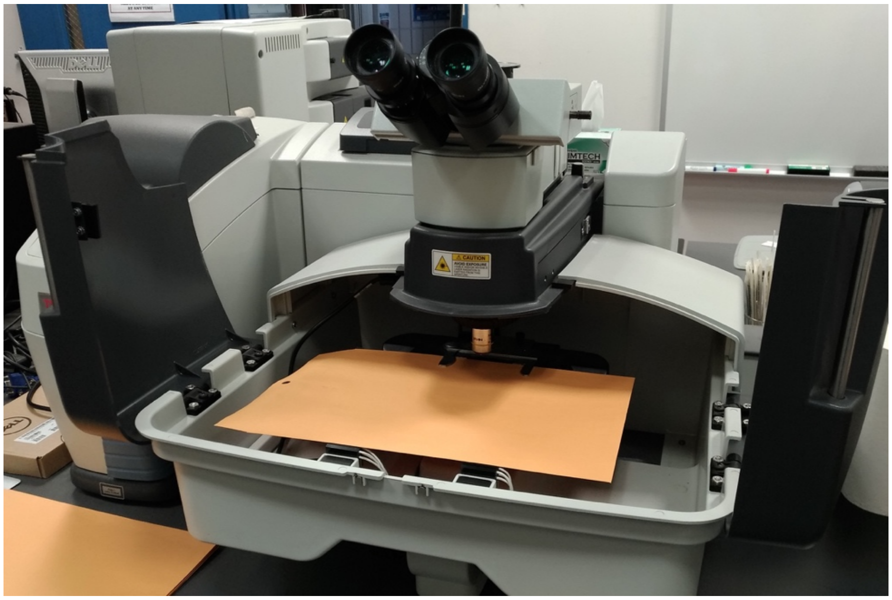


Figure 9. Sample collection of middle right spot on an envelope using the DXR Raman microscope

The DXR Raman microscope by ThermoFisher Scientific was used for this analysis with the Thermo Scientific^{TM} OMNIC^{TM} 9 software. The instrument has spectral range of 3372 to -38 cm^{-1}, an estimated resolution of 4.7 – 8.7 cm-^{1}, a 400 lines/mm grating, an estimated spot size of 3.1 μm and its laser has a 780 nm wavelength. The objective of the microscope is a MPlan 10x/0.25 BD. The selected aperture for the analysis was the 50 μm pinhole and the wavenumbers selected ranged from 50 to 3372 cm^{-1}.

A method development was performed using one envelope from Staples brand and one envelope from Mead brand, where the following parameters were varied:

- Laser energy: the higher the energy, the better Raman scattering although there is risk of damage to the sample. After trying the 20mW energy value, the sample did not get damaged and, thus, this value was selected for every measurement.
- Time of exposure: 5, 10, 20 and 60 seconds

- The number of exposures: 4, 8, 16 and 32.
- The total time of analysis per sample: 20, 40, 80, 160 and 320 seconds.
- Photobleach versus non-photobleach.

The collected spectra were evaluated based on the signal-to-noise ratio. The highest signal-to-noise ratio obtained in a reasonable amount of time for both brands was at 10 seconds and 32 scans, with no photobleaching, making it a total of 320 seconds per sample collection (see Appendix III for a detailed list of values obtained on the signal-to-noise ratio evaluation). These parameters were used for all subsequent analysis.

Polystyrene was used to check the wavelength calibration of the instrument daily. A table of the Raman frequencies for polystyrene can be seen in Appendix IV.

For spectral analysis, the identified peaks in each sample were compared to the peaks of calcite, talc, anatase and rutile (see Table 3). Kaolinite was not considered due to the fact that no Raman spectrum was found in the literature using the same excitation wavelength as the instrument used (780 nm).

Component	**Wavenumbers (cm^{-1})**
Calcite*	1745, 1436, 1085, 711, 281, 152
Talc*	673, 357, 193
Rutile*	611, 446, 237, 141
Anatase*	636, 511, 393, 146, 106

Table 3. Wavenumbers of the usual components found in paper with Raman spectroscopy.

**Data source: rruff.info*

3.2.2.3 X-ray Fluorescence (XRF) Spectroscopy

XRF spectroscopy is commonly used for the qualitative and quantitative determination of elements of the periodic table. In this technique, a beam of X-rays passes through the sample, where its intensity is decreased due to absorption and scattering. The scattering effect is usually very small so it can be disregarded and the absorption spectrum of the element is obtained (1).

XRF analysis was carried out at the United States Secret Service laboratory by Irina Geiman (a forensic chemist and questioned document examiner) and a quantitative elemental analysis was performed on the paper of the samples. The instrument used for the analysis was the EDAX Eagle III μProbe X-ray spectrometer with the following parameters: scan live 300 μsec time at 30 kV, and a Rhodium source.

The outside of the envelopes from five envelopes from the three boxes from the ten different brands were analyzed. Two 3 mm punches from each envelope, one from the front and the other from the back of the envelope, were collected and two spots on each punch were sampled. Therefore, a total number of 600 samples were analyzed. Envelopes right after the ones previously selected from every box were chosen and named from A'-1-1 (where the first 1 is related to the box number and the second 1 is related to the envelope number from that box) through J'-3-5, in order to distinguish them from the first set of envelopes.

The punched samples were placed onto ten different stubs (named A through J, after each of the ten brands). Every punch was named P1 and P2 for each envelope and the two spots selected from each punch were named P1A and P1B. Figure 10 shows all the punches and their names in stub A.

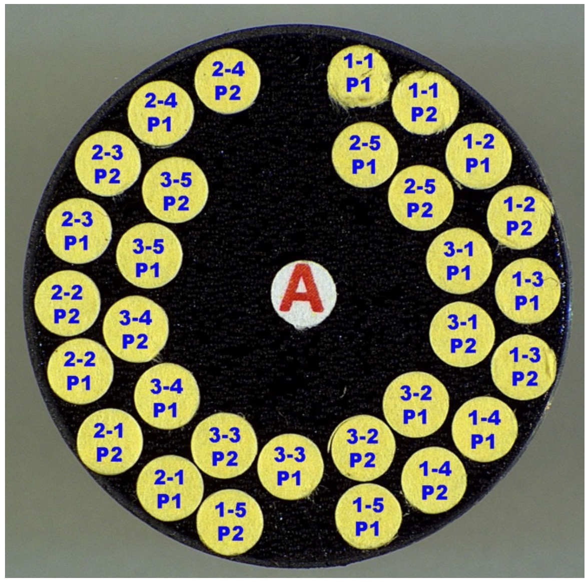


Figure 10. Punches in a stub from each of the envelopes analyzed with XRD in regards to brand A.
Photo courtesy of Irina Geiman

A statistical analysis for every brand was conducted using Student t-test with α=0.001.

3.2.2.4 X-ray Powder Diffraction (XRD)

In XRD, the X-rays enter the sample at a certain angle θ and scattering is produced. The consequence of scattering from a regular distance between the scattering centers, which are of the same order of magnitude as the wavelength of the radiation, causes diffraction (1).

XRD was performed on the samples in situ in order to obtain qualitative information about the compounds present in the paper of the envelopes. One designated location on the paper was analyzed for each sample. Samples were collected from envelopes 1, 3, and 5 of each of the three boxes from the ten different brands purchased, generating a total of 90 samples. The Rigaku MiniFlex II was used for this analysis, with the collection parameters of 3 to 90 degrees collection angles at a fast scan rate of 10 seconds per degree.

Sample preparation consisted of cutting a rectangle of approximate 2x3 inches and placing it on a 2”x3” glass slide to fit into the sample holder of the instrument. Figure 11 shows the location where the sample was cut in the upper right side of the front of the envelope in an area 10 cm below the top of the height of the envelope.

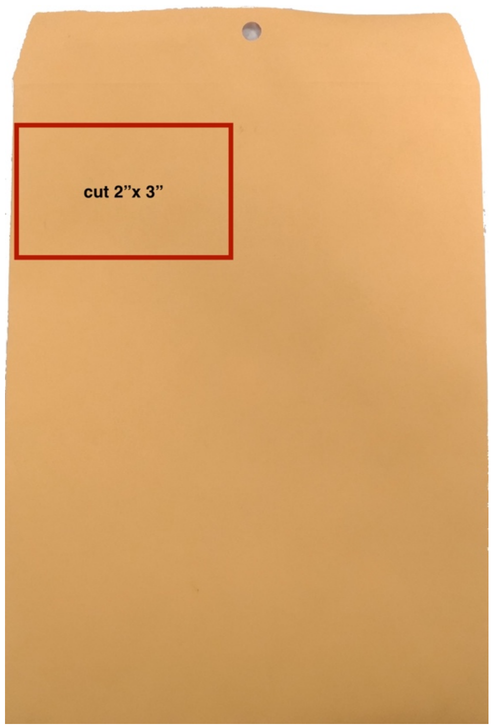


Figure 11. Location of the 2”x3” cut of the sample in the front of the envelope for XRD analysis

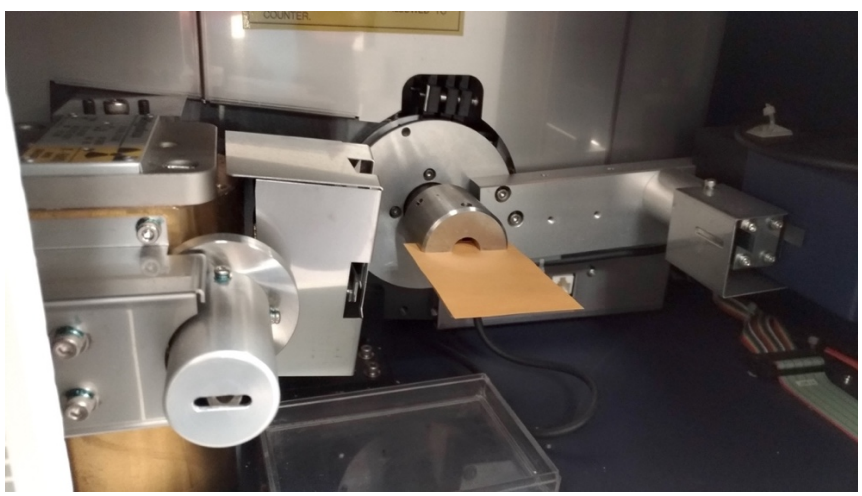


Figure 12. Cut sample placed in the Rigaku Miniflex II X-ray diffractometer

For calibration, a Silicon sample was first run in fast scan at a speed of 10.00 seconds and 2theta = 3 degrees to 90 degrees. Peaks were found and compared to a Silicon standard card where the d(Å) and the 2-Theta values were contrasted to determine if the sample values corresponded to those in the standard card. The Silicon standard card values as well as all the parameters utilized in the software can be consulted in the Appendix V.

Once the instrument's calibration was checked, the samples were analyzed with the parameters previously mentioned. Figure 12 shows how the samples were placed in the instrument.

After the peaks of the samples collected were determined with the software Jade by Materials Data, they were compared to the peaks of calcite, talc, kaolinite, anatase and rutile, whose 2-theta values are displayed in Table 4.

Component	**2-Theta (degrees)**
Calcite	29, 36, 39, 43, 47, 64
Talc	9, 19, 28, 48, 59, 70
Kaolinite	12, 20, 21, 24, 36, 38, 39
Rutile	27, 36, 41, 54, 56, 69
Anatase	25, 37, 48, 53, 62, 75

Table 4. 2-Theta degrees at which peaks of some of the components of paper are found in XRD.
Data source: rruff.info

3.3 Data Analysis

This research used descriptive statistical methods, partial least squares discriminant analysis (PLSDA) and principal component analysis (PCA) to analyze the collected data. Two statistical computer programs were utilized. First, R was used for exploratory data analysis in this study, with codes written by Professor Nicholas D.K. Petraco. Solo by Eigenvector was also used for classification of the FT-IR and Raman spectral data.

PCA is a multivariate statistical analysis technique used to decrease a large number of variables to a smaller number of uncorrelated variables called principal components (PCs). The data is summarized using a reduced number of PCs and the variance is the highest possible within the first PC (26).

PLSDA is a technique based on an algorithm that intensifies the separation between groups observed.

On the other hand, histograms are presented in this study to show the data analysis completed with R. A histogram is a plot of the distribution of a set of numerical data presented in intervals versus the percentage of total values represented within each interval.

3.4 Blind study

A blind study was carried on fifteen envelopes, which were randomly chosen by someone other than the examiner (see Appendix VI for the identification of brands selected). These were analyzed in order to determine if these could be associated to one of the brands. These fifteen envelopes were chosen from either the set of the ten manufacturers in the initial study, or from another source. These were named Blind01 through Blind15.

Additionally, five out of these fifteen envelopes were sent through the mail with a written white letter-sized note inside each one to simulate evidence. These corresponded to envelopes named Blind11 through Blind15. The purpose was to determine if brand identification or discrimination of manila envelopes was affected by the process of being sent through the mail.

Physical features (clasp type, number of adhesive strips, and imprinted brand) were first examined, followed by the color analysis and physical measurements (dimensions, weight, thickness). Next, the chemical analysis by ATR FT-IR spectroscopy and Raman spectroscopy was performed. Due to time constraints, XRF was not conducted. These were all performed as described previously in the initial examination of the manila envelopes.

3.5 New boxes

One new box, named box 4, from brands B, C, D, E and F were purchased 10 months later. This was done to evaluate intra-brand variations for boxes purchased at different times. The new boxes were purchased at exactly the same stores (Amazon and W.B. Mason) and the model ordered was exactly the same.

Physical features (clasp type, number of adhesive strips, and imprinted brand) were first examined, followed by the color analysis and physical measurements (dimensions, weight, thickness). Next, the chemical analysis by ATR FT-IR spectroscopy and Raman spectroscopy was performed as part of the blind study, where envelopes B-4, C-4, D-4, E-4 and F-4 were named Blind 16 through 20, respectively. All of these analyses were studied exactly with the same methodology than the samples for the blind study. XRF was not conducted due to time limitations.

4. RESULTS

All measurements are expressed using the International System of Units (SI).

4.1 Physical Examination

4.1.1 Physical features

Four different types of clasps were found among the ten different brands (see Table 5). Brand A showed clasp type I, brands B, C, D, E, and F had clasp type II, brand H's clasp type was III, brand I showed clasp type IV, and brands G and J contained no clasp. Clasp types I and III are silver in color and types II and IV are golden. The holes in type I are less rounded tan type III. Figure 2 shows the four different types of clasps.

After examining the number of adhesive strips in every envelope, it was established that brands A, B, C, D, E, F and J had two strips and brands G, H, I showed only one strip (see Table 5). Figure 13 shows the different types of adhesives found in the brands purchased.

Only brand D showed the name of the brand imprinted at the bottom of the back of the envelope (see Table 5 and Figure 14).

Envelope #	Clasp type	# of adhesive strips	Imprinted brand
A	I	2	--
B	II	2	--
C	II	2	--
D	II	2	Yes
E	II	2	--
F	II	2	--
G	--	1	--
H	III	1	--
I	IV	1	--
J	--	2	--

Table 5. Physical features found in each of the boxes of every brand

Figure 13. Types of adhesive characteristics found in the ten brands

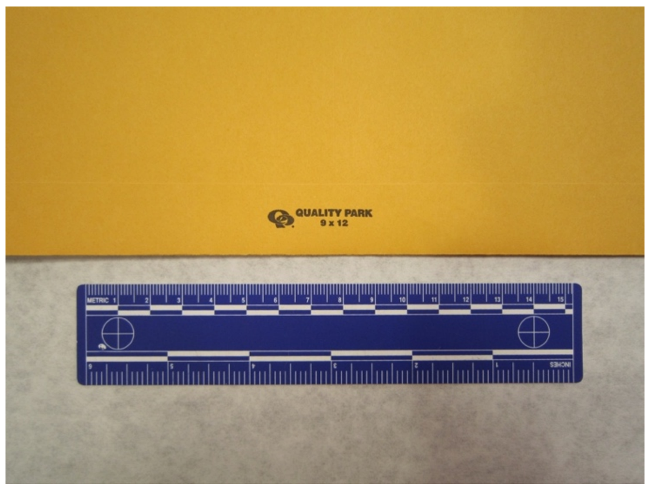


Figure 14. Image of back of envelope (brand D) with imprinted brand and size (“Quality Park 9x12”) in the bottom

4.1.2 Color analysis

The ranges of measurements of the values of channels R, G, and B for each brand of envelope are shown in Table 6. All the measurements obtained in the analysis can be found in Appendix VII.

Brand	R	G	B
A – Staples	974 – 999	797 – 820	462 – 483
B – WB Mason	761 – 768	506 – 521	235 – 244
C – Office Depot	716 – 733	459 – 471	191 – 199
D – Quality Park	716 – 734	458 – 472	188 – 199
E – Columbian	727 – 746	467 – 484	191 – 204
F – Business Source	744 – 766	491 – 513	223 – 236
G – Amazon Basics	716 – 737	451 – 469	180 – 193
H - Check-O-Matic	723 – 745	463 – 482	186 – 201
I – Mead*	715 - 757	465 – 503	204 – 240
I-1	724-757	471-503	204-234
· I-1-1, I-1-2	724-734	471-480	204-211
· I-1-3, I-1-4, I-1-5	742-757	493-503	228-234
I-2 and I-3	715-739	465-486	226-240
J – Jam	717 – 731	456 – 471	186 – 197

Table 6. Ranges of R, G and B values for all brands

**Note the ranges in brand I are higher than the rest of the brands so the values were split by box and by envelopes within a box.*

Four hundred and fifty data values were acquired per channel and they were statistically analyzed with R. The histograms obtained in the statistical analysis can be seen in Figure 15, where the R, G and B values were evaluated separately.

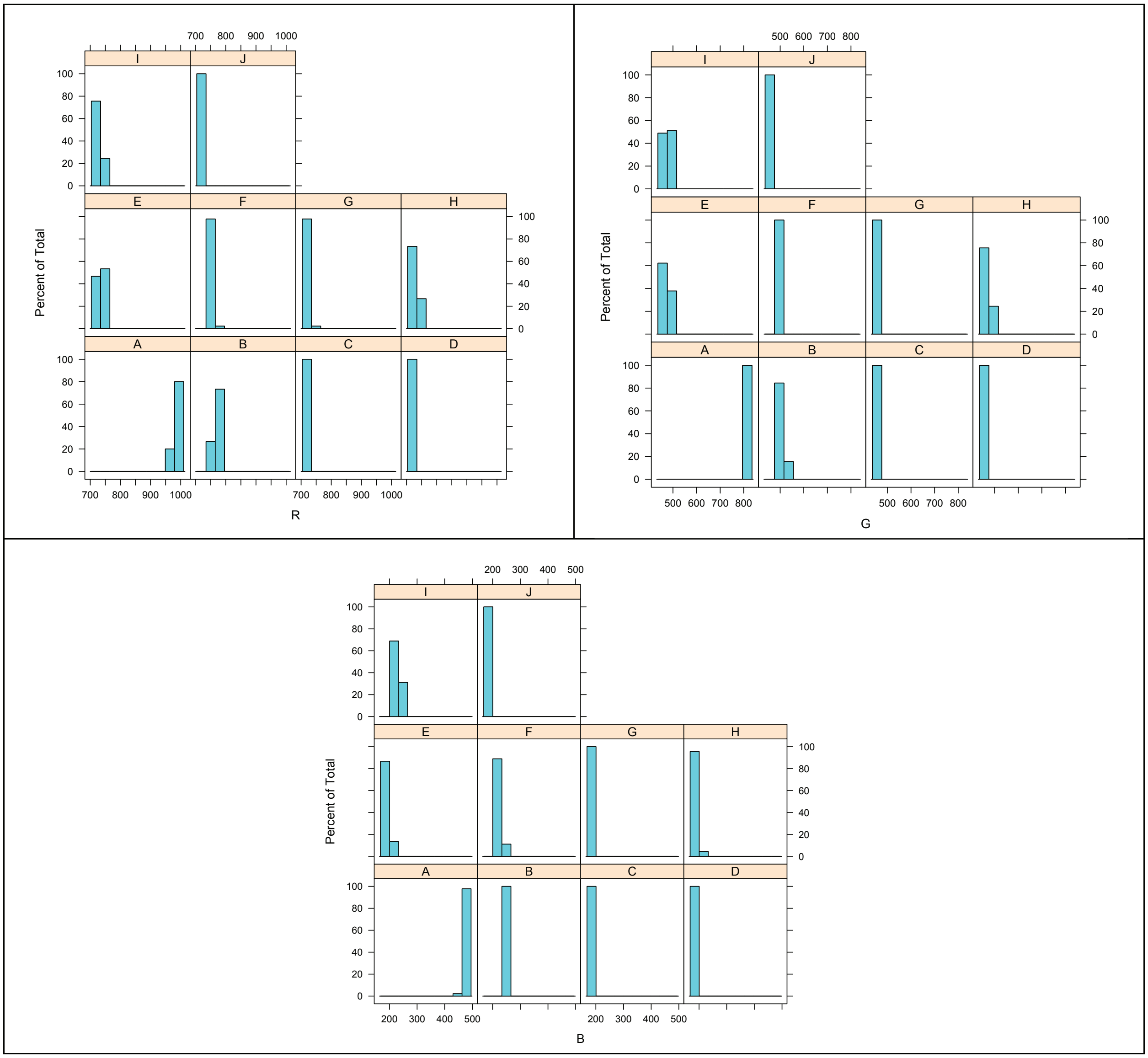


Figure 15. Histograms of R, G, and B values for each brand

Because the RGB values for brand A were very different from those measured of the other envelopes, the histograms were re-plotted without Brand A (Figure 16). Additionally, Brand I showed intra brand variation (which will be discussed in the Discussion section), it was split into two different groups, where “K” has the measurements from box 1 and “I” contains the measurements from boxes 2 and 3.

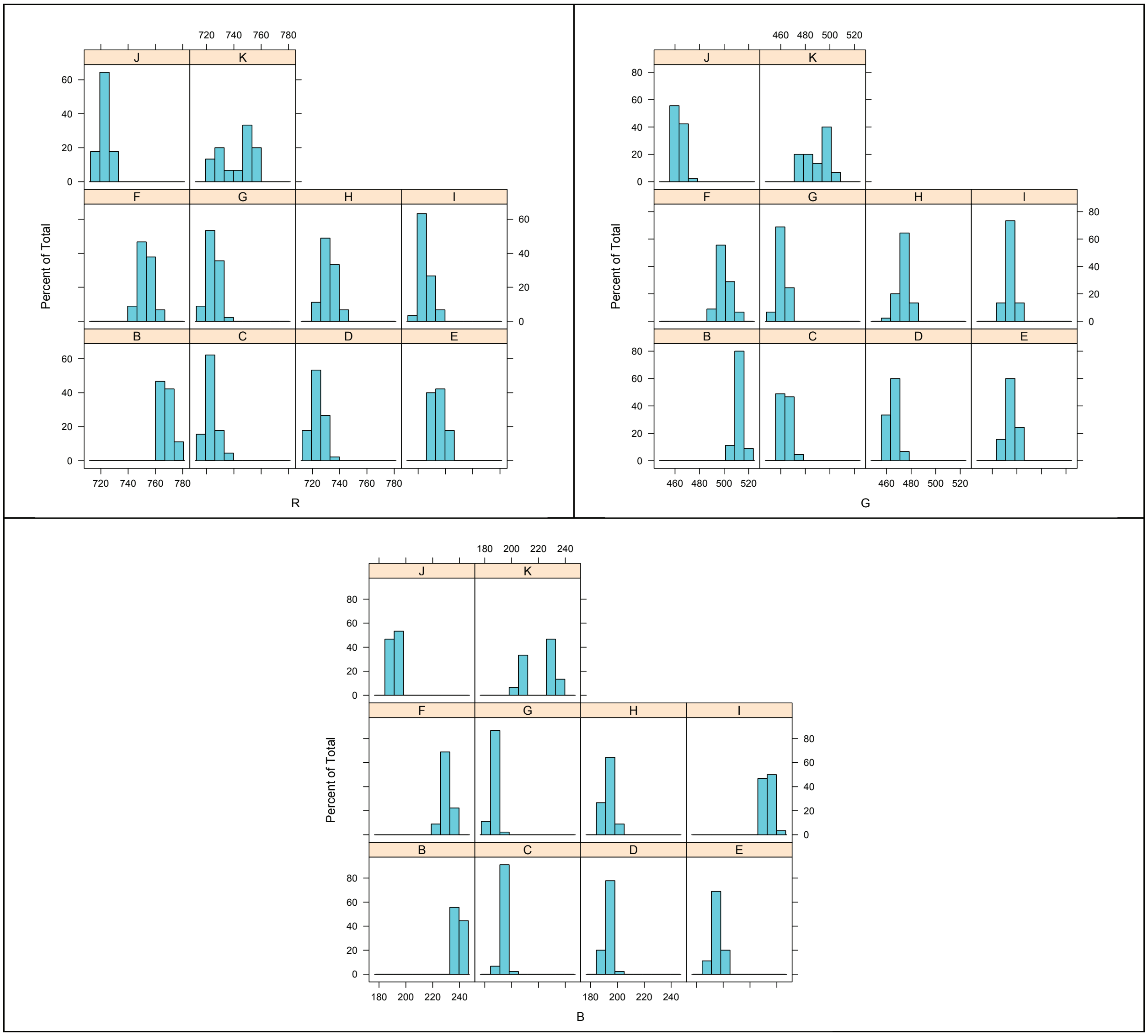


Figure 16. Histograms of R, G, and B values for each brand, except for Brand A. Also, Brand I is split into two different groups, where “K” has the measurements from box 1 and “I” contains the measurements from boxes 2 and 3.

An illustrative example of the differences in color can be seen in Figure 17.

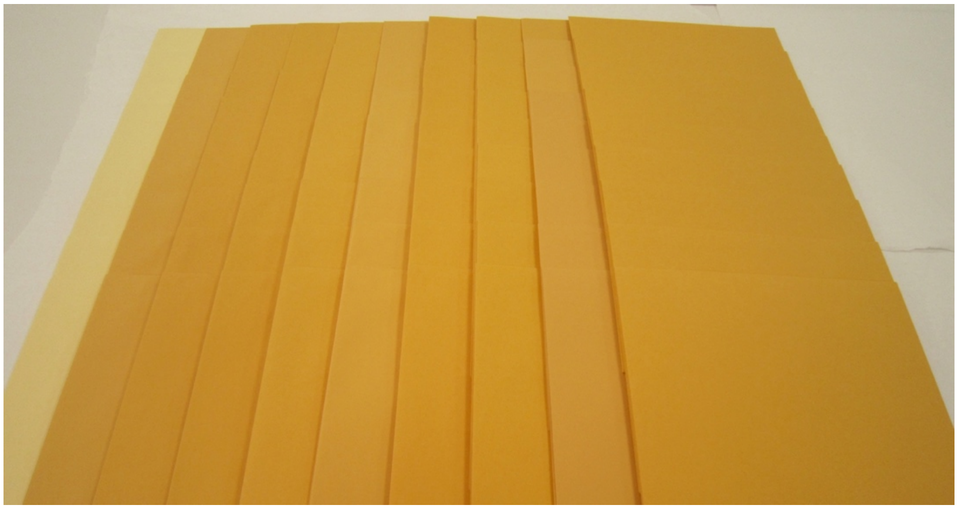


Figure 17. *From left to right*: Manila envelopes (brands A through J)

4.1.3 Alternate Light Sources

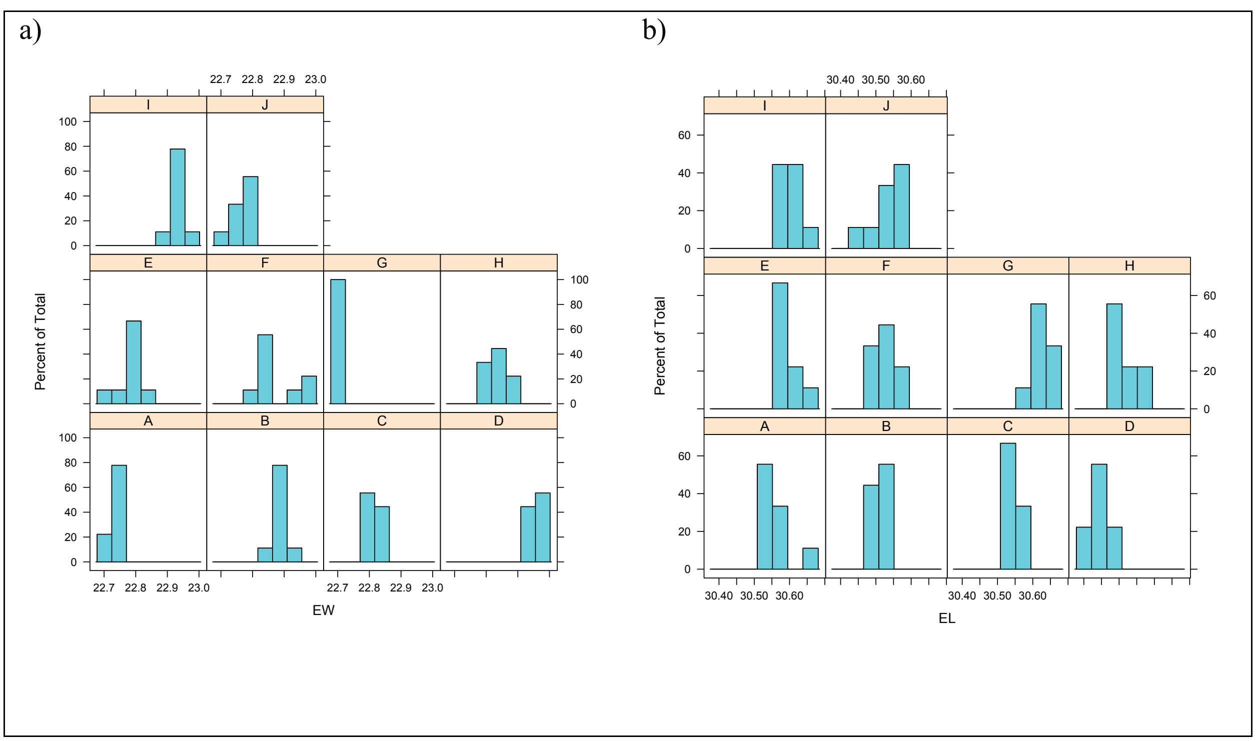
No particular features (scratches, indentation, roughness, etc.) were identified. Slight reflectivity differences could be appreciated making use of the appropriate eye protection.

4.1.4 Physical Measurements

The dimensions of the envelopes obtained after the average was calculated in every brand are shown in Table 7 and represented in the histograms in Figure 18. A detailed table with all the measurement values obtained in triplicate is shown in Appendix VIII.

Brand	Envelope width (cm)	Envelope length (cm)	Flap upper width - w/lift flap (cm)	Flap height (cm)	Lower flap upper width (cm)	Lower flap height (cm)	Adhesive 1 width (cm)	Adhesive 1 height (cm)	Adhesive 2 width (cm)	Adhesive 2 height (cm)	Clasp closure hole diameter (cm)
A	22.73	30.56	20.11	3.61	19.96	2.69	8.09	2.47	8.09	2.46	0.92
B	22.89	30.52	20.62	3.75	21.80	2.13	7.68	1.90	7.67	1.89	0.93
C	22.82	30.54	20.37	3.76	21.85	2.02	7.44	1.91	7.53	1.90	0.89
D	22.96	30.44	20.80	3.74	21.77	2.19	7.76	1.90	7.70	1.90	0.92
E	22.85	30.55	20.78	3.72	21.78	2.12	7.73	1.90	7.67	1.90	0.91
F	22.89	30.52	20.44	3.75	21.91	2.03	7.46	1.91	7.55	1.93	0.91
G	22.70	30.63	20.29	3.49	20.33	2.72	--	--	--	--	--
H	22.84	30.51	20.73	4.11	20.85	2.81	17.98	2.27	--	--	0.84
I1	22.91	30.58	21.02	3.71	21.10	2.28	16.80	2.48	--	--	0.83
I2 + I3	22.94	30.61	21.01	3.74	21.11	2.25	16.84	2.52	--	--	0.84
I	22.93	30.60	21.02	3.73	21.11	2.26	16.83	2.50	--	--	0.84
J	22.77	30.53	18.70	4.54	20.63	2.33	7.84	2.35	7.39	2.36	--

Table 7. Averages of the physical measurements for all brands



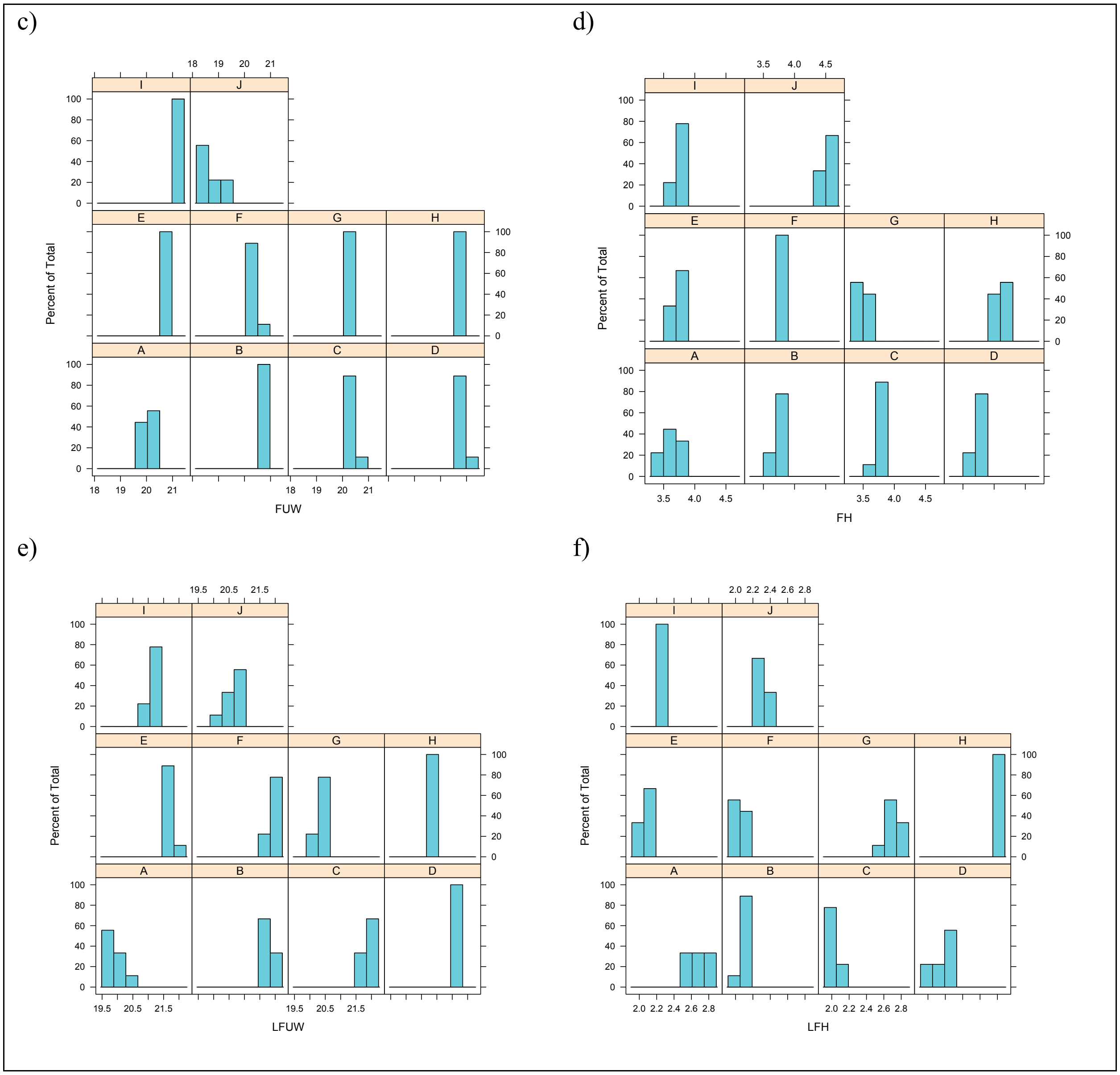


Figure 18. Histograms of a) envelope's width (EW), b) envelope's height or length (EL), c) flap's upper width (FUW), d) flap's height (FH), e) lower flap's upper width (LFUW), and e) lower flap's height

The thickness of the envelopes ranged between 0.13 and 0.18 mm. Table 8 shows the thickness ranges for each of the brands. All the thickness measurements, taken in triplicate, are shown in Appendix IX.

Brand	Thickness Range (mm)
A – Staples	0.15 – 0.18
B – WB Mason	0.13 – 0.15
C – Office Depot	0.15 – 0.16
D – Quality Park	0.15 – 0.16
E – Columbian	0.17 – 0.18
F – Business Source	0.15 – 0.16
G – Amazon Basics	0.15 – 0.16
H – Check-O-Matic	0.14 – 0.16
I – Mead	0.13 – 0.15
J – Jam	0.14 – 0.16

Table 8. Range of thickness values obtained for every brand

The thickness measurements for each brand are displayed graphically in the histogram shown in Figure 19.

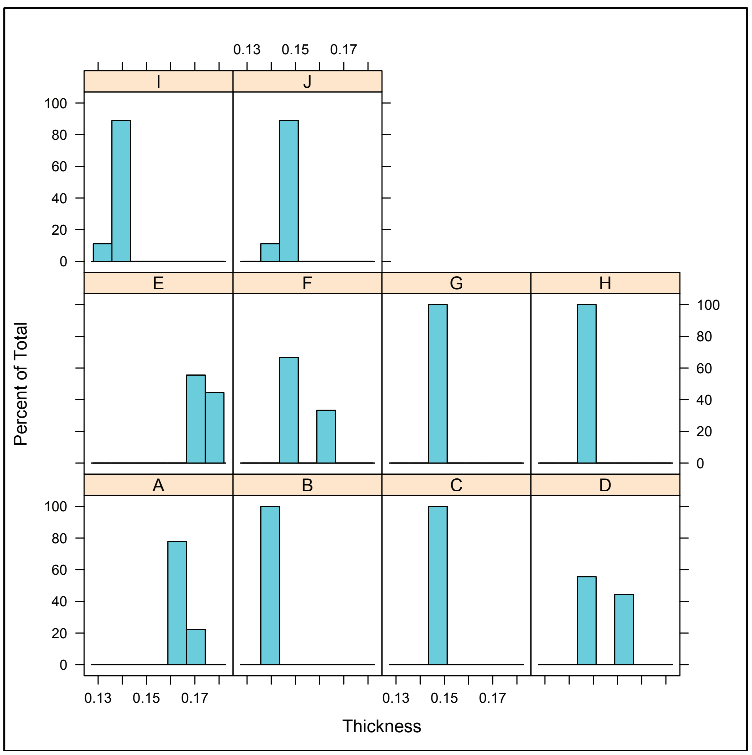


Figure 19. Histogram of the thickness values obtained from the ten brands

Three separate groups can be identified. Group 1 contains brands B and I, group 2 consists of brand E, and group 3 contains brands C, D, F, G, H, J. Brand A shares measurements with group 2 and F and D share measurements with brand A. It can be interpreted that A and E are the thickest brands and D and F are bi-modal.

The weight of the envelopes obtained for every brand ranged according to the values shown in Table 9. All values measured can be found in Appendix X.

Brand	Weight Range (g)
A – Staples	19 – 20
B – WB Mason	16 – 17
C – Office Depot	16 – 17
D – Quality Park	17 – 18
E – Columbian	18 – 20
F – Business Source	16 – 17
G – Amazon Basics	16 – 17
H – Check-O-Matic	17 – 18
I – Mead	14 – 16
J – Jam	16 – 17

Table 9. Weight ranges obtained from the ten brands

The weight measurements for each brand are displayed graphically in the histogram shown in Figure 20.

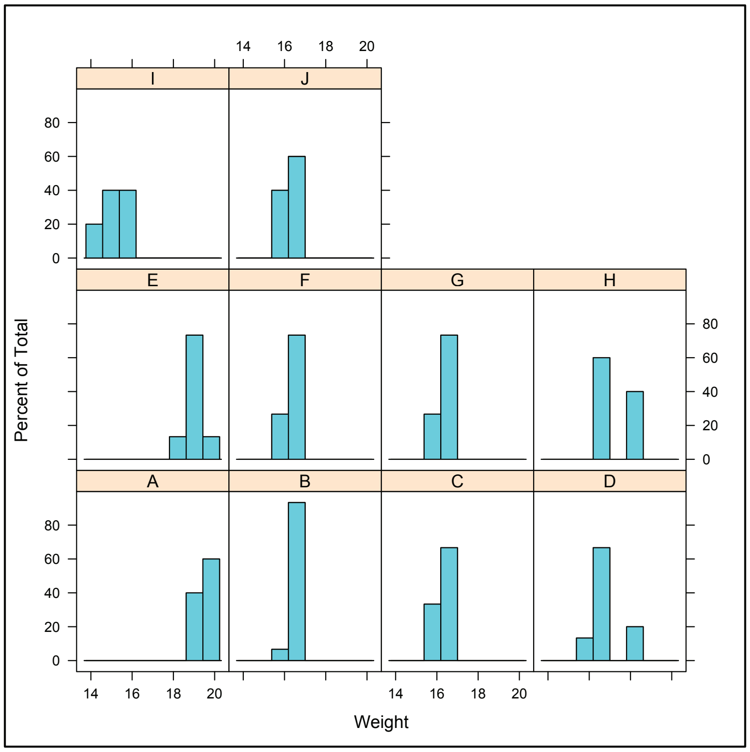


Figure 20. Histogram of the weight values obtained from the ten brands

Three groups can be identified. Group 1 contains brand I, group 2 contains brands A and E, and group 3 contains brands B, C, D, F, G, H and J. Brands E and A are the heaviest brands, brand E overlaps with D and H, brand D has the largest spread, whereas D and H are bi-modal.

4.2 Chemical Examination

4.2.1 ATR FT-IR Spectroscopy

Six-hundred (600) FT-IR spectra were collected in this research, representing the 10 different brands. The average infrared spectra obtained for every brand is shown in Figure 21.

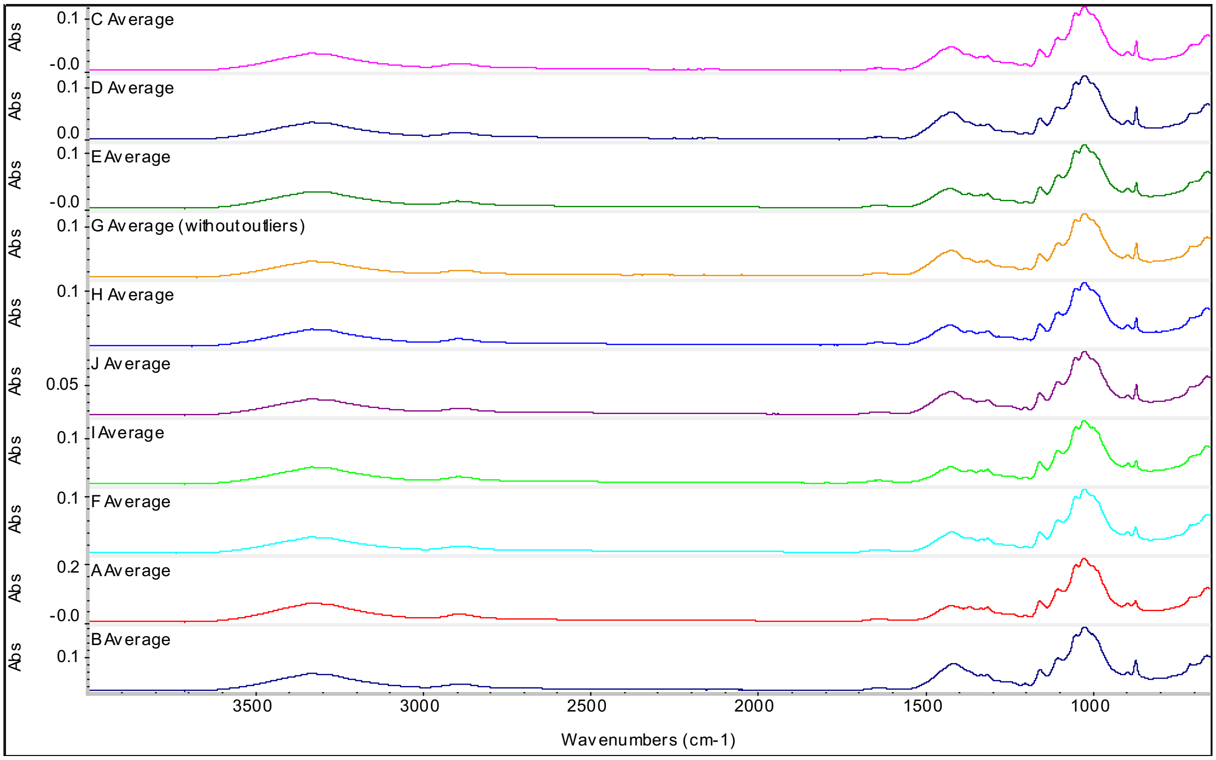


Figure 21. Average FT-IR spectra for each brand of manila envelopes

The 600 FT-IR spectra were chemometrically analyzed with PCA, using a multiplicative signal correction and mean centered data pre-treatment. This divided the brands into 4 different groups: group 1 contained brand A, group 2 contained brand B, group 3 contained brands F and I, and group 4 contained the rest of the brands (C, D, E, G, H, J). This can be seen in the principal component scores plot shown in Figure 22.

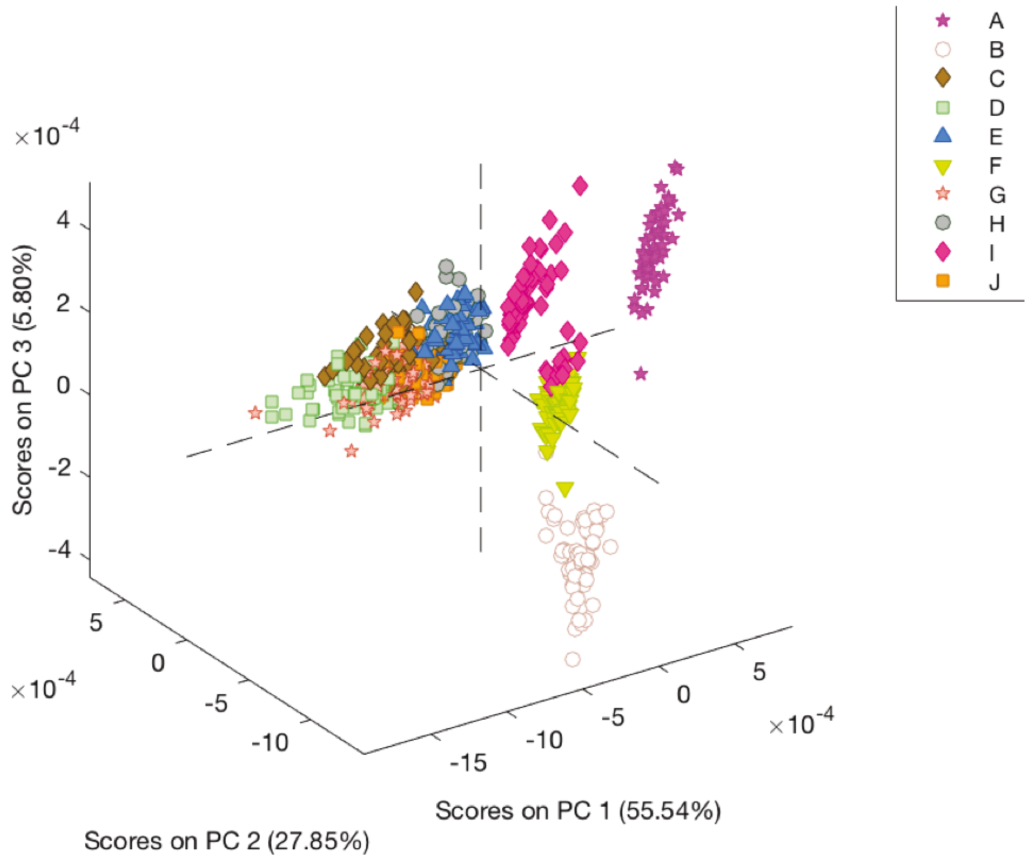
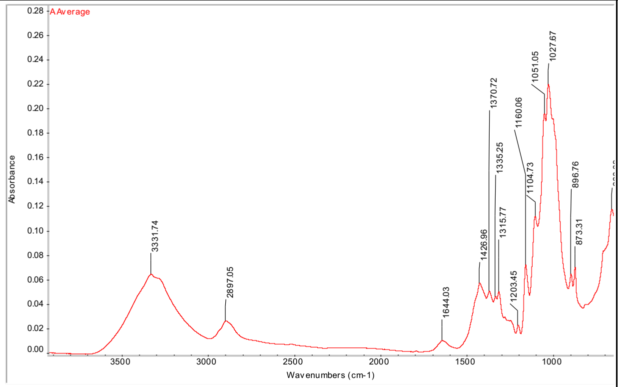


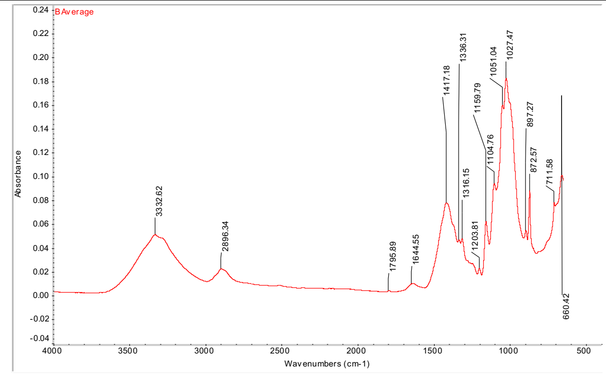
Figure 22. PCA scores plot of the first 3 PCs, using the ATR FT-IR spectral data. Image made with Solo by Eigenvector

The FT-IR spectral data was analyzed to try to identify the chemical components of the manila envelopes. For this analysis, the average spectra for every brand was calculated (Figure 23) and then compared to the known spectra of common paper constituents. Calcite was found to be present in all brands.

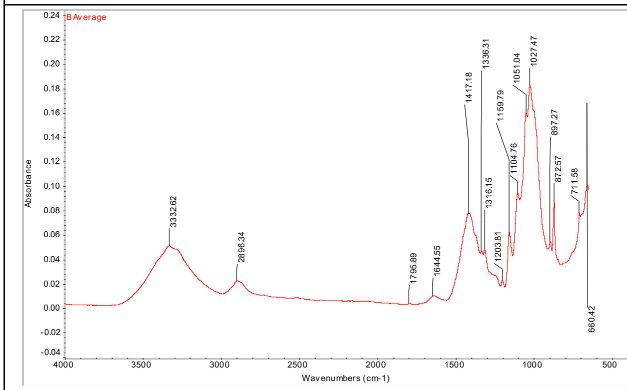
More detailed results (spectra for every box and averages) can be found in Appendix XI.


A Average
Absorbance
Wavenumbers (cm-1)
3331.74
2897.05
1644.03
1426.96
1370.72
1335.25
1315.77
1203.45
1160.06
1104.73
1051.05
1027.67
896.76
873.31

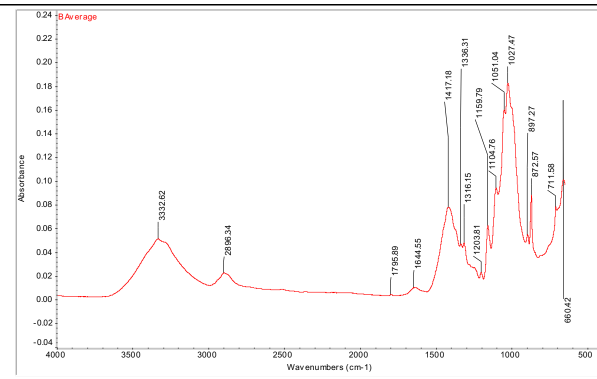
a


B Average
Absorbance
Wavenumbers (cm-1)
3332.62
2896.34
1795.89
1644.55
1417.18
1336.31
1316.15
1203.81
1159.79
1104.76
1051.04
1027.47
897.27
872.57
711.58
660.42

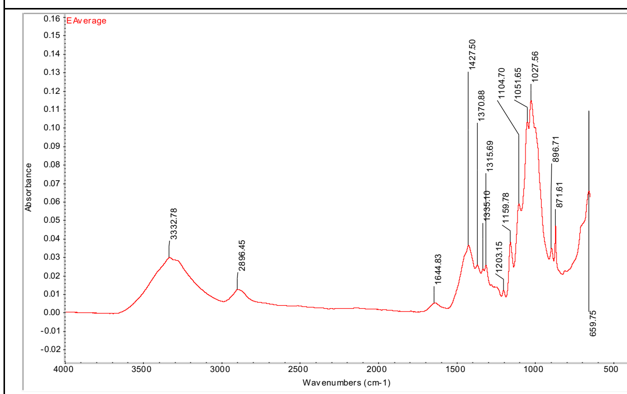
b


B Average
Absorbance
Wavenumbers (cm-1)
3332.62
2896.34
1795.89
1644.55
1417.18
1336.31
1316.15
1203.81
1159.79
1104.76
1051.04
1027.47
897.27
872.57
711.58
660.42

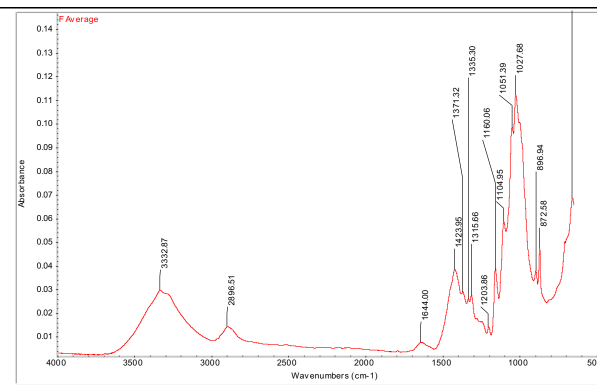
c


B Average
Absorbance
Wavenumbers (cm-1)
3332.62
2896.34
1795.89
1644.55
1417.18
1336.31
1316.15
1203.81
1159.79
1104.76
1051.04
1027.47
897.27
872.57
711.58
660.42

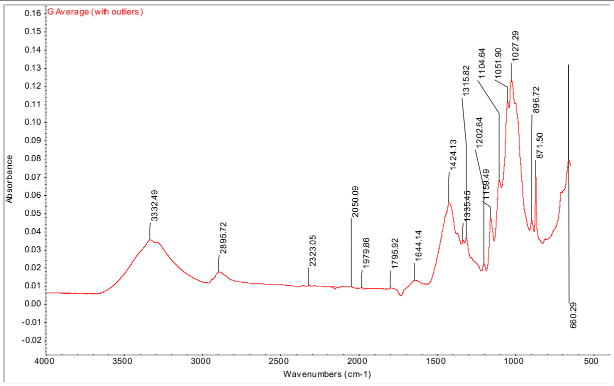
d


E Average
Absorbance
Wavenumbers (cm-1)
3332.78
2896.45
1644.83
1427.50
1370.88
1335.10
1315.69
1203.15
1159.78
1104.70
1051.65
1027.56
896.71
871.61
659.75

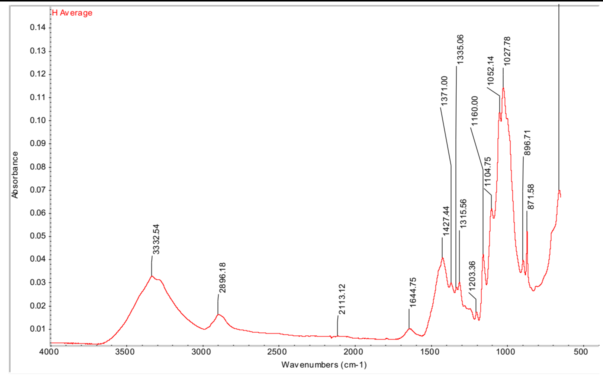
e


F Average
Absorbance
Wavenumbers (cm-1)
3332.87
2896.51
1644.00
1423.95
1371.32
1335.30
1315.66
1203.86
1160.06
1104.95
1051.39
1027.68
896.94
872.58

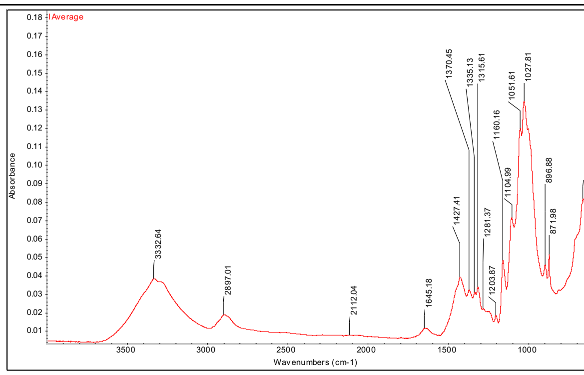
f



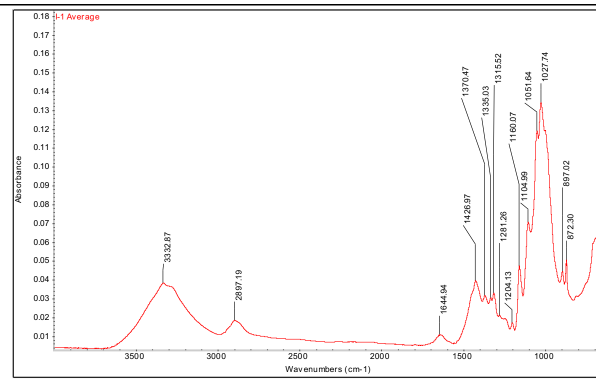
g



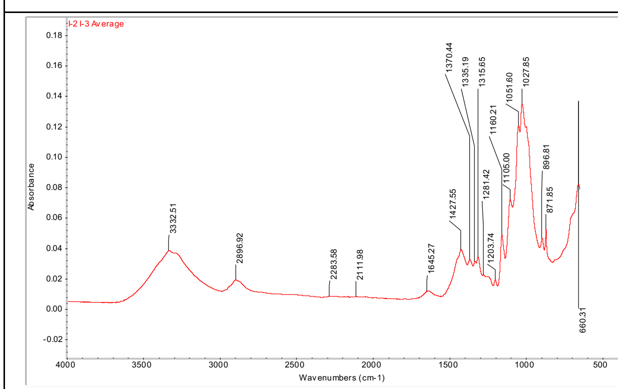
h



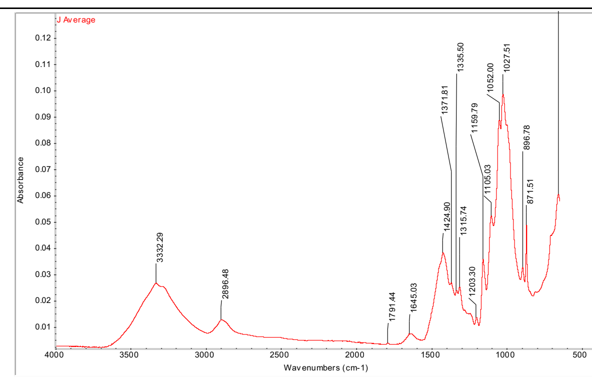
i



j



k



l

Figure 23. Average ATR FT-IR spectra with peak values for brand a) A, b) B, c) C, d) D, e) E, f) F, g) G, h) H, i) I – all boxes, j) I – box 1), k) I – boxes 2 and 3, l) J

4.2.2 Raman Spectroscopy

The average Raman spectra obtained for every brand is shown in Figure 24.

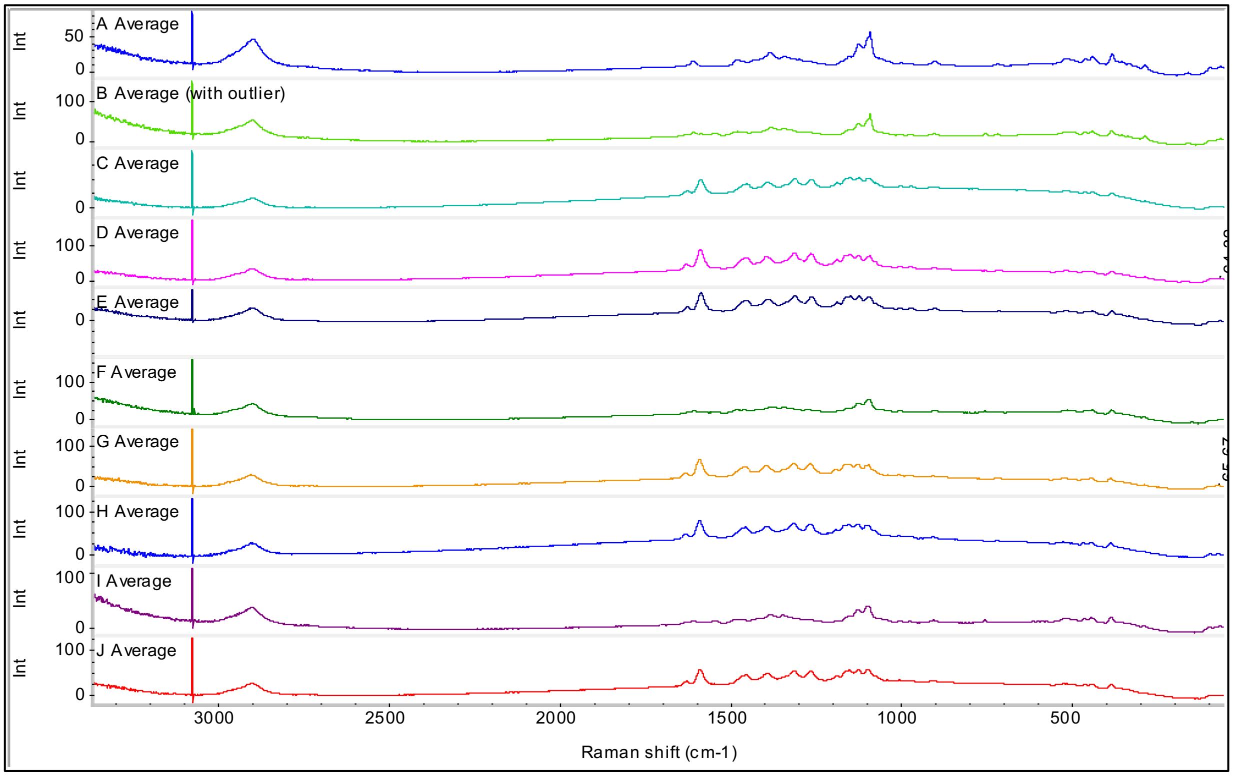


Figure 24. Average values of every brand's Raman spectra

Four hundred and fifty spectra (450) were obtained and analyzed using principal component analysis. The results obtained with this analysis can be divided into three different groups: group 1 contained brand A, group 2 contained brand B, F and I, and group 3 contains the rest of the brands (C, D, E, G, H, J). This differentiation is shown in the principal component scores plot in Figure 25.

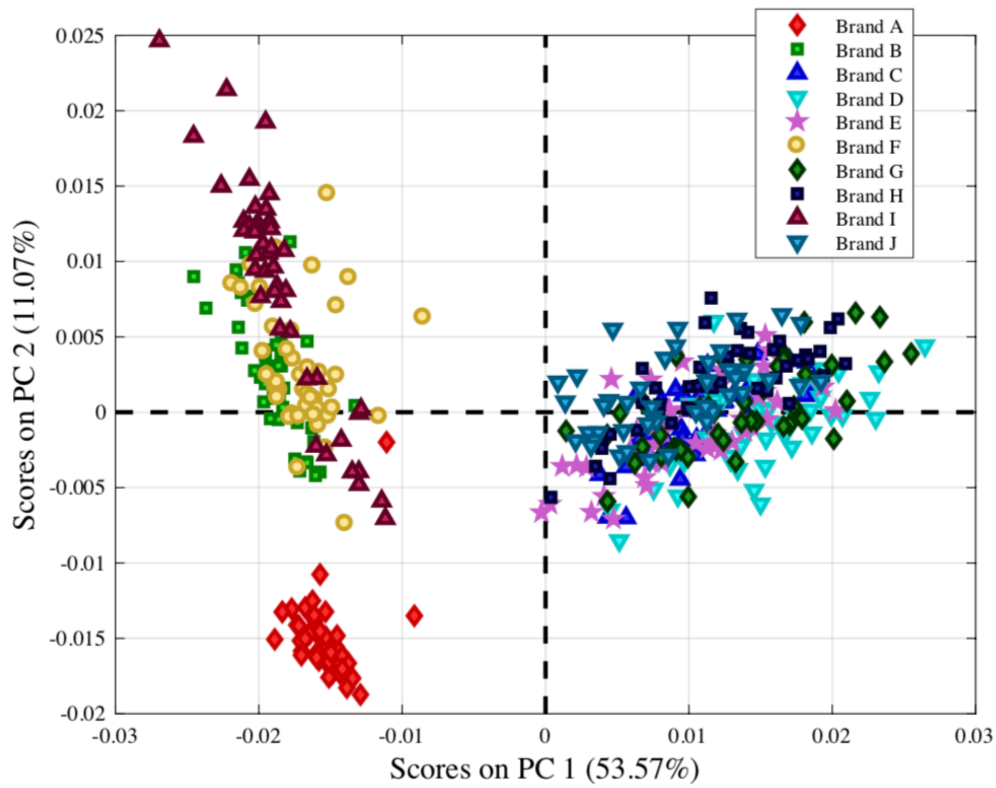


Figure 25. PCA scores plot of the Raman spectra. *Image made with Solo by Eigenvector*

Partial least squares discriminant analysis was then performed and brand B could be separated from brands F and I. Therefore, group 2 now contains brand B, group 3 contains F and I, and group 4 contains brands C, D, E, G, H, J. Figure 26 shows the four different groups obtained with PLSDA.

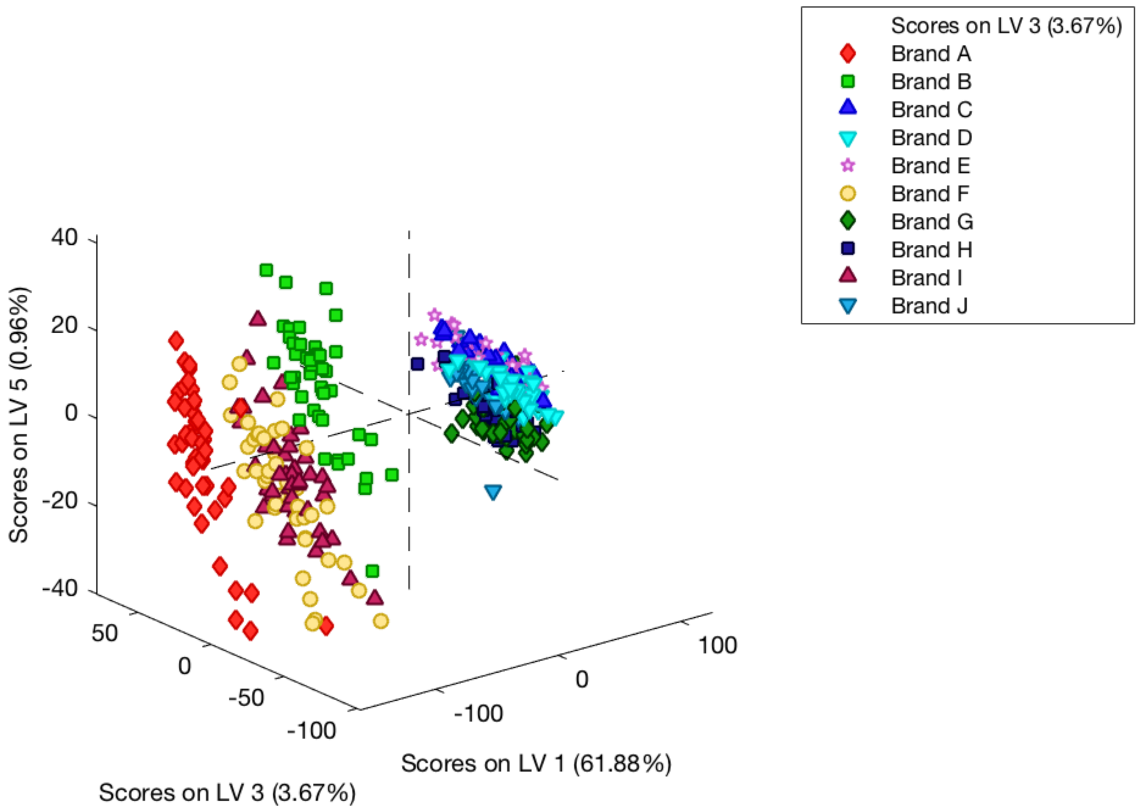
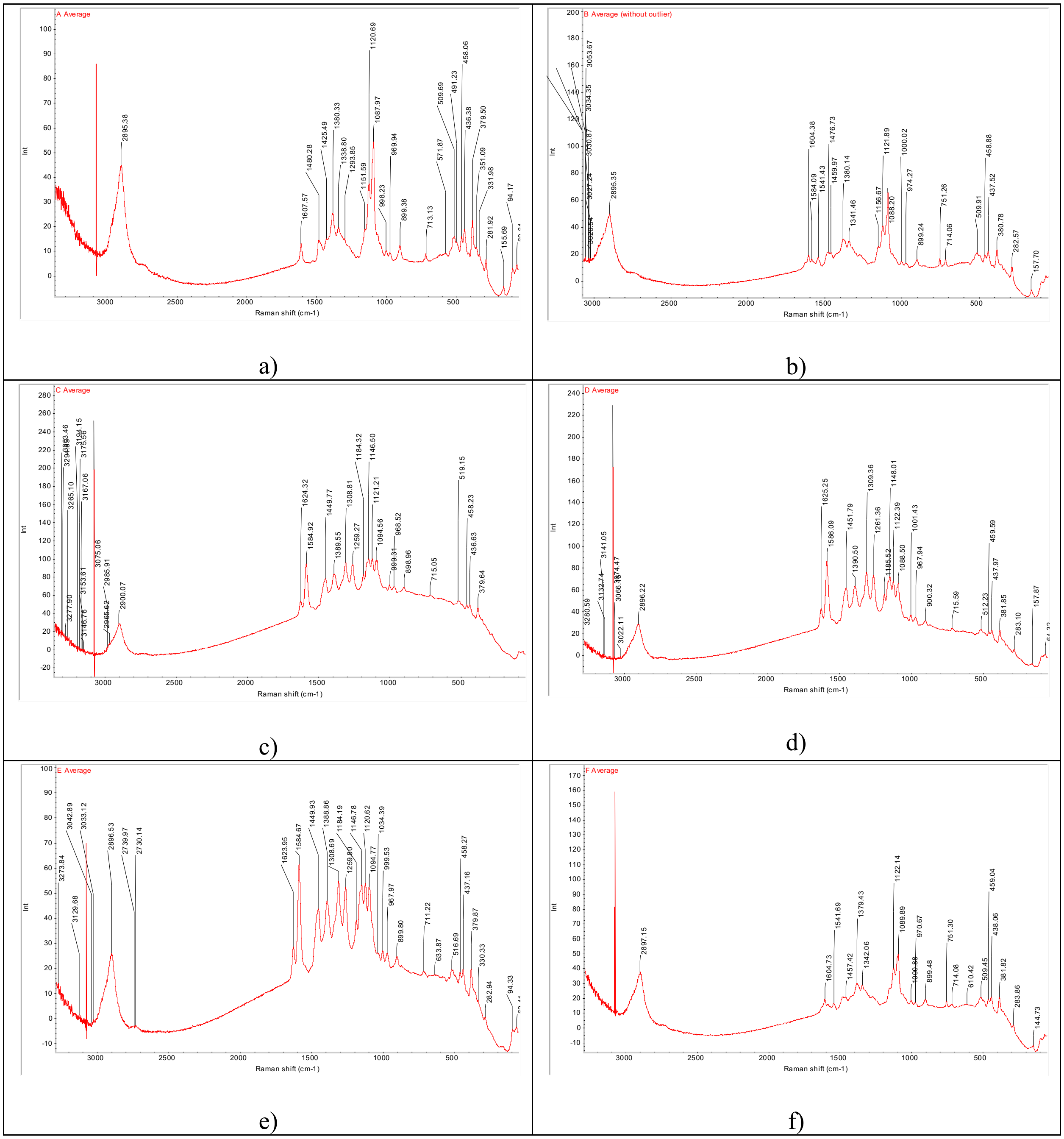


Figure 26. Scores plot of Raman spectra using PLSDA

The Raman spectral data was analyzed to try to identify the chemical components of the manila envelopes. For this analysis, the average spectra for every brand was calculated (Figure 27) and then compared to the known spectra of common paper constituents. Calcite peaks were found in all brands.

More detailed results (spectra for every box and averages) can be found in Appendix XII.


A Average
Int
Raman shift (cm-1)
a)
B Average (without outlier)
Int
Raman shift (cm-1)
b)
C Average
Int
Raman shift (cm-1)
c)
D Average
Int
Raman shift (cm-1)
d)
E Average
Int
Raman shift (cm-1)
e)
F Average
Int
Raman shift (cm-1)
f)

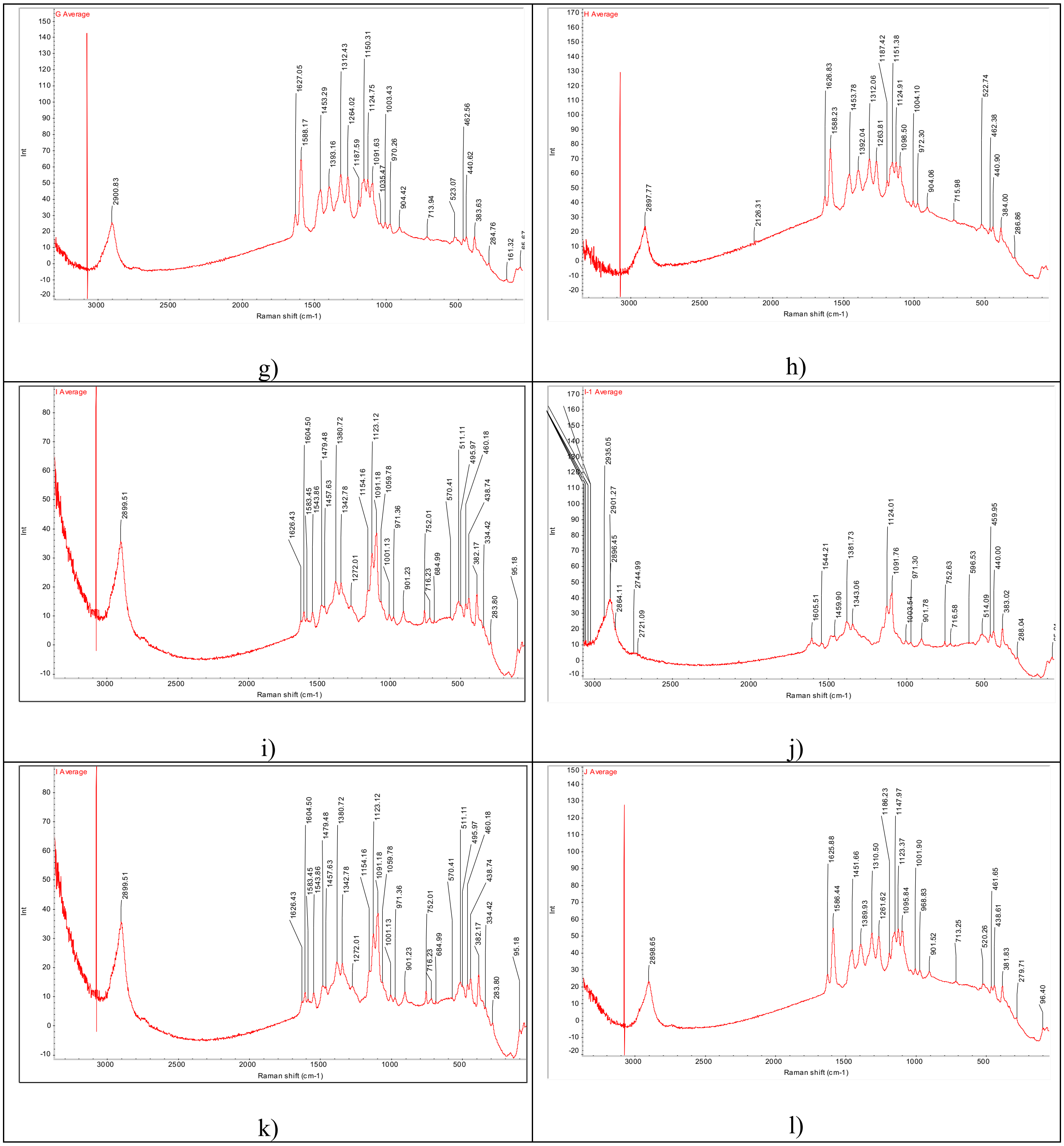


Figure 27. Average Raman spectra with peak values for brand a) A, b) B, c) C, d) D, e) E, f) F, g) G, h) H, i) I – all boxes, j) I – box 1), k) I – boxes 2 and 3, l) J

4.2.3 X-Ray Fluorescence (XRF) Spectroscopy

XRF was used to conduct elemental analysis of the samples. The results obtained for each brand are shown in Table 10.

Brand	Differences within boxes	Differences between boxes	Elements of interest found	Notes
A – Staples	No	No	Ca, S	Sample A"-1-4 has double Al counts than other samples
B – WB Mason	No	No	Ca, S, Si, Al	Sample B"-2-2 has slightly higher counts for all elements
C – Office Depot	No	No	Ca, S	Al counts are too low
D – Quality Park	No	No	Ca, S	Al counts are too low and Ti counts are below LOD
E – Columbian	Little consistency sample to sample	Little consistency box to box	Ca, S	Ti and Al counts hover around LOD levels
F – Business Source	No	No	Ca, S, Si, Al, Ti	---
G – Amazon Basics	No	No	Ca, S	Ti counts below LOD, Al counts hover around LOD levels
H – Check-O-Matic	Little consistency sample to sample	Little consistency box to box, but Box 3 has higher Ca counts than Boxes 1 and 2	Ca, S	Ti and Al counts hover around LOD levels
I – Mead	Samples I-1-3, I-1-4, and I-1-5 have higher levels of Si and Ti than the rest of the samples. No differences within boxes 2 and 3.	No differences between boxes 2 and 3.	Ca, S, Si, and possibly Al	---
J – Jam	No	No	Ca, S	J"-1-1 P1A has significantly more Ti counts than the rest of J-1-1 samples, and Ti counts are below LOD

Table 10. XRF results for all brands

4.2.4 X-Ray Diffraction (XRD)

The X-ray diffractograms in Figure 28 shows the spectra obtained for every brand after the average of values of the three envelopes from each of the three boxes was performed.

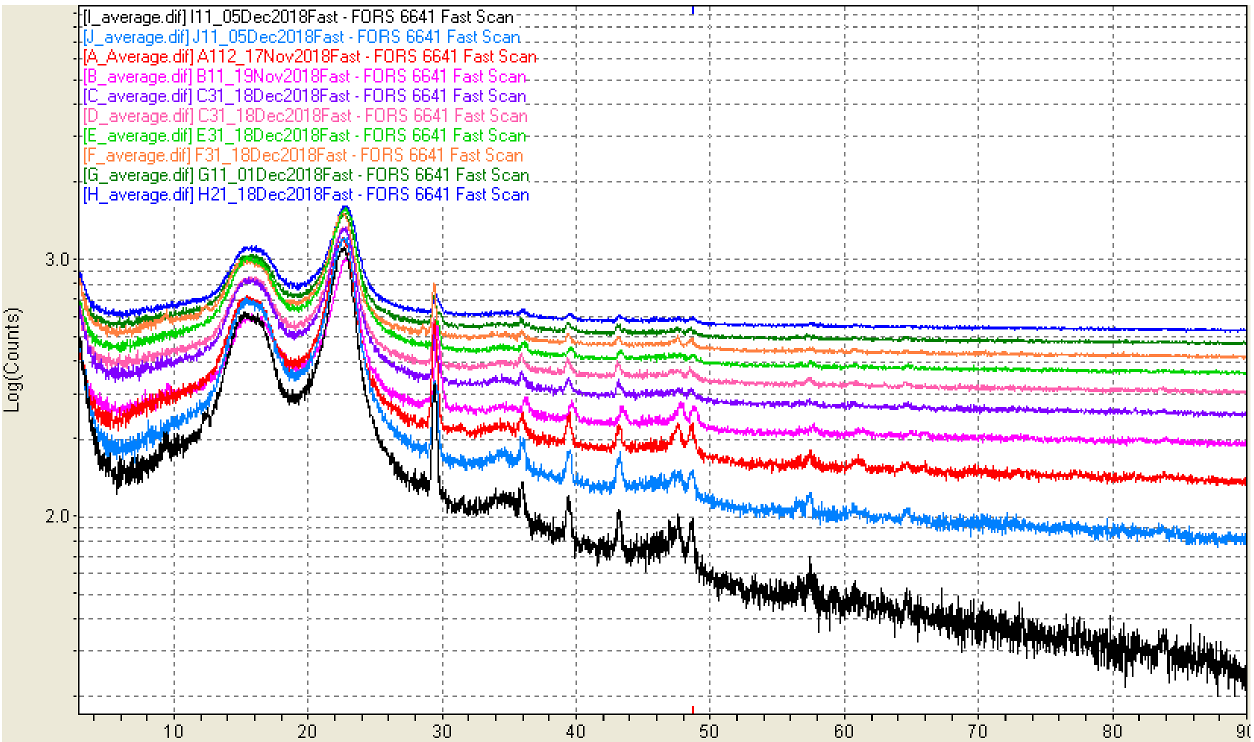


Figure 28. X-ray diffractogram showing the average spectra of every brand

For the analysis of the possible components, ninety diffractograms were examined and the average spectra for every brand were obtained. The detailed results (spectra and data for every box and all averages) can be found in Appendix XIII.

Calcite was found in all samples and no other component was identified.

4.3 Blind Study

Fifteen manila envelopes, five of them (#11 through #15) sent through the mail, were analyzed in order to assess the ability for brand identification using the methods previously described.

Physical Examination

Physical features

After visual examination of the 15 envelopes, the results of the physical feature determination are shown in Table 11.

Envelope #	Type of clasp	# of adhesive strips	Imprinted brand	Possibilities
1	II	2	Yes	D- Quality Park
2	II	2	---	B, C, E, F
3	II	2	---	B, C, E, F
4	III	1	---	H
5	None	1	---	G
6	II	2	Yes	D- Quality Park
7	II	2	---	B, C, E, F
8	I	2	---	A
9	None	2	---	J
10	IV	1	---	I
11	II	2	---	B, C, E, F
12	III	1	---	H
13	II	2	---	B, C, E, F
14	I	2	---	A
15	IV	1	---	I

Table 11. Physical features analyzed in the 15 envelopes of the blind study

Color analysis

Table 12 shows the values obtained for channels R, G and B in the three spots examined from every envelope.

Envelope #	Spot #	R	G	B
1	1	741	480	200
1	2	735	475	201
1	3	731	473	197
2	1	765	500	229
2	2	759	501	233
2	3	749	494	227
3	1	729	471	201
3	2	728	468	199
3	3	734	475	201
4	1	738	481	202
4	2	736	478	199
4	3	744	484	203
5	1	727	464	191
5	2	727	464	192
5	3	723	459	189
6	1	727	467	194
6	2	727	469	197
6	3	736	473	197
7	1	739	479	199
7	2	736	476	199
7	3	738	477	199
8	1	994	820	481
8	2	996	819	478
8	3	985	810	473
9	1	743	476	199
9	2	738	473	195
9	3	736	471	198
10	1	722	471	232
10	2	735	480	235
10	3	732	477	235
11	1	749	479	203

Envelope #	Spot #	R	G	B
11	2	743	475	200
11	3	738	474	202
12	1	761	491	205
12	2	760	489	204
12	3	752	485	204
13	1	779	512	238
13	2	781	516	240
13	3	790	522	244
14	1	1009	845	492
14	2	1010	843	489
14	3	1000	840	487
15	1	736	479	209
15	2	732	475	208
15	3	741	484	213

Table 12. RGB values obtained for the three spots measured in the envelopes selected for the blind study

Alternate Light Sources

ALS was not conducted because the technique was not able to provide any association to brands.

Physical measurements

Tables 13 and 14, respectively, show the results obtained from the measurements of the dimensions and the weights of the blind study envelopes.

Envelope #	Envelope width (cm)	Envelope length (cm)	Flap upper width -w/lift flap (cm)	Flap height (cm)	Lower flap upper width (cm)	Lower flap height (cm)	Adhesive 1 width (cm)	Adhesive 1 height (cm)	Adhesive 2 width (cm)	Adhesive 2 height (cm)	Clasp closure hole diameter (cm)
1	22.90	30.32	20.50	3.78	21.75	2.15	7.58	1.88	7.65	1.90	0.94
2	22.34	30.50	20.50	3.58	21.75	2.18	7.46	1.84	7.50	1.88	0.92
3	22.70	30.45	20.30	3.75	21.75	2.02	7.35	1.82	7.50	1.85	0.90
4	22.85	30.55	20.60	4.18	20.90	2.80	17.90	2.30	--	--	0.85
5	22.65	30.65	20.25	3.50	20.35	2.84	19.10	0.90	--	--	No clasp
6	22.82	30.42	20.58	3.70	21.68	2.20	7.70	1.85	7.60	1.90	0.92
7	22.90	30.55	20.62	3.78	21.80	2.00	7.60	1.90	7.60	1.93	0.90
8	22.62	30.60	19.96	3.62	19.70	2.64	8.00	2.40	8.04	2.40	0.92
9	22.88	30.52	19.20	4.38	20.40	2.38	7.80	2.40	7.30	2.40	No clasp
10	23.10	30.60	20.98	3.70	21.20	2.28	16.80	2.40	--	--	0.92
11	22.75	30.5	20.3	3.78	21.8	2.05	7.48	1.8	7.5	1.8	0.9
12	22.84	30.55	20.65	4.00	20.80	2.80	17.85	2.28	--	--	0.85
13	22.80	30.50	20.50	3.68	21.80	2.18	7.65	1.84	7.60	1.84	0.92
14	22.68	30.55	20.15	3.55	19.98	2.20	8.00	2.50	8.00	2.45	0.92
15	23.05	30.60	20.90	3.75	21.00	2.30	16.65	2.40	--	--	0.92

Table 13. Dimensions obtained after measurements of envelopes 1 through 15 were taken

Envelope #	Weight 1 (g)	Weight 2 (g)	Weight 3 (g)	Weight Average (g)
1	17	17	17	17
2	16	16	16	16
3	16	17	16	16
4	17	18	18	18
5	17	17	18	17
6	17	16	17	17
7	19	19	19	19
8	20	19	19	19
9	16	17	17	17
10	15	15	15	15
11	17	17	18	17
12	17	18	18	18
13	18	17	18	18
14	20	20	20	20
15	15	16	16	16

Table 14. Results of the weights obtained for blind study envelopes 1 through 15

The thickness measurements of the envelopes, taken in triplicate at three different locations, is shown in Table 15.

Envelope #	Spot	Thickness (mm)		Envelope #	Spot	Thickness (mm)
1	1	0.15		8	3	0.17
1	2	0.15		9	1	0.14
1	3	0.15		9	2	0.14
2	1	0.15		9	3	0.14
2	2	0.15		10	1	0.13
2	3	0.15		10	2	0.13
3	1	0.16		10	3	0.13
3	2	0.15		11	1	0.15
3	3	0.15		11	2	0.15
4	1	0.14		11	3	0.16
4	2	0.14		12	1	0.14
4	3	0.15		12	2	0.15
5	1	0.15		12	3	0.16
5	2	0.14		13	1	0.13
5	3	0.15		13	2	0.15
6	1	0.15		13	3	0.16
6	2	0.15		14	1	0.16
6	3	0.15		14	2	0.17
7	1	0.18		14	3	0.17
7	2	0.17		15	1	0.12
7	3	0.17		15	2	0.14
8	1	0.17		15	3	0.13
8	2	0.17				

Table 15. Thickness measurements obtained for the three spots measured on each of the blind study envelopes

Chemical Examination

The chemical analysis of the envelopes from the blind study were completed with those in the new box study, and the results will be presented together in the next section of this thesis.

4.4 New Boxes

Physical Examination

After visual examination of the 5 envelopes, the results of the physical feature determination are shown in Table 16.

Envelope #	Brand	Type of clasp	# of adhesive strips	Imprinted brand
16	B	I	2	No
17	C	II	2	No
18	D	I	2	No
19	E	IV	1	No
20	F	II	2	No

Table 16. Physical features observed in the new boxes

Color analysis

Table 17 shows the values obtained for channels R, G and B in the three spots examined from every envelope.

Envelope #	Spot #	R	G	B
16	1	739	472	194
16	2	740	470	193
16	3	741	472	192
17	1	745	478	199
17	2	741	474	196
17	3	734	471	195
18	1	758	490	211
18	2	762	494	211
18	3	755	490	214
19	1	738	465	218
19	2	737	461	212
19	3	741	470	222
20	1	752	487	206
20	2	747	482	194
20	3	751	486	206

Table 17. Color analysis of new boxes

Physical measurements

Table 18 shows the results obtained from the measurements of the dimensions and the weights of the new box study envelopes.

Envelope #	Envelope width (cm)	Envelope length (cm)	Flap upper width - w/lift flap (cm)	Flap height (cm)	Lower flap upper width (cm)	Lower flap height (cm)	Adhesive 1 width (cm)	Adhesive 1 height (cm)	Adhesive 2 width (cm)	Adhesive 2 height (cm)	Clasp closure hole diameter (cm)
16	22.80	30.50	19.90	3.80	19.46	2.35	7.92	3.10	7.84	3.00	0.98
17	22.65	30.35	18.35	4.10	20.45	2.50	7.80	1.90	7.85	1.96	0.95
18	22.85	30.65	19.30	3.80	19.40	2.35	7.90	3.20	7.80	3.18	0.98
19	22.85	30.60	20.80	3.80	21.35	2.18	16.7	2.55	--	--	0.88
20	22.90	30.50	20.35	3.64	20.90	2.64	7.20	2.20	8.10	2.25	0.95

Table 18. Dimensions obtained for the new box of envelopes 16-20

Table 19 shows the weights taken in triplicate and the weight average of the envelopes from the new boxes.

Envelope #	Weight 1 (g)	Weight 2 (g)	Weight 3 (g)	Weight Average (g)
16	17	16	17	17
17	16	17	17	17
18	17	17	18	17
19	19	20	20	20
20	16	17	17	17

Table 19. Results of the weights obtained for new box envelopes 16-20

The thickness measurements of the envelopes, taken in triplicate at three different locations, is shown in Table 20.

Envelope #	Spot #	Thickness (mm)
16	1	0.14
16	2	0.14
16	3	0.14
17	1	0.14
17	2	0.14
17	3	0.14
18	1	0.13
18	2	0.14
18	3	0.13
19	1	0.16
19	2	0.16
19	3	0.16
20	1	0.14
20	2	0.15
20	3	0.14

Table 20. Thickness measurements obtained for the three spots measured on each of the envelopes from the new boxes

Chemical examination

The results of the chemical examinations of the envelopes for both the blind study (Blind01 through Blind15), and the new boxes (Blind16 through Blind20) are shown below because their analysis was completed together.

Attenuated Total Reflection Fourier Transform Infrared (ATR FT-IR) Spectroscopy

Twenty (20) FT-IR spectra were collected for the blind study and the new boxes purchased. The infrared spectra obtained for every one of them is shown in Figure 29 and Figure 30.

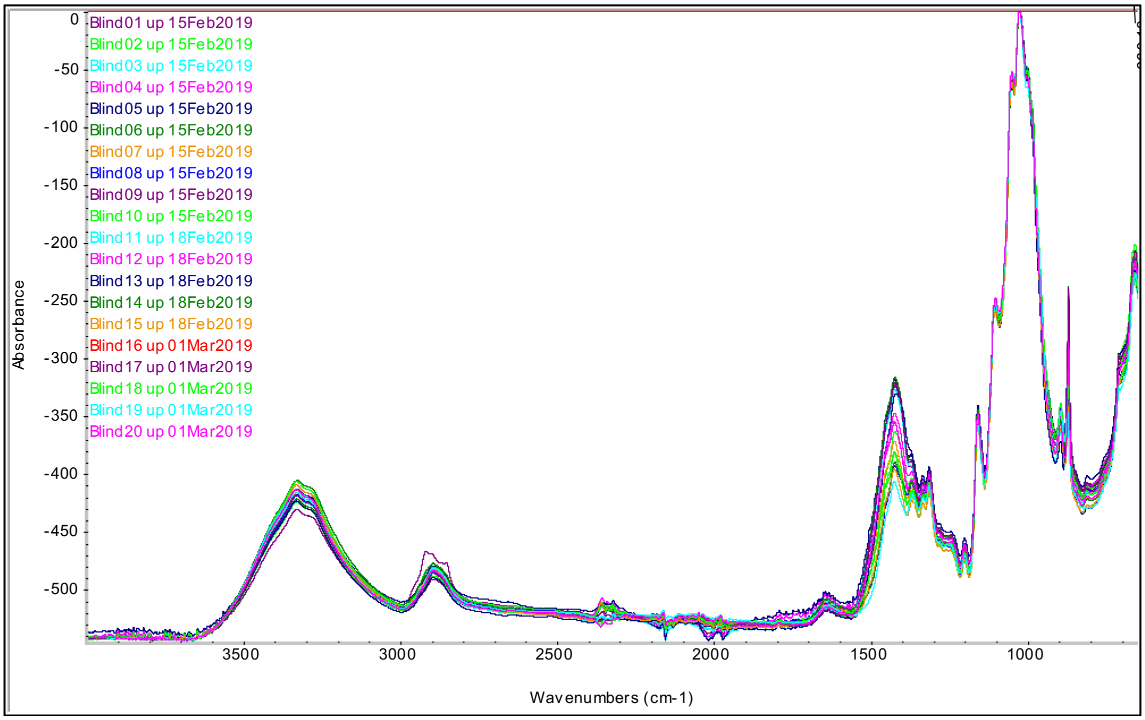


Figure 29. Overlaid FT-IR spectra obtained for the 20 samples analyzed for the blind study and the 5 new boxes

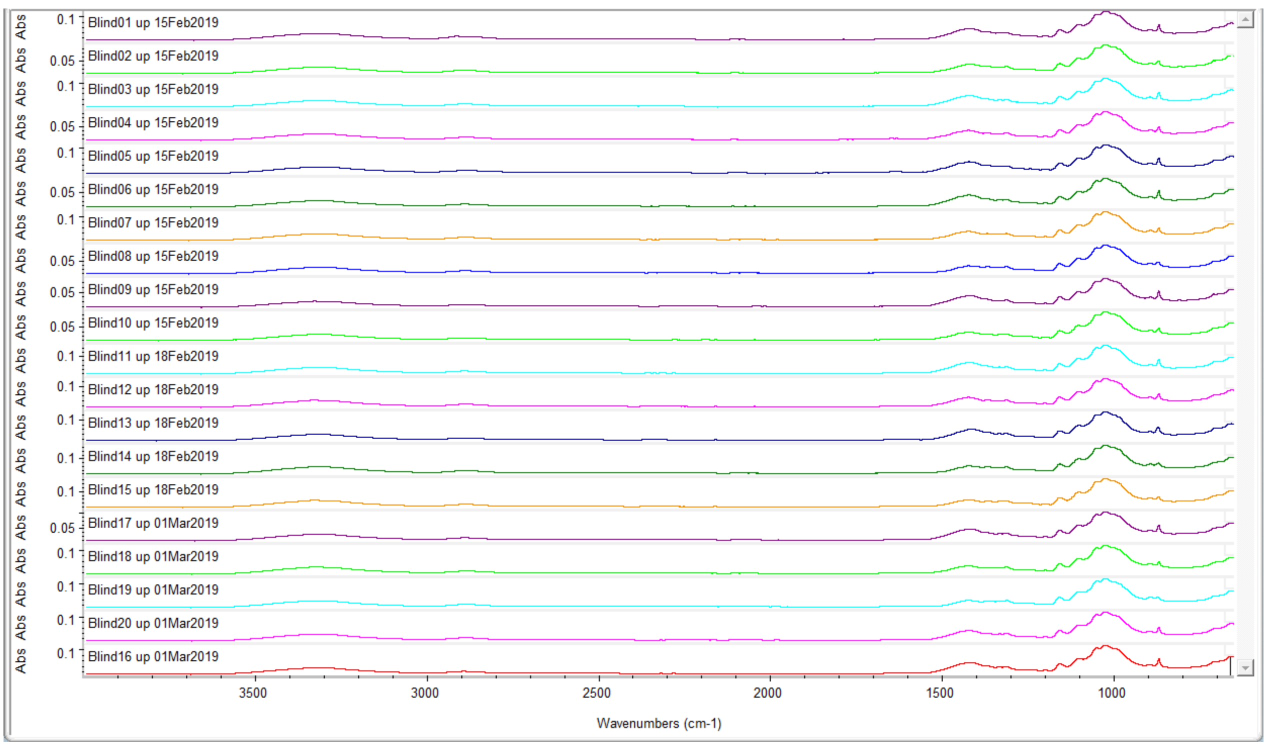


Figure 30. Stack FT-IR spectra obtained for the 20 samples analyzed for the blind study and the 5 new boxes

The FT-IR spectra were chemometrically analyzed with PLSDA. Figure 31 shows the blind samples classification within the 4 different groups obtained in the FT-IR analysis of the ten brands.

Blind samples 01 to 15 were all correctly identified within their groups. Blind17 was correctly assigned to group 3 (brands C, D, E, G, H and J), whereas Blind16 was assigned to group 4 (brands F and I), Blind18 appears in groups 1 (brand A) and group 3, Blind19 to group 1 and Blind 20 was assigned to group 3.

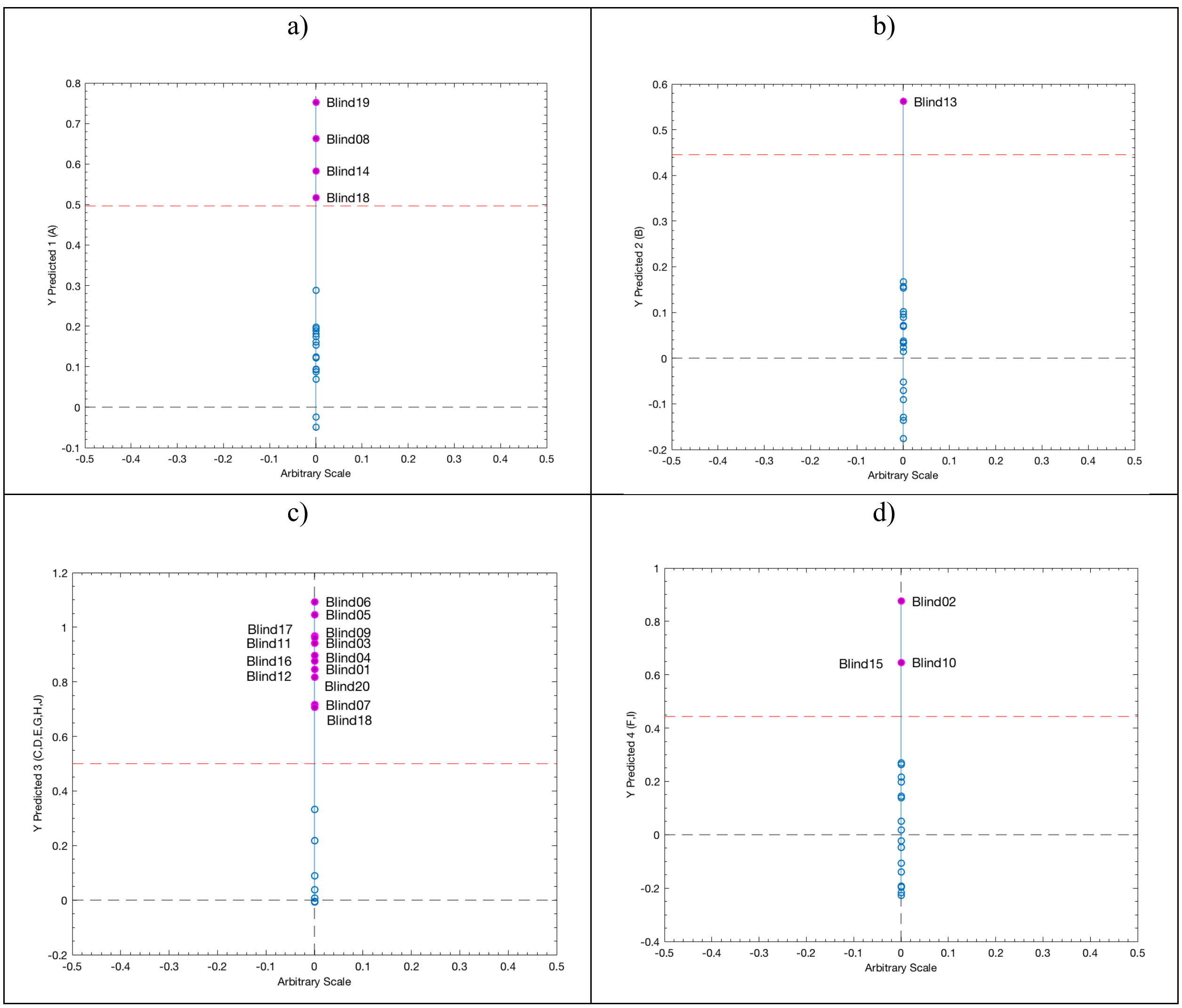


Figure 31. PLSDA prediction of the 20 blind samples within a) group A, b) group B, c) group CDEGHJ, and d) group FI

Raman spectroscopy

The 20 Raman spectra obtained for every samples is shown in Figure 32.

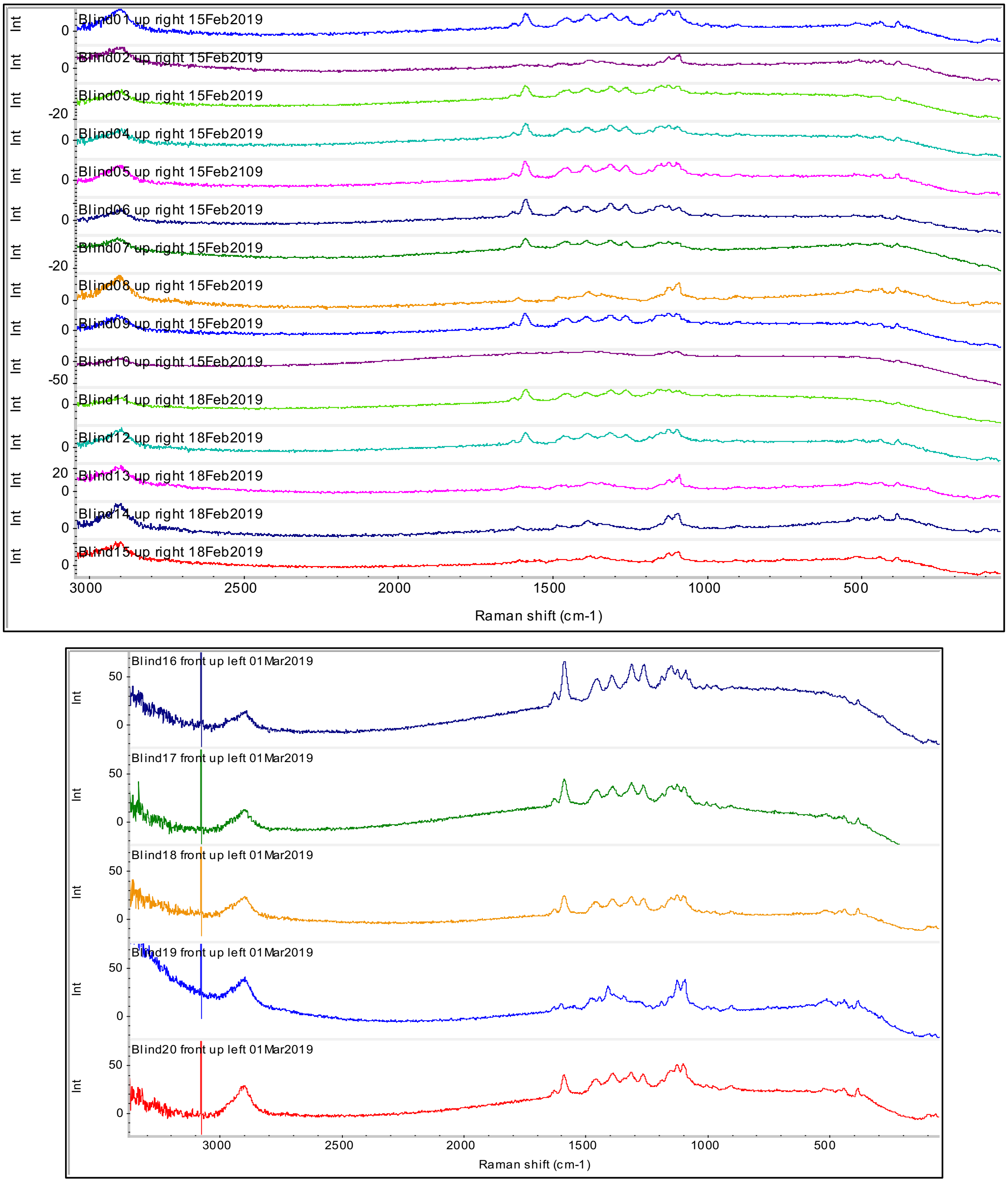


Figure 32. Top image shows Raman spectra collected from Blind 01 to 15. Bottom image shows Raman spectra collected from Blind 16 to 20

The obtained spectra were analyzed with PLSDA. Blind samples 01 to 10 were all correctly assigned. Blind13, Blind14 and Blind 15 were classified in two classes, one of which was correct, and Blind16 and Blind19 were misclassified. The rest of the samples were correctly identified, where Blind08 and Blind14 were attributed to group 1 (brand A), Blind13 to group 2 (brand B), Blinds 2, 8 and 10 to group 3 (brands F and I), and Blinds 1, 3, 4, 5, 6, 7, 9, 11, 12, 17, 18 and 20 to group 4 (brands C, D, E, G, H and J). These results can be seen in the plots shown in Figure 33.

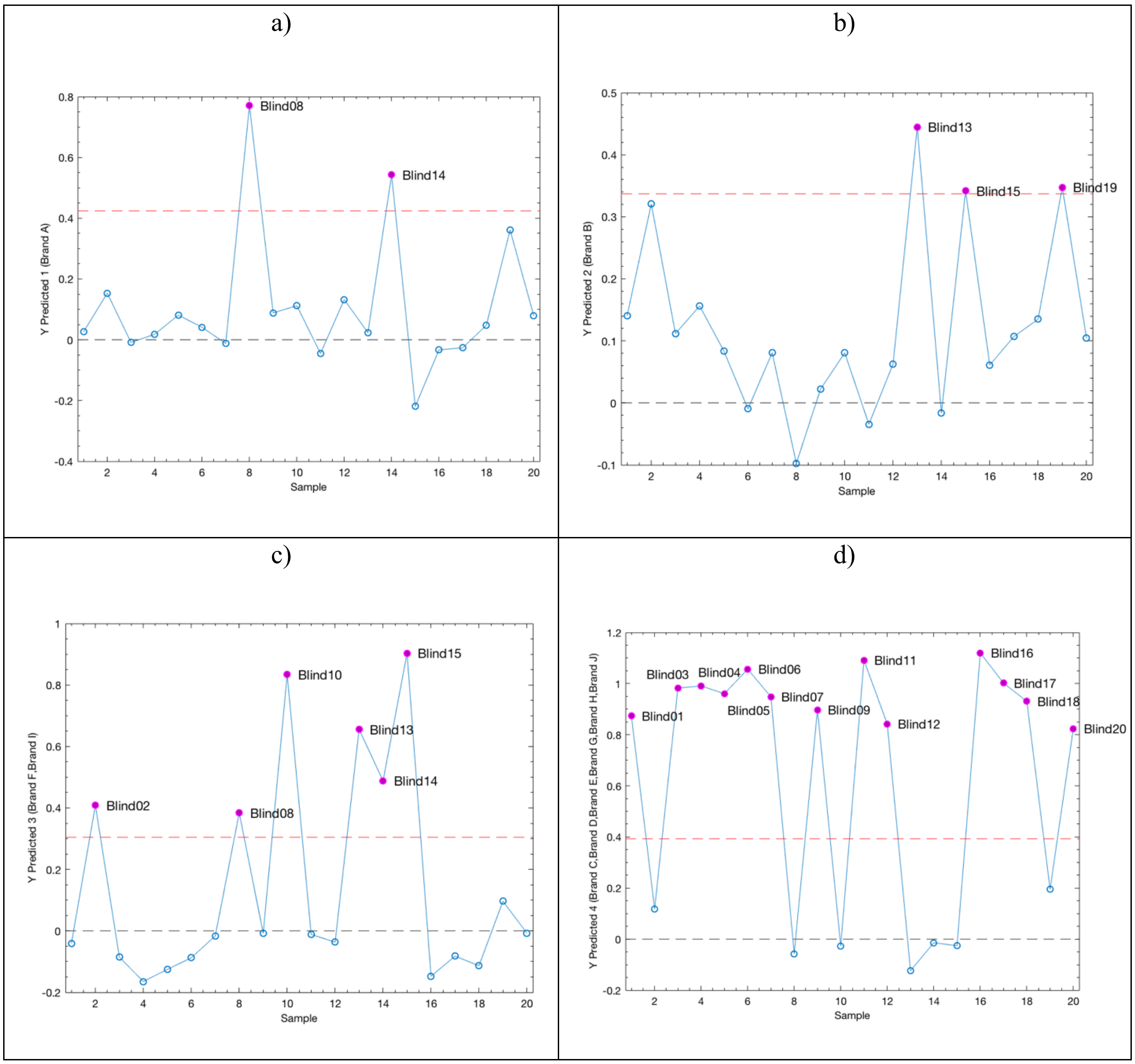


Figure 33. PLSDA plots of the 20 blind samples´ assignment to the four different groups

5. DISCUSSION AND CONCLUSIONS

The purpose of this study was to determine if there are meaningful physical and chemical differences between manila envelopes from different brands, as determined by analytical methods commonly used for paper analysis, that can be used for differentiation, Additionally, intra-brand and intra-box differentiation was investigated.

5.1 Physical Examination

After the examination of the physical features in the 10 brands of manila envelopes, that is, by determining if a clasp was present or not, the clasp type, the number of adhesive strips, and if the brand was imprinted or not in the envelope, brands A, D, G, H, I, and J could be physically differentiated from all other envelopes. However, brands B, C, E, and F could not. This resulted in 7 different classes of envelopes based on the physical features. In the event that the brand's name had not been imprinted in envelope D, this brand could have not been differentiated either and it would have been included in the group of undistinguishable brands.

After the measurement of the RGB values in all brands, those belonging to the above mentioned undistinguishable ones from the physical feature determination, that is, brands B and F could be differentiated. Thus, 8 out of the 10 brands were able to be distinguished from each other based on a combination of their physical features and color values. Brands C and E had some overlapping ranges of color values and, therefore, could not be differentiated. If the brand on D had not be imprinted, D could not have been differentiated from C and E by their values of color, as it can be seen in Table 6 and in the histograms shown in Figures 15 and 16.

For the color measurements alone, four groups can be distinguished by looking at the histograms in Figures 15 and 16: group 1 includes brand A, group 2 is composed of brands C, D, E, G, H, and J and group 3 of B, F and I. Due to the differences within the brand, Brand I belongs in two groups. Box 1 is split between groups 2 and 3, while Boxes 2 and 3 fit within group 2. The histograms for the R, G and B values are indistinguishable within a group, but can be differentiated from the other groups.

From Table 6 and Figure 15, it can be seen that brand I was the only one within this research that showed different intra-brand variation, with differences in the ranges of values between box 1 and boxes 2 and 3. Boxes 2 and 3 showed RGB values within a certain similar range, however box 1 presented a different range of values from the other two boxes. Within box 1 from brand I, intra-box variation was demonstrated, with the first two envelopes having different color values from the last three. This demonstrates that there can be differences between envelopes within a box that are produced during the manufacturing or packaging process. Of note, there were no intra-box nor intra-brand variability among the physical features in this brand. That could mean that the ream of paper was changed but not the template used during the manufacturing process.

ALS showed limited value in discriminating between brands of envelopes. It could be useful for comparing the reflectivity of a questioned and known manila envelope, however, this examination must be performed with caution because the relative intensities might decrease with the age of the paper and its exposition to light (27). On the other hand, it could also be useful if a watermark, scratches, indentation, or other characteristics not visible with the naked eye were present and could be visualized with this type of light sources.

There are meaningful differences in the physical measurements of manila envelopes from different brands. The histograms shown in the results (Figures 18, 19 and 20, and Tables 7, 8 and 9) illustrate the many differences that can occur between brands regarding the dimensions measured, weight, and thickness of the manila envelopes. In fact, brands C and E could now be differentiated by their weight and thickness. Additionally, if brand D had not had the brand imprinted, it could be distinguished at this point from brands C and E by its dimensions. Now, all 10 brands can be totally distinguishable. This demonstrates the ability of physical measurements to differentiate between different brands of manila envelopes.

Note that the results regarding the weight of the envelopes comes from unused envelopes. If envelopes are mailed, any stamp or adhesive glued will add weight to the questioned sample, thus complicating use of this method for use in brand identification.

Ultimately, all brands of manila envelopes were able to be differentiated by a complete physical examination which included examination of physical features, color, dimensions, weight and thickness.

5.2 Chemical Examination

The average ATR FT-IR spectra shown in Figure 21 for the ten brands does not, visually, show significant differences. However, after the collection of all the data, due to the high number of values obtained from the 600 individual spectra samples, a statistical analysis was carried out using Principal Component Analysis. The results obtained from this analysis can be seen in Figure 22, which shows the scores plot of the spectra analyzed. Brands A and B can be clearly differentiated

from the rest of the brands, whereas some of the values of brand I fall within the range of F, and the rest of the brands (C, D, E, G, H and J) appear separate forming another group. Therefore, four different groupings can be identified and, thus, these differences can be useful for inclusions or exclusions when comparing a questioned with a known manila envelope.

PCA of the FT-IR spectra also showed the intra-brand variation for Brand I, with two distinct clusters of Brand I data (as represented by pink diamonds in Figure 22). The larger cluster was from the FT-IR spectra of boxes 2 and 3, and the smaller cluster was from box 1.

FT-IR spectral interpretation was completed to identify the components present in the samples (Figure 23). Unsurprisingly, cellulose peaks (28,29) were found in all samples, as identified using the peaks at ~ 2900, 1420, 1365, 1315, 1155, 1105, and 898 cm^{-1}. Calcite was identified in all brands using the strong peaks at 871 cm^{-1} and 711 cm^{-1}, followed by a weak peak at 1795 cm^{-1}. Neither talc, rutile nor kaolinite were detected in any of the brands, as identified by ATR FT-IR spectroscopy. Either they were not present, or they were below the limit of detection of this method (~10%).

The average Raman spectra for each brand is shown in Figure 24, and there are observable differences between brands. Using PCA, the scores plot (Figure 25) shows that there are 3 distinct groups: Group 1 consists of brand A, Group 2 includes brands B, F and I, and Group 3 contains the rest of the brands, that is, C, D, E, G, H and J. These groups are effectively the same as those from the FT-IR data, with the exception being that brand B was able to be separated from brands F and I using FT-IR. However, PLSDA on the Raman spectra (Figure 26) was able to separate brand B from F and I, although the separation was not as effective as that obtained with the PCA analysis of the FT-IR data.

Raman spectral interpretation was completed to identify the components present in the samples (Figure 27). Several peaks that correspond to calcite (1085, 711 and 281cm^{-1}) were present in all brands. Neither talc, anatase nor rutile were detected. Kaolinite peaks could not be determined as no database was found where the same excited wavelength of 780 nm was used.

Ultimately, both ATR FT-IR and Raman spectroscopy have the potential to be used by criminalists in casework involving manila envelopes to include or exclude questioned envelopes, but not necessarily for brand identification.

XRF is a method that performs a quantitative elemental analysis of the samples, in this case on the paper of the manila envelopes. After the analysis of 600 samples (Table 10), it can be determined that all brands contain calcium (Ca) and sulfur (S) and the results can be grouped into three categories. The first category is that whose brands contain only Ca and S as elements of interest, that is, brands A, C, D, E, G, H and J. Next, the second category has Ca, S, silicon (Si) and aluminum (Al) as elements of interest and the brands that can be included here are B and I. Finally, the third category includes brand F, which has Ca, S, Si, Al and titanium (Ti) as main elements.

No intra-box nor intra-brand variation was found on brands A, B, C, D, F, G and J. Brand E showed little consistency between samples within the same boxes and between boxes, and so did brand H, although box 3 in brand H presented higher calcium counts than the other two boxes. And, finally, brand I showed differences between samples I-1-1 and I-1-2 with regards to the rest of the samples, as well as differences between box 1 and the other two boxes. Boxes 2 and 3 showed no differences between them, though. These differences were already noted when color analysis was performed. These results demonstrate the elemental variability in manila envelopes. It was also noted by the analyst at the Secret Service that "*in paper manufacturing it's common to mix sheets from different*

paper making cycles into a single packaged ream of paper. It's also possible to mix pulps from different batches/manufacturers/recyclers to make the paper before it is packaged or cut. This may explain differences within boxes and box-to-box variations".

By examining the XRD data from all brands (with averages shown in Figure 28), there were no observable differences between brands. The common sizing/coating materials usually found on paper (Calcite, Talc, Kaolinite, Anatase and Rutile) were looked for within the diffractograms of the manila envelopes. The only identified chemical compound that was present in all the samples was Calcite ($CaCO_3$). Peaks at 2-theta angles of approximately 29.4, 39.4 and 43.2 degrees were present in all brands, and some of them, such as brands D, H, I and J showed also a peak at 36.0 degrees and brand F a peak at 47.6, whereas brands A and B presented both of those peaks as well. Thus, there were no visible differences in the results within boxes, between boxes and between manufacturers. Cellulose peaks were also found at approximately 15 and 23 degrees (29) in all brands.

Although visual analysis of the diffractograms was not successful for the discrimination of manila envelopes, it is possible that a multivariate statistical data analysis (e.g. PCA) might prove useful.

5.3 Blind and New Box Studies

First, a macroscopic analysis of the physical features was carried out for the examination of the 15 blind study envelopes. Based on the examination of the type of clasp, the number of adhesive strips and the brand imprint, 10 out of the 15 envelopes were able to be brand identified. These 10 envelopes were determined to belong to the following brands: 1 and 6 correspond to brand D, 4

and 12 to brand H, 5 to brand G, 8 and 14 to brand A, 9 to brand J, and 10 and 15 to brand I. The rest of the envelopes, that is, 2, 3, 7, 11 and 13 could be classified as belonging to any of the following brands: B, C, E, or F. The other five were narrowed down to belonging to either brand B, C, E, or F. The correlation of envelopes to the brands can be seen in Table 11. As that table shows, all types of clasps were found in the blind study, as well as envelopes with no clasp attached. Out of the fifteen envelopes, two of them showed clasp type I, seven showed clasp type II, two had clasp type III, two showed clasp type IV, and two had no clasp. In regards to the number of adhesive strips, envelopes 4, 5, 10, 12 and 15 presented one single strip, whereas the rest of the envelopes showed two strips. Additionally, the brand was clearly imprinted in the bottom of the back of envelopes 1 and 6.

Next, a color analysis was conducted in order to possibly determine to which of these four brands (B, C, E and F) the unknown envelopes (2, 3, 7, 11 and 13) belonged to, as well as to try to determine which of the boxes of brand I envelopes 10 and 15 came from. Color comparison with the color measurements in the previous section of the 150 envelopes (see Tables 6 and 12) determined that envelope number 2 was consistent with that of brand F, envelopes 3 and 7 were consistent with either brands C or E, envelope 11 was consistent with brand E, and envelope 13 with brand B. Moreover, envelope 10 could have come either from box I-2 or I-3, but not from I-1 and envelope 15 was consistent with box I-1.

Envelopes 3 and 7 were then compared to the thickness and weight of the brands C and E previously measured in the experiment, and it was found that envelope 3 was consistent with the weight and thickness of brand C, and envelope 7 was consistent with weight and thickness of brand E.

These results were all consistent with the chosen envelopes for this study, except for envelope 11, which was not picked from brand E but from brand C. At this time, the reason for the brand mis-identification is unknown. There is no obvious reason as why this could have happened, except that this was one of the envelopes sent through the mail. Because it was primarily the color analysis that was used to differentiate brands E and C, a possible explanation is that the envelope could have been exposed to sunlight or UV radiation while in the custody of the postal service that affected its coloration. Or that it was x-raid by the postal service, which melts plastics and could cause changes in the paper color. Another possible explanation is that this envelope was different from those 15 that were randomly chosen to represent this brand, and the intra-brand variation was just not captured in the learning set. However, when looking at the dimensions of the different parts of the envelope and comparing them to the one obtained for the major study, most of the dimensions are consistent with those of brand C. This could be due to the manufacturer sub-contracting another supplier or simply by them buying already made envelopes from the other company and selling them as their own, which could happen if they were low on supplies and needed to fill a large order.

For the blind study, box identification was not attempted because there was no intra-brand variation observed during this research, except for with brand I. The blind study was able to correctly box identify envelopes 10 and 15 because they came from Brand I. This intra-brand variation can be used by criminalists to increase the evidentiary significance of a manila envelope association.

In regards to the new boxes, these presented different physical features than the previously purchased boxes from the same brands. Envelopes 16, 17, 18, 19 and 20 correspond to the new

boxes of brands B, C, D, E and F, respectively. Envelopes 16 and 18 presented clasp type I, 17 and 20 showed clasp type II and envelope 19 type IV. Envelopes 16, 17, 18 and 20 presented two adhesive strips, and only 19 had one. None of the envelopes from the new boxes had the brand imprinted. This included envelope 18, which came from brand D, which had brand imprinting on the envelopes from the original boxes. Therefore, by just looking at the type of clasp, the number of adhesives and if the brand was imprinted or not, envelopes 16 and 18 presented the same characteristics as brand A's original boxes, envelopes 17 and 20 appeared to be the same as the original boxes of brands B, C, E and F, and envelope 19 the same as the original I boxes. Once the color was analyzed, envelopes 16 and 18 presented a different color than brand A and, therefore, were inconsistent with their previous boxes. In envelope 17, R and G values were higher than the original boxes and in envelopes 19 and 20, the G and B values were lower than the original ones. On the other hand, the weight values of the five envelopes were within the ranges of their respective brands. However, regarding the thickness, only envelope 16 fell into the range of brand B, envelopes 17, 18 and 19 presented lower values than brands C, D and E, respectively, and envelope 20's spot 2 showed a thickness within the range of brand F but the other two spots fell out of such range. A detailed comparison of the physical features and measurements is shown in the comparison Tables 21, 22, 23, and 24. Thus, the boxes from the same brands and model numbers purchased at a later date were different to the originally purchased boxes in the many of the examined physical features and measurements.

Envelope #	Clasp Type	# of adhesive strips	Imprinted brand	Original box envelope #	Clasp Type	# of adhesive strips	Imprinted brand
16	I	2	No	B	II	2	No
17	II	2	No	C	II	2	No
18	I	2	No	D	II	2	Yes
19	IV	1	No	E	II	2	No
20	II	2	No	F	II	2	No

Table 21. Comparison of the physical features between the new and the original boxes

Envelope #	R	G	B	Original box envelope #	R	G	B
16	739-741	470-472	192-194	B	761 – 768	506 – 521	235 – 244
17	734-745	471-478	195-199	C	716 – 733	459 – 471	191 – 199
18	755-762	490-494	211-214	D	716 – 734	458 – 472	188 – 199
19	737-741	461-470	212-222	E	727 – 746	467 – 484	191 – 204
20	747-752	482-486	194-206	F	744 – 766	491 – 513	223 – 236

Table 22. Comparison of the R, G, and B values between the new and the original boxes

Envelope #	Weight (g)	Thickness (mm)	Original box envelope #	Weight (g)	Thickness (mm)
16	16 - 17	0.14	B	16 - 17	0.13 – 0.15
17	16 - 17	0.14	C	16 - 17	0.15 – 0.16
18	17 - 18	0.13 - 0.14	D	17 - 18	0.15 – 0.16
19	19 - 20	0.16	E	18 - 20	0.17 – 0.18
20	16 - 17	0.14 - 0.15	F	16 - 17	0.15 – 0.16

Table 23. Comparison of the weight and the thickness between the new and the original boxes

Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
16	22.80	30.50	19.90	3.80	19.46	2.35	7.92	3.10	7.84	3.00	0.98
17	22.65	30.35	18.35	4.10	20.45	2.50	7.80	1.90	7.85	1.96	0.95
18	22.85	30.65	19.30	3.80	19.40	2.35	7.90	3.20	7.80	3.18	0.98
19	22.85	30.60	20.80	3.80	21.35	2.18	16.7	2.55	--	--	0.88
20	22.90	30.50	20.35	3.64	20.90	2.64	7.20	2.20	8.10	2.25	0.95
B	22.89	30.52	20.62	3.75	21.80	2.13	7.68	1.90	7.67	1.89	0.93
C	22.82	30.54	20.37	3.76	21.85	2.02	7.44	1.91	7.53	1.90	0.89
D	22.96	30.44	20.80	3.74	21.77	2.19	7.76	1.90	7.70	1.90	0.92
E	22.85	30.55	20.78	3.72	21.78	2.12	7.73	1.90	7.67	1.90	0.91
F	22.89	30.52	20.44	3.75	21.91	2.03	7.46	1.91	7.55	1.93	0.91

Table 24. Comparison of the physical measurements between the new and the original boxes

The blind study results from the chemical analysis with ATR FT-IR showed that blind samples 01 to 15 were all correctly identified. However, the new boxes presented differences in regards to the original boxes. Only Blind17 was properly identified as to belonging to Group 4, Blind 16, 19 and 20 were misclassified and Blind18 showed multiple classifications. These results are shown in Figure 31.

After Raman analysis (see Figure 33), samples Blind01 to 10 were all correctly identified within their respective groups. Blind13, 14 and 15 were assigned to two different groups, Blind 16 and 19 were wrongly identified and the rest were properly assigned to their groups.

5.4 Conclusions

This study has demonstrated the ability of physical examination for the brand identification of manila envelopes. Of particular value for brand identification is characterization of the type of

clasp, the number of adhesive strips, and the imprinted brand, or any other visual aspect of the envelope (e.g., the form of the flaps) and the examination of the color or RGB values. Other analytical methods examined in this research (ALS, physical measurements, ATR FT-IR spectroscopy, Raman spectroscopy and XRF) have value for inclusions or exclusions, but were not capable of brand identification. However, if any part of the envelope is missing, such as the clasp and/or the flap, or if only a small portion of the envelope is recovered (i.e., in the case of mail bombings), these techniques can be useful in the discrimination process of a forensic examination. XRD did not show the ability to differentiate the different brands of manila envelopes examined in this research. Ultimately, it was shown that by using traditional forensic analysis methods, the ten purchased brands demonstrated a high level of variability that would enable the comparison of a questioned to a known set of manila envelopes. Thus, if an envelope found at a crime scene is compared to the ones found in a box at a suspect's home, it should be possible to include or exclude the questioned envelope to the box found, which has the potential to add significant value beneficial to an investigation.

Differences were found within a box and between boxes within the same brand. This indicates intra-box and intra-brand variation, which can increase the evidentiary significance of questioned manila envelopes. Although the occurrence of intra-box variability was quite small (in this study, it only occurred in one of the 30 boxes purchased), it is important to take this into consideration when analyzing known samples. Thus, different envelopes from the same box should always be analyzed.

The results of this research demonstrated that examining the physical features should be the first step in an analytical protocol of the forensic analysis of manila envelope. A physical examination

of the physical features (the type of clasp, number of adhesive strips, brand impression, the form of the upper and/or lower flap, and a color analysis) was shown to be highly discriminating, less time consuming, and required less resources. Physical measurements should be the next step followed by an instrumental and chemical analysis of the envelopes, making use of the ATR FT-IR spectrometer and/or the Raman spectrometer. ATR FT-IR spectroscopy is recommended over Raman spectroscopy because, although both were able to distinguish the same number of groups among the ten brands, less data analysis was required, the separation in groups was more effective and the time of analysis for each sample was considerably less. If the analyst has access to XRF, this might be useful methods for the confirmation of the results, but did not provide additional discrimination beyond what was already shown using the previously described methods. However, XRF proved to be a good technique to detect intra-box and intra-brand variation, thus it would have value in an investigation.

5.5 Further Research

There is a plethora of additional research involving the characterization and discrimination of manila envelopes. There are other variables to take into consideration that have importance for forensic examination of manila envelopes. For example, the analysis of the adhesives and the inner surface of the paper envelopes (which are often uncoated) could add more information for the discrimination and/or identification of a brand of manila envelopes. The back seam adhesive (i.e., the adhesive that keeps certain areas where the envelope is glued together in the back (30)), on the center and the bottom areas of the envelope, could also be examined and analyzed to determine if it has value for brand or box identification.

Exposing manila envelopes to different environmental conditions, prior to physical and chemical analysis, should be examined. For example, how the physical and chemical characteristics vary when a manila envelope is exposed to water (i.e., rain) or sunlight, should be examined. Moreover, it would be interesting to see how the color values would be affected by other causes, such as aging and photobleaching. Additionally, examination of manila envelopes after latent fingerprint analysis (including the application of powders and/or other enhancement methods), should be explored.

Other analytical methods for analysis should be examined for their discriminating potential with respect to manila envelopes. For example, LIBS and LA-ICP-MS have provided discriminatory results within different brands of paper, thus, applying LIBS to manila envelopes could be useful in forensic discrimination process. Thin Layer Chromatography (TLC) may also give important results in the analysis of dyes or pigments in the paper, and thus has the potential to add value to the comparison of questioned and known samples of manila envelopes.

APPENDIX I

Color Meter PCE-RGB2 Specifications from Manufacturer

- Measuring geometry: circular illumination at 45º, measurement at 0º.
- Spectral range: 400-700 nm.
- Light source: Two white LED lamp.
- Color sensors: 3-color photo transistors (red, green, and blue photo transistors).
- Measurement: R (red) value = 0 to 1023, G (green) value = 0 to 1023, B (blue) value = 0 to 1023.

APPENDIX II

Polystyrene NIST Standard 1921a frequencies

Frequencies (cm^{-1})
842.09
906.85
1028.34
1069.20
1154.62
1583.07
1601.37
2850.14
3026.38
3060.03
3082.14

Table 25. Polystyrene NIST Standard 1921a frequencies for ATR FT-IR analysis

APPENDIX III

Values obtained for the evaluation of signal-to-noise ratio for Raman spectroscopy

Mead envelope

Parameters	Time of exposure (s)	# of exposures	Total time of analysis (s)	Signal (S)	cm^{-1}	RMS Noise (N) (2000-1700 cm-1)	S/N
Laser: 20mW, no photobleach	5	4	20	50.137	1087	2.715	18.46666667
	5	8	40	50.801	1088	1.73671	29.25128548
	5	16	80	64.163	1087	1.13085	56.73873635
	5	32	160	49.922	1087	0.84135	59.33559161
	10	4	40	42.843	1095	1.60931	26.62196842
	10	8	80	42.081	1097	0.89855	46.83211841
	10	16	160	51.601	1097	0.71642	72.02618576
	10	32	320	51.197	1097	0.41756	122.6099243
	20	4	80	44.455	1095	1.09601	40.56076131
	20	8	160	35.552	1096	0.63618	55.88355497
	20	16	320	19.85	1,089	0.41006	48.40267278
	20	32	640	12.12	1095	0.28312	42.80870302
	60	4	240	10.825	1095	0.40353	26.82576264
	60	8	480	12.55	1095	0.26787	46.85108448
Laser: 20mW, photobleach	5	4	20	45.823	1087	2.53047	18.10849368
	5	8	40	63.746	1092	1.72694	36.9126895
	5	16	80	50.501	1087	1.20708	41.83732644
	5	32	160	49.177	1088	0.84716	58.0492469
	10	4	40	42.876	1096	1.37905	31.09096842
	10	8	80	38.975	1095	1.00901	38.62697099
	10	16	160	40.528	1096	0.55963	72.41927702
	10	32	320	49.218	1097	0.39535	124.4922221
	20	4	80	37.796	1095	0.91252	41.41936615
	20	8	160	43.257	1095	0.57626	75.06507479
	20	16	320	17.081	1095	0.43309	39.43983929
	20	32	640	11.433	1095	0.2588	44.17697063
	60	4	240	10.275	1096	0.41503	24.75724646
	60	8	480	11.768	1094	0.29995	39.23320553

Table 26. Values obtained for the evaluation of signal-to-noise ratio for Raman spectroscopy for envelope brand Mead

Staples envelope

Parameters	Time of exposure (s)	# of exposures	Total time of analysis (s)	Signal (S)	cm^{-1}	RMS Noise (N) (2000-1700 cm-1)	S/N
Laser: 20mW, no photobleach	5	4	20	53.834	1087	2.18021	24.6921168
	5	8	40	71.771	1087	1.7215	41.6909672
	5	16	80	61.738	1087	0.93939	65.7213724
	5	32	160	53.661	1087	0.52729	101.767528
	10	4	40	51.876	1087	1.47324	35.2121854
	10	8	80	53.95	1087	0.88649	60.8579905
	10	16	160	60.402	1087	0.5903	102.324242
	10	32	320	56.016	1087	0.3952	141.740891
	20	4	80	44.128	1087	0.75248	58.6434191
	20	8	160	47.456	1087	0.54982	86.3118839
	20	16	320	50.06	1087	0.35426	141.308643
	20	32	640	55.255	1087	0.30307	182.317616
	60	4	240	57.557	1087	0.45367	126.869751
	60	8	480	59.55	1088	0.30385	195.984861
Laser: 20mW, photobleach	5	4	20	76.886	1087	2.18459	35.1947047
	5	8	40	62.156	1087	1.51613	40.9964845
	5	16	80	53.107	1087	0.82213	64.5968399
	5	32	160	53.15	1088	0.62747	84.7052449
	10	4	40	50.741	1087	1.26878	39.9919608
	10	8	80	57.549	1087	0.87022	66.1315529
	10	16	160	49.614	1087	0.57789	85.8537092
	10	32	320	54.588	1087	0.39797	137.166118
	20	4	80	42.043	1087	0.71388	58.8936516
	20	8	160	44.457	1087	0.59869	74.2571281
	20	16	320	48.499	1087	0.35158	137.945844
	20	32	640	58.679	1087	0.24094	243.541961
	60	4	240	57.687	1087	0.43775	131.780697
	60	8	480	66.218	1088	0.31817	208.121445

Table 27. Values obtained for the evaluation of signal-to-noise ratio for Raman spectroscopy for envelope brand Staples

APPENDIX IV

Table of the Raman frequencies for polystyrene

Frequencies (cm^{-1})
620.9
795.8
1001.4
1031.8
1155.3
1450.5
1583.1
1602.3
2852.4
2904.5
3054.3

Table 28. Polystyrene frequencies for Raman analysis (31)

APPENDIX V

Silicon standard card values and parameters

Radiation=CuK_{α}1 Calibration=Internal λ=1.5405982

d(Å)	I(f)	2-Theta
3.1355	100.0	28.443
1.9201	55.0	47.303
1.6375	30.0	56.122
1.3577	6.0	69.132
1.2459	11.0	76.379
1.1086	12.0	88.028

Table 29. Silicon standard card values (32)

APPENDIX VI

Envelopes selected for blind study and summary of results

Blind #	True Class (Brand & Box)	Physical Examination (Brand)	PLS-DA ATR FT-IR (Groups)	PLS-DA Raman (Groups)
01	D1	D	C, D, E, G, H, J	C, D, E, G, H, J
02	F1	F	F, I	F, I
03	C2	C	C, D, E, G, H, J	C, D, E, G, H, J
04	H1	H	C, D, E, G, H, J	C, D, E, G, H, J
05	G3	G	C, D, E, G, H, J	C, D, E, G, H, J
06	D1	D	C, D, E, G, H, J	C, D, E, G, H, J
07	E2	E	C, D, E, G, H, J	C, D, E, G, H, J
08	A2	A	A	A & F, I
09	J1	J	C, D, E, G, H, J	C, D, E, G, H, J
10	I3	I2/I3	F, I	F, I
11 (mailed)	C2	E	C, D, E, G, H, J	C, D, E, G, H, J
12 (mailed)	H2	H	C, D, E, G, H, J	C, D, E, G, H, J
13 (mailed)	B1	B	B	B & F, I
14 (mailed)	A1	A	A	A & F, I
15 (mailed)	I1	I1	F, I	B & F, I
16 (new box)	B4	--	C, D, E, G, H, J	C, D, E, G, H, J
17 (new box)	C4	--	C, D, E, G, H, J	C, D, E, G, H, J
18 (new box)	D4	--	A, & C, D, E, G, H, J	C, D, E, G, H, J
19 (new box)	E4	--	A	B
20 (new box)	F4	--	C, D, E, G, H, J	C, D, E, G, H, J

Table 30. Envelopes selected for the blind study, including brand and box number, and results obtained after physical examination, PLSDA analysis on ATR FT-IR data, and PLSDA analysis on Raman data

APPENDIX VII

RGB values obtained from every brand

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
Staples	A	1	1	1	989	814	472
	A	1	1	2	983	811	475
	A	1	1	3	982	810	471
	A	1	2	1	989	811	471
	A	1	2	2	985	809	474
	A	1	2	3	977	800	465
	A	1	3	1	985	809	474
	A	1	3	2	983	807	470
	A	1	3	3	974	797	462
	A	1	4	1	979	802	467
	A	1	4	2	978	805	473
	A	1	4	3	979	804	466
	A	1	5	1	980	801	466
	A	1	5	2	984	805	469
	A	1	5	3	988	813	477
	A	2	1	1	981	807	476
	A	2	1	2	994	816	478
	A	2	1	3	981	805	472
	A	2	2	1	978	805	471
	A	2	2	2	990	811	474
	A	2	2	3	979	806	472
	A	2	3	1	978	800	466
	A	2	3	2	985	808	474
	A	2	3	3	980	803	469
	A	2	4	1	986	811	478
	A	2	4	2	983	807	474
	A	2	4	3	983	805	473
	A	2	5	1	977	801	467
	A	2	5	2	983	806	474
	A	2	5	3	985	808	476
	A	3	1	1	983	809	476
	A	3	1	2	988	808	476
	A	3	1	3	986	809	474

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	A	3	2	1	984	809	474
	A	3	2	2	999	820	483
	A	3	2	3	980	806	474
	A	3	3	1	987	810	472
	A	3	3	2	986	810	474
	A	3	3	3	987	808	471
	A	3	4	1	984	808	474
	A	3	4	2	992	815	478
	A	3	4	3	989	815	480
	A	3	5	1	992	817	482
	A	3	5	2	986	808	471
	A	3	5	3	989	813	479
WB Mason	B	1	1	1	777	520	243
	B	1	1	2	772	515	241
	B	1	1	3	761	508	238
	B	1	2	1	770	513	240
	B	1	2	2	764	510	237
	B	1	2	3	771	515	241
	B	1	3	1	766	512	238
	B	1	3	2	768	513	240
	B	1	3	3	762	509	236
	B	1	4	1	762	511	238
	B	1	4	2	763	508	236
	B	1	4	3	767	513	240
	B	1	5	1	771	515	239
	B	1	5	2	769	516	242
	B	1	5	3	765	511	239
	B	2	1	1	775	518	243
	B	2	1	2	771	516	239
	B	2	1	3	765	511	239
	B	2	2	1	765	510	237
	B	2	2	2	774	517	240
	B	2	2	3	767	512	240
	B	2	3	1	767	511	240
	B	2	3	2	766	513	237
	B	2	3	3	778	521	244
	B	2	4	1	771	513	240

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	B	2	4	2	766	511	238
	B	2	4	3	774	516	242
	B	2	5	1	763	509	237
	B	2	5	2	762	507	235
	B	2	5	3	769	514	240
	B	3	1	1	762	511	237
	B	3	1	2	763	508	237
	B	3	1	3	772	515	240
	B	3	2	1	763	509	238
	B	3	2	2	765	511	238
	B	3	2	3	763	511	239
	B	3	3	1	761	506	236
	B	3	3	2	771	514	239
	B	3	3	3	769	514	240
	B	3	4	1	769	515	242
	B	3	4	2	765	510	237
	B	3	4	3	768	514	239
	B	3	5	1	769	513	241
	B	3	5	2	767	512	238
	B	3	5	3	766	513	241
Office Depot	C	1	1	1	728	469	197
	C	1	1	2	722	463	195
	C	1	1	3	721	463	192
	C	1	2	1	719	461	194
	C	1	2	2	722	462	193
	C	1	2	3	726	468	196
	C	1	3	1	720	463	192
	C	1	3	2	726	467	196
	C	1	3	3	721	463	191
	C	1	4	1	719	459	191
	C	1	4	2	724	464	197
	C	1	4	3	722	463	192
	C	1	5	1	719	461	191
	C	1	5	2	728	467	196
	C	1	5	3	733	471	197
	C	2	1	1	722	463	193
	C	2	1	2	721	462	193

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	C	2	1	3	719	462	194
	C	2	2	1	721	465	195
	C	2	2	2	728	466	195
	C	2	2	3	719	462	194
	C	2	3	1	730	469	196
	C	2	3	2	722	462	193
	C	2	3	3	722	464	193
	C	2	4	1	716	459	194
	C	2	4	2	718	461	192
	C	2	4	3	722	463	194
	C	2	5	1	722	461	192
	C	2	5	2	720	464	197
	C	2	5	3	723	464	193
	C	3	1	1	733	471	199
	C	3	1	2	723	463	193
	C	3	1	3	732	470	198
	C	3	2	1	723	465	195
	C	3	2	2	721	461	195
	C	3	2	3	723	464	193
	C	3	3	1	725	467	195
	C	3	3	2	728	467	196
	C	3	3	3	723	464	193
	C	3	4	1	725	466	195
	C	3	4	2	728	466	195
	C	3	4	3	720	462	193
	C	3	5	1	725	466	194
	C	3	5	2	720	460	193
	C	3	5	3	731	470	196
Quality Park	D	1	1	1	720	463	191
	D	1	1	2	729	469	194
	D	1	1	3	722	463	192
	D	1	2	1	718	461	193
	D	1	2	2	730	470	197
	D	1	2	3	723	466	191
	D	1	3	1	717	461	192
	D	1	3	2	721	463	192
	D	1	3	3	718	460	188

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	D	1	4	1	721	463	192
	D	1	4	2	728	467	194
	D	1	4	3	718	458	190
	D	1	5	1	722	462	192
	D	1	5	2	728	469	198
	D	1	5	3	729	470	196
	D	2	1	1	719	462	195
	D	2	1	2	716	459	190
	D	2	1	3	726	465	193
	D	2	2	1	722	462	191
	D	2	2	2	722	465	197
	D	2	2	3	716	460	190
	D	2	3	1	722	465	192
	D	2	3	2	724	467	193
	D	2	3	3	727	471	197
	D	2	4	1	725	468	196
	D	2	4	2	722	464	195
	D	2	4	3	734	472	195
	D	2	5	1	721	463	192
	D	2	5	2	728	469	199
	D	2	5	3	725	464	190
	D	3	1	1	724	470	197
	D	3	1	2	724	466	195
	D	3	1	3	731	471	197
	D	3	2	1	726	465	193
	D	3	2	2	724	465	194
	D	3	2	3	730	470	195
	D	3	3	1	722	466	193
	D	3	3	2	724	467	194
	D	3	3	3	716	461	189
	D	3	4	1	730	468	195
	D	3	4	2	725	466	195
	D	3	4	3	730	470	195
	D	3	5	1	725	468	194
	D	3	5	2	726	467	192
	D	3	5	3	727	470	197
Columbian	E	1	1	1	745	482	201

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	E	1	1	2	746	484	200
	E	1	1	3	741	480	198
	E	1	2	1	735	472	196
	E	1	2	2	738	476	198
	E	1	2	3	732	473	191
	E	1	3	1	736	475	195
	E	1	3	2	732	474	196
	E	1	3	3	738	481	203
	E	1	4	1	740	476	196
	E	1	4	2	737	474	196
	E	1	4	3	742	480	197
	E	1	5	1	735	478	200
	E	1	5	2	741	480	203
	E	1	5	3	737	479	201
	E	2	1	1	729	470	191
	E	2	1	2	734	473	195
	E	2	1	3	730	474	198
	E	2	2	1	737	476	198
	E	2	2	2	735	477	197
	E	2	2	3	732	471	192
	E	2	3	1	738	477	195
	E	2	3	2	736	475	196
	E	2	3	3	734	476	196
	E	2	4	1	732	473	195
	E	2	4	2	727	467	191
	E	2	4	3	728	470	191
	E	2	5	1	731	474	196
	E	2	5	2	731	471	196
	E	2	5	3	730	471	195
	E	3	1	1	731	474	196
	E	3	1	2	727	467	194
	E	3	1	3	736	478	198
	E	3	2	1	729	469	193
	E	3	2	2	733	471	195
	E	3	2	3	736	477	195
	E	3	3	1	741	483	204
	E	3	3	2	727	469	197
	E	3	3	3	738	479	201

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	E	3	4	1	738	477	198
	E	3	4	2	727	468	191
	E	3	4	3	730	472	195
	E	3	5	1	737	479	199
	E	3	5	2	732	473	197
	E	3	5	3	741	481	198
Business Source	F	1	1	1	753	499	229
	F	1	1	2	750	496	227
	F	1	1	3	752	498	228
	F	1	2	1	753	500	229
	F	1	2	2	751	497	228
	F	1	2	3	754	500	228
	F	1	3	1	753	499	227
	F	1	3	2	744	493	226
	F	1	3	3	756	500	229
	F	1	4	1	753	498	227
	F	1	4	2	748	495	226
	F	1	4	3	751	498	228
	F	1	5	1	744	491	223
	F	1	5	2	749	497	228
	F	1	5	3	746	493	225
	F	2	1	1	756	505	231
	F	2	1	2	756	505	234
	F	2	1	3	756	504	233
	F	2	2	1	748	499	230
	F	2	2	2	756	505	233
	F	2	2	3	763	509	234
	F	2	3	1	766	513	236
	F	2	3	2	757	504	233
	F	2	3	3	757	506	232
	F	2	4	1	756	506	232
	F	2	4	2	755	505	233
	F	2	4	3	760	507	233
	F	2	5	1	756	504	232
	F	2	5	2	757	506	235
	F	2	5	3	763	511	236

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	F	3	1	1	754	499	228
	F	3	1	2	750	498	228
	F	3	1	3	750	494	225
	F	3	2	1	747	495	226
	F	3	2	2	747	497	228
	F	3	2	3	759	504	230
	F	3	3	1	750	498	227
	F	3	3	2	749	497	228
	F	3	3	3	748	496	227
	F	3	4	1	751	499	229
	F	3	4	2	754	498	227
	F	3	4	3	760	505	230
	F	3	5	1	749	496	226
	F	3	5	2	751	497	227
	F	3	5	3	744	491	223
Amazon Basics	G	1	1	1	722	459	187
	G	1	1	2	730	465	188
	G	1	1	3	722	460	186
	G	1	2	1	718	451	181
	G	1	2	2	728	464	189
	G	1	2	3	727	463	188
	G	1	3	1	718	457	184
	G	1	3	2	724	461	188
	G	1	3	3	724	460	189
	G	1	4	1	725	464	190
	G	1	4	2	721	459	185
	G	1	4	3	716	453	180
	G	1	5	1	717	455	183
	G	1	5	2	728	463	188
	G	1	5	3	722	459	186
	G	2	1	1	728	464	190
	G	2	1	2	729	463	191
	G	2	1	3	723	461	189
	G	2	2	1	722	462	187
	G	2	2	2	724	461	189
	G	2	2	3	724	460	186

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	G	2	3	1	724	461	188
	G	2	3	2	725	463	189
	G	2	3	3	723	459	185
	G	2	4	1	728	464	189
	G	2	4	2	721	459	185
	G	2	4	3	724	459	187
	G	2	5	1	721	458	185
	G	2	5	2	727	462	188
	G	2	5	3	721	460	186
	G	3	1	1	727	462	188
	G	3	1	2	726	461	188
	G	3	1	3	728	465	189
	G	3	2	1	725	461	186
	G	3	2	2	727	464	191
	G	3	2	3	724	460	186
	G	3	3	1	727	463	187
	G	3	3	2	737	469	193
	G	3	3	3	721	456	181
	G	3	4	1	723	462	188
	G	3	4	2	729	465	190
	G	3	4	3	722	460	185
	G	3	5	1	729	466	190
	G	3	5	2	727	464	189
	G	3	5	3	728	463	186
Check-O-Matic	H	1	1	1	737	478	196
	H	1	1	2	736	476	196
	H	1	1	3	729	473	193
	H	1	2	1	732	475	196
	H	1	2	2	731	472	195
	H	1	2	3	738	480	197
	H	1	3	1	737	479	200
	H	1	3	2	742	482	201
	H	1	3	3	729	472	192
	H	1	4	1	745	482	198
	H	1	4	2	741	478	196
	H	1	4	3	731	475	194

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	H	1	5	1	730	472	195
	H	1	5	2	733	476	198
	H	1	5	3	733	474	192
	H	2	1	1	731	474	196
	H	2	1	2	730	472	194
	H	2	1	3	733	476	196
	H	2	2	1	736	475	196
	H	2	2	2	732	474	195
	H	2	2	3	731	474	194
	H	2	3	1	739	478	198
	H	2	3	2	729	473	197
	H	2	3	3	732	475	195
	H	2	4	1	739	478	199
	H	2	4	2	733	476	198
	H	2	4	3	731	477	198
	H	2	5	1	730	473	194
	H	2	5	2	738	480	201
	H	2	5	3	737	480	198
	H	3	1	1	729	469	189
	H	3	1	2	733	473	192
	H	3	1	3	726	469	189
	H	3	2	1	727	467	190
	H	3	2	2	723	463	186
	H	3	2	3	730	472	191
	H	3	3	1	728	467	188
	H	3	3	2	725	466	189
	H	3	3	3	725	467	188
	H	3	4	1	728	467	187
	H	3	4	2	732	473	194
	H	3	4	3	723	466	188
	H	3	5	1	734	473	190
	H	3	5	2	729	471	193
	H	3	5	3	730	470	188
Mead	I	1	1	1	730	478	211
	I	1	1	2	724	471	204
	I	1	1	3	734	480	209
	I	1	2	1	732	480	210

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	I	1	2	2	725	473	206
	I	1	2	3	732	479	209
	I	1	3	1	742	493	230
	I	1	3	2	747	495	229
	I	1	3	3	757	503	234
	I	1	4	1	755	501	234
	I	1	4	2	750	496	230
	I	1	4	3	749	497	231
	I	1	5	1	747	495	231
	I	1	5	2	747	493	228
	I	1	5	3	754	499	232
	I	2	1	1	731	480	236
	I	2	1	2	715	465	226
	I	2	1	3	729	478	235
	I	2	2	1	722	474	234
	I	2	2	2	722	469	229
	I	2	2	3	720	472	230
	I	2	3	1	724	475	232
	I	2	3	2	725	474	231
	I	2	3	3	729	479	235
	I	2	4	1	724	475	233
	I	2	4	2	720	471	230
	I	2	4	3	727	475	233
	I	2	5	1	739	486	240
	I	2	5	2	724	475	232
	I	2	5	3	737	483	238
	I	3	1	1	723	476	234
	I	3	1	2	720	470	230
	I	3	1	3	729	477	235
	I	3	2	1	726	474	232
	I	3	2	2	724	473	229
	I	3	2	3	725	475	234
	I	3	3	1	730	478	235
	I	3	3	2	726	473	230
	I	3	3	3	728	478	233
	I	3	4	1	723	474	233
	I	3	4	2	725	473	231
	I	3	4	3	721	471	229

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	I	3	5	1	728	477	234
	I	3	5	2	720	470	228
	I	3	5	3	726	477	235
Jam	J	1	1	1	728	467	194
	J	1	1	2	725	465	192
	J	1	1	3	722	462	192
	J	1	2	1	723	462	190
	J	1	2	2	717	456	189
	J	1	2	3	725	464	193
	J	1	3	1	725	464	191
	J	1	3	2	726	464	192
	J	1	3	3	721	461	193
	J	1	4	1	726	466	193
	J	1	4	2	722	462	193
	J	1	4	3	722	460	189
	J	1	5	1	717	457	186
	J	1	5	2	723	464	193
	J	1	5	3	722	460	189
	J	2	1	1	721	461	187
	J	2	1	2	718	457	188
	J	2	1	3	718	457	188
	J	2	2	1	728	467	193
	J	2	2	2	722	459	189
	J	2	2	3	722	460	190
	J	2	3	1	723	464	192
	J	2	3	2	724	464	195
	J	2	3	3	721	461	192
	J	2	4	1	723	462	190
	J	2	4	2	723	464	195
	J	2	4	3	723	460	191
	J	2	5	1	731	471	197
	J	2	5	2	722	462	192
	J	2	5	3	721	461	190
	J	3	1	1	719	459	190
	J	3	1	2	717	460	191
	J	3	1	3	724	463	191
	J	3	2	1	719	460	188

Brand	Brand #	Box #	Envelope #	Spot #	R	G	B
	J	3	2	2	727	464	196
	J	3	2	3	725	466	195
	J	3	3	1	725	462	190
	J	3	3	2	719	458	192
	J	3	3	3	728	467	194
	J	3	4	1	727	465	191
	J	3	4	2	726	465	190
	J	3	4	3	723	463	192
	J	3	5	1	729	468	193
	J	3	5	2	729	467	194
	J	3	5	3	726	466	192

Table 31. RGB values obtained for every envelope analyzed from every brand

APPENDIX VIII

Physical Measurements Results

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Staples	A	1	1	22.72	30.55	20.30	3.50	20.20	2.82	8.02	2.38	8.00	2.38	0.92
		1		22.72	30.54	20.28	3.52	20.20	2.82	8.05	2.40	8.04	2.35	0.92
		1		22.74	30.54	20.32	3.52	20.20	2.82	8.04	2.40	8.04	2.35	0.92
		1	Average 1	22.73	30.54	20.30	3.51	20.20	2.82	8.04	2.39	8.03	2.36	0.92
		1	3	22.72	30.55	20.25	3.50	20.30	2.85	8.08	2.45	8.02	2.40	0.90
		1		22.74	30.55	20.24	3.48	20.28	2.85	8.05	2.45	8.05	2.38	0.90
		1		22.72	30.55	20.20	3.50	20.30	2.85	8.06	2.45	8.02	2.40	0.92
		1	Average 3	22.73	30.55	20.23	3.49	20.29	2.85	8.06	2.45	8.03	2.39	0.91
		1	5	22.74	30.54	20.40	3.48	20.25	2.78	8.10	2.50	8.10	2.50	0.92
		1		22.75	30.55	20.38	3.50	20.25	2.75	8.12	2.48	8.12	2.48	0.94
		1		22.72	30.54	20.38	3.50	20.25	2.78	8.10	2.50	8.10	2.50	0.94
		1	Average 5	22.74	30.54	20.39	3.49	20.25	2.77	8.11	2.49	8.11	2.49	0.93
		2	1	22.72	30.70	20.18	3.70	19.70	2.68	8.02	2.50	8.12	2.50	0.94
		2		22.74	30.65	20.18	3.65	19.70	2.68	8.05	2.50	8.12	2.50	0.92
		2		22.74	30.60	20.15	3.68	19.72	2.70	8.05	2.50	8.12	2.48	0.92
		2	Average 1	22.73	30.65	20.17	3.68	19.71	2.69	8.04	2.50	8.12	2.49	0.93
		2	3	22.72	30.55	19.98	3.72	19.60	2.54	8.14	2.50	8.10	2.50	0.92
		2		22.72	30.58	20.00	3.72	19.58	2.55	8.12	2.48	8.10	2.48	0.92
		2		22.74	30.58	19.98	3.74	19.60	2.55	8.14	2.50	8.12	2.50	0.92
		2	Average 3	22.73	30.57	19.99	3.73	19.59	2.55	8.13	2.49	8.11	2.49	0.92
		2	5	22.72	30.58	19.88	3.65	20.05	2.68	8.10	2.54	8.12	2.48	0.94
		2		22.72	30.55	19.88	3.68	20.08	2.65	8.12	2.52	8.12	2.48	0.94
		2		22.72	30.55	19.85	3.65	20.08	2.68	8.12	2.52	8.12	2.49	0.92
			Average 5	22.72	30.56	19.87	3.66	20.07	2.67	8.11	2.53	8.12	2.48	0.93
		3	1	22.75	30.55	20.00	3.75	19.70	2.54	8.14	2.45	8.10	2.40	0.92
		3		22.72	30.55	20.00	3.75	19.70	2.52	8.12	2.46	8.10	2.44	0.94
		3		22.75	30.55	19.98	3.74	19.68	2.54	8.12	2.45	8.12	2.42	0.94
			Average 1	22.74	30.55	19.99	3.75	19.69	2.53	8.13	2.45	8.11	2.42	0.93
		3	3	22.74	30.55	20.05	3.72	19.80	2.58	8.12	2.50	8.12	2.50	0.92

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Staples	A	3		22.72	30.55	20.04	3.72	19.82	2.58	8.14	2.48	8.12	2.50	0.92
		3		22.72	30.55	20.04	3.74	19.82	2.58	8.14	2.48	8.12	2.50	0.92
			Average 3	22.73	30.55	20.04	3.73	19.81	2.58	8.13	2.49	8.12	2.50	0.92
		3	5	22.72	30.55	19.75	3.68	19.65	2.62	8.12	2.60	8.12	2.60	0.92
		3		22.72	30.56	19.75	3.68	19.65	2.62	8.12	2.58	8.14	2.58	0.92
		3		22.72	30.56	19.74	3.68	19.66	2.62	8.12	2.58	8.14	2.60	0.94
			Average 5	22.72	30.56	19.75	3.68	19.65	2.62	8.12	2.59	8.13	2.59	0.93
	A Average			22.73	30.56	20.11	3.61	19.96	2.69	8.09	2.47	8.09	2.46	0.92
W.B.Mason	B	1	1	22.88	30.48	20.62	3.80	21.90	2.04	7.65	1.90	7.66	1.88	0.94
		1		22.90	30.48	20.60	3.78	21.88	2.05	7.68	1.88	7.64	1.88	0.92
		1		22.88	30.50	20.60	3.80	21.88	2.06	7.65	1.88	7.66	1.90	0.94
			Average 1	22.89	30.49	20.61	3.79	21.89	2.05	7.66	1.89	7.65	1.89	0.93
		1	3	22.88	30.55	20.56	3.85	21.80	2.12	7.68	1.90	7.62	1.86	0.92
		1		22.90	30.54	20.58	3.84	21.82	2.12	7.70	1.88	7.62	1.88	0.94
		1		22.88	30.55	20.58	3.84	21.82	2.12	7.70	1.90	7.62	1.86	0.94
			Average 3	22.89	30.55	20.57	3.84	21.81	2.12	7.69	1.89	7.62	1.87	0.93
		1	5	22.86	30.54	20.68	3.72	21.85	2.08	7.70	2.00	7.65	2.00	0.94
		1		22.88	30.52	20.68	3.72	21.85	2.10	7.72	2.00	7.65	1.98	0.92
		1		22.88	30.54	20.66	3.74	21.85	2.08	7.72	1.98	7.68	2.00	0.92
			Average 5	22.87	30.53	20.67	3.73	21.85	2.09	7.71	1.99	7.66	1.99	0.93
		2	1	22.85	30.48	20.60	3.70	21.80	2.18	7.66	1.90	7.68	1.90	0.92
		2	1	22.88	30.48	20.58	3.70	21.80	2.18	7.66	1.88	7.65	1.88	0.92
		2	1	22.85	30.50	20.58	3.68	21.78	2.18	7.68	1.88	7.68	1.90	0.92
			Average 1	22.86	30.49	20.59	3.69	21.79	2.18	7.67	1.89	7.67	1.89	0.92
		2	3	22.90	30.48	20.56	3.80	21.70	2.15	7.65	1.86	7.70	1.88	0.94
		2	3	22.90	30.50	20.58	3.80	21.74	2.14	7.65	1.88	7.68	1.86	0.94
		2	3	22.90	30.50	20.56	3.80	21.74	2.14	7.64	1.88	7.70	1.86	0.94
			Average 3	22.90	30.49	20.57	3.80	21.73	2.14	7.65	1.87	7.69	1.87	0.94
		2	5	22.90	30.55	20.60	3.72	21.80	2.16	7.75	1.90	7.68	1.88	0.92
		2	5	22.92	30.55	20.58	3.74	21.78	2.15	7.74	1.90	7.70	1.88	0.92
		2	5	22.90	30.54	20.60	3.72	21.80	2.16	7.74	1.90	7.70	1.86	0.94
			Average 5	22.91	30.55	20.59	3.73	21.79	2.16	7.74	1.90	7.69	1.87	0.93
		3	1	22.90	30.48	20.60	3.78	21.75	2.14	7.64	1.85	7.70	1.86	0.92

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
W.B.Mason	B	3	1	22.90	30.50	20.58	3.78	21.75	2.12	7.62	1.86	7.70	1.86	0.92
		3	1	22.90	30.50	20.60	3.78	21.76	2.12	7.62	1.86	7.70	1.86	0.92
			Average 1	22.90	30.49	20.59	3.78	21.75	2.13	7.63	1.86	7.70	1.86	0.92
		3	3	22.88	30.55	20.60	3.76	21.85	2.12	7.65	1.92	7.68	1.92	0.92
		3	3	22.90	30.55	20.62	3.76	21.85	2.12	7.66	1.94	7.68	1.92	0.92
		3	3	22.90	30.54	20.60	3.75	21.86	2.12	7.66	1.92	7.68	1.94	0.92
			Average 3	22.89	30.55	20.61	3.76	21.85	2.12	7.66	1.93	7.68	1.93	0.92
		3	5	22.88	30.55	20.75	3.66	21.70	2.20	7.68	1.90	7.65	1.85	0.94
		3	5	22.90	30.50	20.72	3.68	21.74	2.18	7.70	1.90	7.64	1.86	0.94
		3	5	22.90	30.54	20.75	3.68	21.70	2.18	7.68	1.92	7.65	1.86	0.94
			Average 5	22.89	30.53	20.74	3.67	21.71	2.19	7.69	1.91	7.65	1.86	0.94
	B Average			22.89	30.52	20.62	3.75	21.80	2.13	7.68	1.90	7.67	1.89	0.93
Office Depot	C	1	1	22.80	30.56	20.38	3.72	21.90	2.14	7.50	1.98	7.50	2.00	0.90
		1	1	22.78	30.58	20.40	3.72	21.88	2.12	7.48	1.98	7.52	1.98	0.88
		1	1	22.80	30.56	20.38	3.72	21.88	2.14	7.50	2.00	7.50	2.00	0.88
			Average 1	22.79	30.57	20.39	3.72	21.89	2.13	7.49	1.99	7.51	1.99	0.89
		1	3	22.82	30.58	20.40	3.70	21.85	1.98	7.40	1.96	7.50	1.98	0.90
		1	3	22.82	30.58	20.60	3.70	21.86	2.00	7.40	1.98	7.50	1.96	0.90
		1	3	22.84	30.56	20.60	3.68	21.86	2.00	7.42	1.98	7.50	1.96	0.90
			Average 3	22.83	30.57	20.53	3.69	21.86	1.99	7.41	1.97	7.50	1.97	0.90
		1	5	22.80	30.52	20.40	3.72	21.80	2.08	7.44	1.88	7.60	1.90	0.88
		1	5	22.82	30.50	20.40	3.72	21.80	2.10	7.44	1.86	7.60	1.88	0.90
		1	5	22.82	30.50	20.38	3.72	21.80	2.10	7.45	1.88	7.60	1.88	0.90
			Average 5	22.81	30.51	20.39	3.72	21.80	2.09	7.44	1.87	7.60	1.89	0.89
		2	1	22.82	30.55	20.30	3.82	21.88	1.95	7.45	1.86	7.48	1.90	0.88
		2	1	22.82	30.54	20.28	3.80	21.90	1.96	7.44	1.88	7.50	1.88	0.88
		2	1	22.82	30.54	20.28	3.82	21.90	1.96	7.44	1.88	7.48	1.90	0.90
			Average 1	22.82	30.54	20.29	3.81	21.89	1.96	7.44	1.87	7.49	1.89	0.89
		2	3	22.82	30.55	20.30	3.82	21.85	2.02	7.42	1.88	7.50	1.88	0.88
		2	3	22.82	30.54	20.32	3.80	21.86	2.00	7.44	1.90	7.50	1.88	0.90
		2	3	22.82	30.55	20.30	3.80	21.86	2.02	7.42	1.90	7.50	1.88	0.90
			Average 3	22.82	30.55	20.31	3.81	21.86	2.01	7.43	1.89	7.50	1.88	0.89
		2	5	22.82	30.55	20.38	3.80	21.86	2.04	7.50	1.86	7.48	1.85	0.88

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Office Depot	C	2	5	22.84	30.56	20.36	3.80	21.88	2.02	7.48	1.85	7.50	1.86	0.80
		2	5	22.82	30.55	20.38	3.78	21.88	2.02	7.48	1.86	7.50	1.85	0.90
			Average 5	22.83	30.55	20.37	3.79	21.87	2.03	7.49	1.86	7.49	1.85	0.86
		3	1	22.80	30.54	20.40	3.78	21.80	2.00	7.42	1.82	7.52	1.80	0.90
		3	1	22.82	30.52	20.42	3.80	21.80	2.02	7.44	1.84	7.50	1.80	0.88
		3	1	22.82	30.52	20.40	3.80	21.80	2.00	7.44	1.84	7.52	1.82	0.90
			Average 1	22.81	30.53	20.41	3.79	21.80	2.01	7.43	1.83	7.51	1.81	0.89
		3	3	22.82	30.54	20.35	3.78	21.84	2.02	7.42	1.94	7.58	1.88	0.90
		3	3	22.80	30.52	20.34	3.78	21.84	2.00	7.42	1.95	7.58	1.88	0.90
		3	3	22.82	30.52	20.35	3.78	21.82	2.02	7.42	1.94	7.58	1.90	0.90
			Average 3	22.81	30.53	20.35	3.78	21.83	2.01	7.42	1.94	7.58	1.89	0.90
		3	5	22.82	30.55	20.28	3.75	21.88	1.98	7.42	1.92	7.58	1.92	0.90
		3	5	22.80	30.56	20.28	3.75	21.88	1.98	7.44	1.94	7.58	1.92	0.90
		3	5	22.82	30.56	20.26	3.74	21.88	2.00	7.44	1.92	7.60	1.92	0.92
			Average 5	22.81	30.56	20.27	3.75	21.88	1.99	7.43	1.93	7.59	1.92	0.91
	C Average			22.82	30.54	20.37	3.76	21.85	2.02	7.44	1.91	7.53	1.90	0.89
Quality Park	D	1	1	22.98	30.38	20.72	3.72	21.80	2.28	7.74	1.94	7.70	1.94	0.90
		1	1	22.98	30.40	20.70	3.72	21.78	2.30	7.72	1.96	7.70	1.92	0.92
		1	1	22.98	30.40	20.70	3.72	21.78	2.28	7.74	1.96	7.68	1.92	0.90
			Average 1	22.98	30.39	20.71	3.72	21.79	2.29	7.73	1.95	7.69	1.93	0.91
		1	3	22.92	30.40	20.68	3.76	21.78	2.18	7.78	1.88	7.68	1.88	0.92
		1	3	22.94	30.40	20.70	3.75	21.76	2.20	7.80	1.88	7.68	1.86	0.92
		1	3	22.94	30.42	20.70	3.75	21.78	2.18	7.78	1.88	7.70	1.88	0.90
			Average 3	22.93	30.41	20.69	3.75	21.77	2.19	7.79	1.88	7.69	1.87	0.91
		1	5	22.94	30.45	20.66	3.70	21.80	2.18	7.70	1.94	7.72	1.90	0.90
		1	5	22.94	30.45	20.68	3.70	21.80	2.18	7.72	1.94	7.70	1.90	0.92
		1	5	22,94	30.45	22.66	3.70	21.78	2.20	7.70	1.94	7.70	1.92	0.92
			Average 5	22.94	30.45	21.33	3.70	21.79	2.19	7.71	1.94	7.71	1.91	0.91
		2	1	22.94	30.50	20.76	3.64	21.84	2.28	7.78	1.86	7.68	1.88	0.92
		2	1	22.94	30.48	20.78	3.65	21.82	2.30	7.80	1.85	7.70	1.88	0.92
		2	1	22.95	30.48	20.76	3.64	21.84	2.28	7.78	1.86	7,68	1.88	0.90
			Average 1	22.94	30.48	20.91	3.66	21.82	2.26	7.77	1.88	7.70	1.89	0.91
		2	3	22.98	30.46	20.80	3.86	21.78	2.06	7.80	1.90	7.65	1.95	0.92

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Quality Park	D	2	3	22.98	30.48	20.78	3.84	21.80	2.04	7.78	1.90	7.66	1.95	0.92
		2	3	22.96	30.46	20.78	3.85	21.78	2.06	7.80	1.92	7.66	1.96	0.92
			Average 3	22.97	30.47	20.79	3.85	21.79	2.05	7.79	1.91	7.66	1.95	0.92
		2	5	22.98	30.45	20.74	3.78	21.70	2.20	7.80	1.92	7.70	1.94	0.92
		2	5	22.96	30.45	20.74	3.78	21.72	2.22	7.80	1.90	7.72	1.92	0.92
		2	5	22.96	30.46	20.74	3.76	21.70	2.22	7.78	1.92	7.72	1.92	0.92
			Average 5	22.97	30.45	20.74	3.77	21.71	2.21	7.79	1.91	7.71	1.93	0.92
		3	1	22.96	30.45	20.68	3.66	21.80	2.24	7.78	1.84	7.72	1.84	0.92
		3	1	22.98	30.46	20.66	3.68	21.78	2.24	7.78	1.85	7.72	1.84	0.92
		3	1	22.96	30.45	20.68	3.66	21.80	2.24	7.78	1.84	7.72	1.84	0.92
			Average 1	22.97	30.45	20.67	3.67	21.79	2.24	7.78	1.84	7.72	1.84	0.92
		3	3	22.94	30.45	20.70	3.74	21.78	2.28	7.80	1.90	7.68	1.88	0.92
		3	3	22.94	30.44	20.68	3.72	21.80	2.30	7.80	1.88	7.70	1.90	0.92
		3	3	22.96	30.45	20.70	3.72	21.80	2.28	7.78	1.88	7.68	1.90	0.92
			Average 3	22.95	30.45	20.69	3.73	21.79	2.29	7.79	1.89	7.69	1.89	0.92
		3	5	22.96	30.45	20.70	3.80	21.65	2.02	7.72	1.90	7.72	1.90	0.92
		3	5	22.96	30.44	20.68	3.78	21.65	2.02	7.70	1.88	7.70	1.90	0.92
		3	5	22.96	30.46	20.70	3.80	21.66	2.02	7.70	1.88	7.70	1.90	0.92
			Average 5	22.96	30.45	20.69	3.79	21.65	2.02	7.71	1.89	7.71	1.90	0.92
	D Average			22.96	30.44	20.80	3.74	21.77	2.19	7.76	1.90	7.70	1.90	0.92
Columbian	E	1	1	22.74	30.58	20.80	3.64	21.62	2.12	7.64	1.90	7.65	1.88	0.90
		1	1	22.75	30.60	20.78	3.64	21.62	2.12	7.64	1.92	7.66	1.88	0.90
		1	1	22.74	30.60	20.80	3.62	21.62	2.12	7.62	1.90	7.65	1.90	0.90
			Average 1	22.74	30.59	20.79	3.63	21.62	2.12	7.63	1.91	7.65	1.89	0.90
		1	3	22.82	30.55	20.78	3.74	21.82	2.04	7.72	1.94	7.62	1.90	0.92
		1	3	22.82	30.56	20.76	3.74	21.84	2.04	7.74	1.94	7.62	1.88	0.92
		1	3	22.84	30.58	20.76	3.75	21.84	2.04	7.72	1.94	7.62	1.90	0.92
			Average 3	22.83	30.56	20.77	3.74	21.83	2.04	7.73	1.94	7.62	1.89	0.92
		1	5	22.80	30.60	20.72	3.74	21.78	2.04	7.68	1.92	7.65	1.96	0.92
		1	5	22.80	30.60	20.70	3.74	21.78	2.04	7.70	1.94	7.66	1.96	0.92
		1	5	22.80	30.60	20.70	3.76	21.76	2.04	7.68	1.94	7.66	1.98	0.92
			Average 5	22.80	30.60	20.71	3.75	21.77	2.04	7.69	1.93	7.66	1.97	0.92
		2	1	22.70	30.66	20.80	3.65	21.90	2.08	7.70	1.90	7.65	1.90	0.90

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Columbian	E	2	1	22.72	30.68	20.78	3.64	21.80	2.08	7.72	1.92	7.66	1.92	0.92
		2	1	22.72	30.68	20.80	3.64	21.80	2.06	7.72	1.92	7.66	1.90	0.90
			Average 1	22.71	30.67	20.79	3.64	21.83	2.07	7.71	1.91	7.66	1.91	0.91
		2	3	22.80	30.58	20.78	3.64	21.84	2.10	7.75	1.90	7.65	1.88	0.90
		2	3	22.80	30.60	20.76	3.64	21.84	2.08	7.74	1.88	7.64	1.86	0.92
		2	3	22.82	30.60	20.78	3.65	21.82	2.10	7.74	1.90	7.64	1.88	0.90
			Average 3	22.81	30.59	20.77	3.64	21.83	2.09	7.74	1.89	7.64	1.87	0.91
		2	5	22.80	30.58	20.85	3.72	21.75	2.10	7.66	1.90	7.64	1.88	0.92
		2	5	22.80	30.58	20.84	3.72	21.75	2.10	7.68	1.90	7.64	1.88	0.90
		2	5	22.80	30.60	20.85	3.72	21.75	2.10	7.68	1.90	7.65	1.90	0.92
			Average 5	22.80	30.59	20.85	3.72	21.75	2.10	7.67	1.90	7.64	1.89	0.91
		3	1	22.82	30.60	20.85	3.70	21.85	2.05	7.68	1.90	7.60	1.88	0.92
		3	1	22.80	30.58	20.84	3.72	21.84	2.06	7.68	1.88	7.58	1.86	0.92
		3	1	22.82	30.60	20.85	3.72	21.85	2.05	7.70	1.90	7.60	1.86	0.92
			Average 1	22.81	30.59	20.85	3.71	21.85	2.05	7.69	1.89	7.59	1.87	0.92
		3	3	22.80	30.60	20.78	3.76	21.80	2.08	7.65	1.92	7.68	1.90	0.90
		3	3	22.78	30.62	20.80	3.76	21.78	2.10	7.64	1.90	7.68	1.90	0.90
		3	3	22.78	30.62	20.78	3.76	21.80	2.10	7.66	1.90	7.68	1.88	0.90
			Average 3	22.79	30.61	20.79	3.76	21.79	2.09	7.65	1.91	7.68	1.89	0.90
		3	5	22.82	30.60	20.85	3.76	21.78	2.08	7.78	1.94	7.68	1.88	0.92
		3	5	22.80	30.58	20.84	3.75	21.80	2.10	7.76	1.92	7.70	1.90	0.92
		3	5	22.80	30.60	20.86	3.75	21.80	2.08	7.78	1.94	7.68	1.90	0.92
			Average 5	22.81	30.59	20.85	3.75	21.79	2.09	7.77	1.93	7.69	1.89	0.92
	E Average			22.85	30.55	20.78	3.72	21.78	2.12	7.73	1.90	7.67	1.90	0.91
Business Source	F	1	1	22.88	30.58	20.50	3.72	21.70	2.05	7.46	1.82	7.55	1.86	0.92
		1	1	22.86	30.56	20.48	3.70	21.74	2.06	7.45	1.84	7.54	1.86	0.92
		1	1	22.80	30.58	20.50	3.70	21.72	2.06	7.45	1.84	7.55	1.86	0.92
			Average 1	22.85	30.57	20.49	3.71	21.72	2.06	7.45	1.83	7.55	1.86	0.92
		1	3	22.85	30.55	20.46	3.72	21.85	2.08	7.45	1.90	7.54	1.92	0.92
		1	3	22.86	30.55	20.44	3.74	21.84	2.08	7.46	1.88	7.52	1.92	0.92
		1	3	22.86	30.54	20.45	3.74	21.84	2.06	7.46	1.90	7.55	1.92	0.92
			Average 3	22.86	30.55	20.45	3.73	21.84	2.07	7.46	1.89	7.54	1.92	0.92
		1	5	22.84	30.50	20.50	3.75	21.90	2.10	7.40	1.90	7.58	1.95	0.92

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Business Source	F	1	5	22.82	30.50	20.48	3.74	21.88	2.10	7.42	1.92	7.58	1.96	0.90
		1	5	22.82	30.50	20.48	3.75	21.90	2.10	7.42	1.92	7.58	1.98	0.92
			Average 5	22.83	30.50	20.49	3.75	21.89	2.10	7.41	1.91	7.58	1.96	0.91
		2	1	22.98	30.50	20.38	3.82	22.00	2.00	7.44	1.94	7.54	1.95	0.90
		2	1	22.98	30.52	20.40	3.82	22.00	2.00	7.45	1.95	7.55	1.95	0.92
		2	1	22.98	30.50	20.38	3.80	22.20	2.00	7.45	1.94	7.55	1.96	0.90
			Average 1	22.98	30.51	20.39	3.81	22.07	2.00	7.45	1.94	7.55	1.95	0.91
		2	3	22.94	30.50	20.48	3.74	21.94	2.02	7.50	1.90	7.55	1.94	0.90
		2	3	22.96	30.48	20.48	3.74	21.95	2.00	7.48	1.92	7.55	1.96	0.92
		2	3	22.96	30.50	20.46	3.72	21.95	2.02	7.48	1.92	7.56	1.96	0.92
			Average 3	22.95	30.49	20.47	3.73	21.95	2.01	7.49	1.91	7.55	1.95	0.91
		2	5	22.98	30.50	20.40	3.80	22.15	1.95	7.45	1.98	7.62	2.00	0.90
		2	5	23.00	30.48	20.38	3.82	22.12	1.94	7.46	1.96	7.60	2.00	0.90
		2	5	22.98	30.50	20.38	3.82	22.12	1.95	7.46	1.96	7.60	1.98	0.92
			Average 5	22.99	30.49	20.39	3.81	22.13	1.95	7.46	1.97	7.61	1.99	0.91
		3	1	22.80	30.56	20.34	3.82	22.04	1.98	7.58	1.90	7.58	1.88	0.92
		3	1	22.82	30.58	20.35	3.80	22.04	1.96	7.56	1.88	7.60	1.88	0.90
		3	1	22.80	30.55	20.35	3.82	22.02	1.96	7.56	1.88	7.58	1.86	0.92
			Average 1	22.81	30.56	20.35	3.81	22.03	1.97	7.57	1.89	7.59	1.87	0.91
		3	3	22.85	30.52	20.54	3.70	21.70	2.12	7.45	1.90	7.46	1.94	0.90
		3	3	22.86	30.52	20.54	3.70	21.70	2.12	7.44	1.92	7.48	1.92	0.90
		3	3	22.86	30.50	20.52	3.70	21.72	2.12	7.44	1.92	7.48	1.94	0.90
			Average 3	22.86	30.51	20.53	3.70	21.71	2.12	7.44	1.91	7.47	1.93	0.90
		3	5	22.86	30.50	20.42	3.72	21.88	2.00	7.45	1.94	7.55	1.94	0.92
		3	5	22.88	30.52	20.40	3.72	21.88	2.00	7.44	1.94	7.55	1.94	0.90
		3	5	22.85	30.52	20.40	3.74	21.86	2.00	7.44	1.94	7.56	1.94	0.92
			Average 5	22.86	30.51	20.41	3.73	21.87	2.00	7.44	1.94	7.55	1.94	0.91
	F Average			22.89	30.52	20.44	3.75	21.91	2.03	7.46	1.91	7.55	1.93	0.91
Amazon Basics	G	1	1	22.68	30.65	20.20	3.62	20.50	2.75	-	-	-	-	None
		1	1	22.70	30.62	20.18	3.60	20.52	2.76	-	-	-	-	None
		1	1	22.70	30.64	20.18	3.60	20.52	2.75	-	-	-	-	None
			Average 1	22.69	30.64	20.19	3.61	20.51	2.75					
		1	3	22.70	30.60	20.14	3.60	20.40	2.70	-	-	-	-	None

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Amazon Basics	G	1	3	22.70	30.64	20.12	3.60	20.38	2.68	-	-	-	-	None
		1	3	22.72	30.64	20.12	3.60	20.40	2.70	-	-	-	-	None
			Average 3	22.71	30.63	20.13	3.60	20.39	2.69					
		1	5	22.70	30.62	20.46	3.46	20.40	2.80	-	-	-	-	None
		1	5	22.68	30.60	20.48	3.44	20.40	2.80	-	-	-	-	None
		1	5	22.70	30.60	20.46	3.46	20.42	2.80	-	-	-	-	None
			Average 5	22.69	30.61	20.47	3.45	20.41	2.80					
		2	1	22.70	30.64	20.08	3.54	20.40	2.70	-	-	-	-	None
		2	1	22.70	30.62	20.10	3.52	20.40	2.70	-	-	-	-	None
		2	1	22.70	30.64	20.10	3.54	20.40	2.70	-	-	-	-	None
			Average 1	22.70	30.63	20.09	3.53	20.40	2.70					
		2	3	22.70	30.58	20.38	3.38	20.30	2.74	-	-	-	-	None
		2	3	22.72	30.58	20.40	3.40	20.30	2.74	-	-	-	-	None
		2	3	22.70	30.60	20.38	3.40	20.30	2.75	-	-	-	-	None
			Average 3	22.71	30.59	20.39	3.39	20.30	2.74					
		2	5	22.70	30.62	20.18	3.60	20.32	2.60	-	-	-	-	None
		2	5	22.70	30.64	20.18	3.60	20.32	2.60	-	-	-	-	None
		2	5	22.70	30.64	20.16	3.60	20.32	2.60	-	-	-	-	None
			Average 5	22.70	30.63	20.17	3.60	20.32	2.60					
		3	1	22.70	30.62	20.34	3.48	20.16	2.74	-	-	-	-	None
		3	1	22.70	30.60	20.35	3.50	20.16	2.72	-	-	-	-	None
		3	1	22.70	30.62	20.34	3.50	20.18	2.74	-	-	-	-	None
			Average 1	22.70	30.61	20.34	3.49	20.17	2.73					
		3	3	22.70	30.64	20.45	3.38	20.20	2.70	-	-	-	-	None
		3	3	22.70	30.65	20.46	3.40	20.20	2.70	-	-	-	-	None
		3	3	22.70	30.65	20.45	3.40	20.20	2.68	-	-	-	-	None
			Average 3	22.70	30.65	20.45	3.39	20.20	2.69					
		3	5	22.72	30.64	20.40	3.34	20.30	2.75	-	-	-	-	None
		3	5	22.72	30.66	20.42	3.35	20.30	2.76	-	-	-	-	None
		3	5	22.70	30.65	20.40	3.35	20.30	2.75	-	-	-	-	None
			Average 5	22.71	30.65	20.41	3.35	20.30	2.75					
	G Average			22.70	30.63	20.29	3.49	20.33	2.72					
Check-O-Matic	H	1	1	22.80	30.50	20.70	4.06	20.76	2.82	17.88	2.28	-	-	0.84

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Check-O-Matic	H	1	1	22.80	30.50	20.72	4.08	20.74	2.82	17.90	2.28	-	-	0.84
		1	1	22.80	30.52	20.72	4.08	20.76	2.80	17.88	2.28	-	-	0.84
			Average 1	22.80	30.51	20.71	4.07	20.75	2.81	17.89	2.28			0.84
		1	3	22.80	30.48	20.68	4.12	20.82	2.82	17.95	2.28	-	-	0.84
		1	3	22.82	30.48	20.70	4.14	20.80	2.82	17.96	2.28	-	-	0.85
		1	3	22.82	30.50	20.70	4.14	20.82	2.80	17.95	2.26	-	-	0.84
			Average 3	22.81	30.49	20.69	4.13	20.81	2.81	17.95	2.27			0.84
		1	5	22.84	30.48	20.68	4.08	20.75	2.80	17.88	2.22	-	-	0.84
		1	5	22.84	30.50	20.68	4.08	20.76	2.82	17.92	2.24	-	-	0.85
		1	5	22.82	30.48	20.68	4.10	20.76	2.82	17.90	2.22	-	-	0.85
			Average 5	22.83	30.49	20.68	4.09	20.76	2.81	17.90	2.23			0.85
		2	1	22.80	30.52	20.70	4.12	20.84	2.80	18.00	2.24	-	-	0.85
		2	1	22.82	30.54	20.70	4.12	20.86	2.78	17.98	2.24	-	-	0.85
		2	1	22.80	30.52	20.70	4.10	20.85	2.80	18.00	2.26	-	-	0.85
			Average 1	22.81	30.53	20.70	4.11	20.85	2.79	17.99	2.25			0.85
		2	3	22.88	30.58	20.72	4.20	20.88	2.80	17.96	2.30	-	-	0.84
		2	3	22.86	30.56	20.74	4.18	20.90	2.80	17.98	2.28	-	-	0.84
		2	3	22.86	30.58	20.72	4.20	20.90	2.80	17.98	2.30	-	-	0.82
			Average 3	22.87	30.57	20.73	4.19	20.89	2.80	17.97	2.29			0.83
		2	5	22.84	30.48	20.76	4.06	20.92	2.80	17.96	2.28	-	-	0.84
		2	5	22.84	30.50	20.76	4.08	20.90	2.80	17.98	2.26	-	-	0.84
		2	5	22.86	30.50	20.76	4.08	20.90	2.80	17.98	2.26	-	-	0.84
			Average 5	22.85	30.49	20.76	4.07	20.91	2.80	17.97	2.27			0.84
		3	1	22.88	30.58	20.78	4.10	20.92	2.80	18.08	2.30	-	-	0.84
		3	1	22.88	30.56	20.76	4.12	20.90	2.80	18.08	2.30	-	-	0.84
		3	1	22.88	30.58	20.76	4.12	20.92	2.80	18.08	2.30	-	-	0.85
			Average 1	22.88	30.57	20.77	4.11	20.91	2.80	18.08	2.30			0.84
		3	3	22.84	30.50	20.76	4.12	20.85	2.80	18.00	2.24	-	-	0.84
		3	3	22.85	30.48	20.76	4.12	20.84	2.82	18.02	2.22	-	-	0.85
		3	3	22.86	30.50	20.74	4.12	20.84	2.82	18.02	2.24	-	-	0.84
			Average 3	22.85	30.49	20.75	4.12	20.84	2.81	18.01	2.23			0.84
		3	5	22.82	30.48	20.78	4.08	20.90	2.80	18.02	2.28	-	-	0.84
		3	5	22.82	30.50	20.76	4.08	20.90	2.82	18.04	2.30	-	-	0.84

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Check-O-Matic	H	3	5	22.84	30.48	20.78	4.08	20.88	2.80	18.04	2.28	-	-	0.85
			Average 5	22.83	30.49	20.77	4.08	20.89	2.81	18.03	2.29			0.84
	H Average			22.84	30.51	20.73	4.11	20.85	2.81	17.98	2.27			0.84
Mead	I	1	1	22.90	30.56	21.00	3.72	21.05	2.30	16.78	2.64	-	-	0.82
		1	1	22.90	30.55	21.00	3.72	21.05	2.30	16.76	2.64	-	-	0.84
		1	1	22.90	30.56	20.98	3.74	21.06	2.30	16.78	2.64	-	-	0.84
			Average 1	22.90	30.56	20.99	3.73	21.05	2.30	16.77	2.64			0.83
		1	3	22.92	30.60	21.02	3.68	21.15	2.28	16.80	2.40	-	-	0.84
		1	3	22.92	30.60	21.04	3.68	21.15	2.28	16.80	2.42	-	-	0.82
		1	3	22.94	30.58	21.02	3.68	21.14	2.28	16.82	2.42	-	-	0.84
			Average 3	22.93	30.59	21.03	3.68	21.15	2.28	16.81	2.41			0.83
		1	5	22.92	30.60	21.05	3.74	21.10	2.26	16.82	2.40	-	-	0.82
		1	5	22.92	30.58	21.04	3.72	21.10	2.24	16.82	2.40	-	-	0.84
		1	5	22.90	30.60	21.04	3.72	21.12	2.24	16.80	2.40	-	-	0.84
			Average 5	22.91	30.59	21.04	3.73	21.11	2.25	16.81	2.40			0.83
		2	1	22.92	30.60	21.02	3.74	21.10	2.30	16.88	2.58	-	-	0.84
		2	1	22.92	30.58	21.04	3.74	21.08	2.28	16.88	2.58	-	-	0.84
		2	1	22.90	30.58	21.04	3.74	21.10	2.30	16.90	2.56	-	-	0.85
			Average 1	22.91	30.59	21.03	3.74	21.09	2.29	16.89	2.57			0.84
		2	3	22.94	30.60	21.00	3.70	21.10	2.25	16.80	2.54	-	-	0.84
		2	3	22.94	30.60	21.02	3.72	21.08	2.26	16.82	2.52	-	-	0.85
		2	3	22.95	30.60	21.00	3.70	21.10	2.26	16.82	2.52	-	-	0.84
			Average 3	22.94	30.60	21.01	3.71	21.09	2.26	16.81	2.53			0.84
		2	5	22.95	30.62	21.00	3.72	21.05	2.25	16.86	2.54	-	-	0.84
		2	5	22.94	30.60	21.00	3.72	21.04	2.24	16.88	2.54	-	-	0.85
		2	5	22.94	30.60	21.02	3.72	21.05	2.26	16.88	2.55	-	-	0.84
			Average 5	22.94	30.61	21.01	3.72	21.05	2.25	16.87	2.54			0.84
		3	1	22.98	30.60	21.00	3.75	21.18	2.22	16.82	2.50	-	-	0.84
		3	1	23.00	30.60	21.00	3.76	21.18	2.22	16.84	2.48	-	-	0.85
		3	1	22.98	30.62	20.98	3.75	21.16	2.22	16.82	2.50	-	-	0.84
			Average 1	22.99	30.61	20.99	3.75	21.17	2.22	16.83	2.49			0.84
		3	3	22.92	30.64	21.05	3.68	21.10	2.30	16.86	2.46	-	-	0.84
		3	3	22.94	30.64	21.06	3.70	21.10	2.30	16.86	2.46	-	-	0.84

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Mead	I	3	3	22.94	30.64	21.04	3.68	21.12	2.30	16.88	2.48	-	-	0.84
			Average 3	22.93	30.64	21.05	3.69	21.11	2.30	16.87	2.47			0.84
		3	5	22.94	30.60	20.98	3.80	21.16	2.20	16.80	2.48	-	-	0.84
		3	5	22.94	30.62	21.00	3.80	21.14	2.20	16.80	2.50	-	-	0.84
		3	5	22.92	30.60	20.98	3.82	21.14	2.20	16.80	2.48	-	-	0.84
			Average 5	22.93	30.61	20.99	3.81	21.15	2.20	16.80	2.49			0.84
			I1 Average	22.91	30.58	21.02	3.71	21.10	2.28	16.80	2.48			0.83
			I2 + I3 Average	22.94	30.61	21.01	3.74	21.11	2.25	16.84	2.52			0.84
	I Average			22.93	30.60	21.02	3.73	21.11	2.26	16.83	2.50			0.84
Jam	J	1	1	22.72	30.44	18.50	4.60	20.80	2.30	7.80	2.50	7.42	2.62	None
		1	1	22.72	30.45	18.50	4.62	20.80	2.30	7.82	2.50	7.40	2.62	None
		1	1	22.70	30.45	18.48	4.60	20.78	2.30	7.82	2.52	7.42	2.60	None
			Average 1	22.71	30.45	18.49	4.61	20.79	2.30	7.81	2.51	7.41	2.61	
		1	3	22.74	30.58	19.35	4.38	20.20	2.40	7.84	2.20	7.30	2.20	None
		1	3	22.74	30.58	19.38	4.38	20.20	2.40	7.86	2.18	7.32	2.20	None
		1	3	22.76	30.58	19.38	4.40	20.20	2.40	7.86	2.18	7.32	2.20	None
			Average 3	22.75	30.58	19.37	4.39	20.20	2.40	7.85	2.19	7.31	2.20	
		1	5	22.80	30.50	18.28	4.62	20.70	2.28	7.90	2.56	7.40	2.50	None
		1	5	22.80	30.52	18.26	4.62	20.68	2.30	7.90	2.58	7.40	2.48	None
		1	5	22.80	30.50	18.28	4.62	20.70	2.30	7.88	2.58	7.40	2.48	None
			Average 5	22.80	30.51	18.27	4.62	20.69	2.29	7.89	2.57	7.40	2.49	
		2	1	22.75	30.56	18.35	4.55	20.80	2.30	7.84	2.30	7.42	2.32	None
		2	1	22.76	30.55	18.32	4.54	20.82	2.30	7.86	2.30	7.44	2.30	None
		2	1	22.75	30.56	18.35	4.54	20.82	2.30	7.86	2.30	7.44	2.30	None
			Average 1	22.75	30.56	18.34	4.54	20.81	2.30	7.85	2.30	7.43	2.31	
		2	3	22.75	30.55	18.32	4.65	20.92	2.24	7.82	2.40	7.38	2.40	None
		2	3	22.75	30.56	18.30	4.65	20.94	2.22	7.80	2.42	7.36	2.42	None
		2	3	22.74	30.58	18.32	4.66	20.92	2.24	7.82	2.40	7.38	2.40	None
			Average 3	22.75	30.56	18.31	4.65	20.93	2.23	7.81	2.41	7.37	2.41	
		2	5	22.78	30.55	18.65	4.52	20.65	2.30	7.84	2.40	7.36	2.36	None
		2	5	22.78	30.55	18.65	4.52	20.65	2.30	7.86	2.38	7.38	2.38	None
		2	5	22.80	30.56	18.64	4.52	20.64	2.32	7.84	2.40	7.38	2.38	None
			Average 5	22.79	30.55	18.65	4.52	20.65	2.31	7.85	2.39	7.37	2.37	

Brand	Letter	Box	Envelope #	EW (cm)	EL (cm)	FUW (cm)	FH (cm)	LFUW (cm)	LFH (cm)	Adh. 1 width (cm)	Adh. 1 height (cm)	Adh. 2 width (cm)	Adh. 2 height (cm)	Clasp hole diameter (cm)
Jam	J	3	1	22.80	30.58	19.35	4.45	20.50	2.40	7.82	2.12	7.38	2.18	None
		3	1	22.82	30.58	19.36	4.44	20.52	2.40	7.85	2.12	7.40	2.18	None
		3	1	22.80	30.56	19.35	4.44	20.50	2.40	7.85	2.10	7.40	2.20	None
			Average 1	22.81	30.57	19.35	4.44	20.51	2.40	7.84	2.11	7.39	2.19	
		3	3	22.80	30.50	18.50	4.60	20.75	2.30	7.82	2.46	7.40	2.45	None
		3	3	22.80	30.52	18.50	4.60	20.75	2.30	7.82	2.46	7.40	2.46	None
		3	3	22.80	30.50	18.48	4.58	20.76	2.30	7.82	2.45	7.42	2.46	None
			Average 3	22.80	30.51	18.49	4.59	20.75	2.30	7.82	2.46	7.41	2.46	
		3	5	22.80	30.46	19.04	4.50	20.30	2.40	7.85	2.18	7.40	2.22	None
		3	5	22.80	30.48	19.00	4.50	20.28	2.40	7.86	2.18	7.40	2.22	None
		3	5	22.80	30.48	19.02	4.50	20.30	2.40	7.86	2.20	7.40	2.20	None
			Average 5	22.80	30.47	19.02	4.50	20.29	2.40	7.86	2.19	7.40	2.21	
	J Average			22.77	30.53	18.70	4.54	20.63	2.33	7.84	2.35	7.39	2.36	

Table 32. Physical measurement results obtained in triplicate for every envelope analyzed from every brand

APPENDIX IX

Thickness measurements of all brands

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
Staples	A	1	1	1	0.18	0.17	0.17	0.17
	A	1	1	2	0.17	0.16	0.17	0.17
	A	1	1	3	0.16	0.16	0.17	0.16
	A	1	2	1	0.17	0.17	0.17	0.17
	A	1	2	2	0.18	0.17	0.17	0.17
	A	1	2	3	0.17	0.16	0.17	0.17
	A	1	3	1	0.16	0.17	0.16	0.16
	A	1	3	2	0.16	0.16	0.16	0.16
	A	1	3	3	0.16	0.16	0.16	0.16
	A	1	4	1	0.17	0.17	0.17	0.17
	A	1	4	2	0.17	0.17	0.16	0.17
	A	1	4	3	0.17	0.17	0.16	0.17
	A	1	5	1	0.16	0.16	0.16	0.16
	A	1	5	2	0.17	0.16	0.17	0.17
	A	1	5	3	0.16	0.16	0.16	0.16
	A	2	1	1	0.17	0.17	0.16	0.17
	A	2	1	2	0.16	0.16	0.16	0.16
	A	2	1	3	0.16	0.16	0.16	0.16
	A	2	2	1	0.17	0.17	0.17	0.17
	A	2	2	2	0.16	0.16	0.16	0.16
	A	2	2	3	0.16	0.17	0.17	0.17
	A	2	3	1	0.16	0.16	0.16	0.16
	A	2	3	2	0.16	0.16	0.16	0.16
	A	2	3	3	0.15	0.16	0.15	0.15
	A	2	4	1	0.17	0.16	0.16	0.16
	A	2	4	2	0.16	0.16	0.16	0.16
	A	2	4	3	0.16	0.16	0.16	0.16
	A	2	5	1	0.16	0.16	0.16	0.16
	A	2	5	2	0.16	0.16	0.16	0.16
	A	2	5	3	0.16	0.16	0.15	0.16
	A	3	1	1	0.17	0.17	0.16	0.17

Brand	Brand #	Box #	Envelope #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	A	3	1	2	0.16	0.16	0.16	0.16
	A	3	1	3	0.16	0.16	0.16	0.16
	A	3	2	1	0.17	0.17	0.17	0.17
	A	3	2	2	0.17	0.17	0.17	0.17
	A	3	2	3	0.17	0.17	0.17	0.17
	A	3	3	1	0.17	0.18	0.18	0.18
	A	3	3	2	0.17	0.17	0.17	0.17
	A	3	3	3	0.16	0.17	0.16	0.16
	A	3	4	1	0.16	0.16	0.16	0.16
	A	3	4	2	0.16	0.16	0.16	0.16
	A	3	4	3	0.16	0.16	0.15	0.16
	A	3	5	1	0.16	0.17	0.17	0.17
	A	3	5	2	0.16	0.16	0.16	0.16
	A	3	5	3	0.16	0.16	0.16	0.16
WB Mason	B	1	1	1	0.14	0.14	0.14	0.14
	B	1	1	2	0.14	0.14	0.14	0.14
	B	1	1	3	0.14	0.14	0.14	0.14
	B	1	2	1	0.15	0.14	0.14	0.14
	B	1	2	2	0.14	0.14	0.14	0.14
	B	1	2	3	0.14	0.14	0.14	0.14
	B	1	3	1	0.14	0.15	0.15	0.15
	B	1	3	2	0.14	0.14	0.14	0.14
	B	1	3	3	0.14	0.14	0.14	0.14
	B	1	4	1	0.14	0.14	0.14	0.14
	B	1	4	2	0.14	0.14	0.14	0.14
	B	1	4	3	0.15	0.15	0.14	0.15
	B	1	5	1	0.15	0.14	0.14	0.14
	B	1	5	2	0.14	0.14	0.14	0.14
	B	1	5	3	0.14	0.14	0.14	0.14
	B	2	1	1	0.14	0.14	0.14	0.14
	B	2	1	2	0.14	0.14	0.14	0.14
	B	2	1	3	0.13	0.14	0.14	0.14
	B	2	2	1	0.14	0.14	0.14	0.14
	B	2	2	2	0.14	0.13	0.14	0.14

Brand	Brand #	Box #	Envelope #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	B	2	2	3	0.13	0.14	0.13	0.13
	B	2	3	1	0.14	0.14	0.14	0.14
	B	2	3	2	0.14	0.14	0.13	0.14
	B	2	3	3	0.14	0.14	0.14	0.14
	B	2	4	1	0.14	0.14	0.14	0.14
	B	2	4	2	0.14	0.14	0.14	0.14
	B	2	4	3	0.14	0.14	0.14	0.14
	B	2	5	1	0.14	0.14	0.14	0.14
	B	2	5	2	0.14	0.14	0.14	0.14
	B	2	5	3	0.14	0.14	0.14	0.14
	B	3	1	1	0.14	0.14	0.14	0.14
	B	3	1	2	0.14	0.14	0.14	0.14
	B	3	1	3	0.14	0.13	0.13	0.13
	B	3	2	1	0.14	0.14	0.14	0.14
	B	3	2	2	0.14	0.14	0.14	0.14
	B	3	2	3	0.14	0.14	0.14	0.14
	B	3	3	1	0.15	0.15	0.15	0.15
	B	3	3	2	0.15	0.14	0.14	0.14
	B	3	3	3	0.14	0.14	0.14	0.14
	B	3	4	1	0.15	0.15	0.14	0.15
	B	3	4	2	0.14	0.14	0.14	0.14
	B	3	4	3	0.14	0.14	0.14	0.14
	B	3	5	1	0.14	0.14	0.14	0.14
	B	3	5	2	0.14	0.14	0.14	0.14
	B	3	5	3	0.14	0.14	0.14	0.14
Office Depot	C	1	1	1	0.16	0.15	0.15	0.15
	C	1	1	2	0.15	0.16	0.15	0.15
	C	1	1	3	0.15	0.15	0.15	0.15
	C	1	2	1	0.15	0.15	0.15	0.15
	C	1	2	2	0.15	0.15	0.15	0.15
	C	1	2	3	0.15	0.15	0.15	0.15
	C	1	3	1	0.15	0.15	0.15	0.15
	C	1	3	2	0.15	0.15	0.15	0.15
	C	1	3	3	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Envelope #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	C	1	4	1	0.16	0.16	0.15	0.16
	C	1	4	2	0.16	0.16	0.16	0.16
	C	1	4	3	0.15	0.15	0.15	0.15
	C	1	5	1	0.15	0.15	0.15	0.15
	C	1	5	2	0.16	0.15	0.16	0.16
	C	1	5	3	0.15	0.15	0.15	0.15
	C	2	1	1	0.16	0.16	0.16	0.16
	C	2	1	2	0.15	0.15	0.15	0.15
	C	2	1	3	0.15	0.15	0.15	0.15
	C	2	2	1	0.16	0.16	0.16	0.16
	C	2	2	2	0.16	0.16	0.15	0.16
	C	2	2	3	0.15	0.15	0.15	0.15
	C	2	3	1	0.16	0.15	0.15	0.15
	C	2	3	2	0.15	0.15	0.15	0.15
	C	2	3	3	0.15	0.15	0.15	0.15
	C	2	4	1	0.15	0.15	0.15	0.15
	C	2	4	2	0.15	0.15	0.15	0.15
	C	2	4	3	0.15	0.15	0.15	0.15
	C	2	5	1	0.15	0.15	0.15	0.15
	C	2	5	2	0.16	0.15	0.15	0.15
	C	2	5	3	0.15	0.15	0.16	0.15
	C	3	1	1	0.15	0.15	0.15	0.15
	C	3	1	2	0.15	0.15	0.15	0.15
	C	3	1	3	0.15	0.15	0.15	0.15
	C	3	2	1	0.15	0.15	0.15	0.15
	C	3	2	2	0.15	0.15	0.15	0.15
	C	3	2	3	0.15	0.15	0.15	0.15
	C	3	3	1	0.15	0.15	0.15	0.15
	C	3	3	2	0.15	0.15	0.15	0.15
	C	3	3	3	0.15	0.15	0.15	0.15
	C	3	4	1	0.15	0.15	0.15	0.15
	C	3	4	2	0.15	0.15	0.16	0.15
	C	3	4	3	0.15	0.15	0.15	0.15
	C	3	5	1	0.15	0.16	0.15	0.15
	C	3	5	2	0.15	0.15	0.16	0.15
	C	3	5	3	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
Quality Park	D	1	1	1	0.16	0.16	0.15	0.16
	D	1	1	2	0.16	0.15	0.15	0.15
	D	1	1	3	0.15	0.15	0.15	0.15
	D	1	2	1	0.15	0.16	0.16	0.16
	D	1	2	2	0.16	0.16	0.16	0.16
	D	1	2	3	0.15	0.15	0.15	0.15
	D	1	3	1	0.16	0.15	0.15	0.15
	D	1	3	2	0.15	0.15	0.15	0.15
	D	1	3	3	0.15	0.15	0.15	0.15
	D	1	4	1	0.16	0.16	0.16	0.16
	D	1	4	2	0.16	0.16	0.16	0.16
	D	1	4	3	0.16	0.15	0.15	0.15
	D	1	5	1	0.16	0.16	0.16	0.16
	D	1	5	2	0.15	0.15	0.15	0.15
	D	1	5	3	0.15	0.15	0.15	0.15
	D	2	1	1	0.16	0.16	0.16	0.16
	D	2	1	2	0.16	0.16	0.16	0.16
	D	2	1	3	0.16	0.16	0.16	0.16
	D	2	2	1	0.16	0.16	0.16	0.16
	D	2	2	2	0.15	0.16	0.16	0.16
	D	2	2	3	0.16	0.16	0.15	0.16
	D	2	3	1	0.16	0.16	0.16	0.16
	D	2	3	2	0.16	0.16	0.16	0.16
	D	2	3	3	0.16	0.16	0.16	0.16
	D	2	4	1	0.15	0.15	0.15	0.15
	D	2	4	2	0.16	0.16	0.16	0.16
	D	2	4	3	0.15	0.15	0.15	0.15
	D	2	5	1	0.16	0.15	0.15	0.15
	D	2	5	2	0.15	0.15	0.15	0.15
	D	2	5	3	0.15	0.16	0.15	0.15
	D	3	1	1	0.16	0.15	0.15	0.15
	D	3	1	2	0.16	0.16	0.16	0.16
	D	3	1	3	0.16	0.15	0.15	0.15
	D	3	2	1	0.16	0.16	0.16	0.16
	D	3	2	2	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	D	3	2	3	0.15	0.16	0.15	0.15
	D	3	3	1	0.15	0.15	0.15	0.15
	D	3	3	2	0.15	0.15	0.15	0.15
	D	3	3	3	0.15	0.15	0.15	0.15
	D	3	4	1	0.16	0.16	0.16	0.16
	D	3	4	2	0.16	0.15	0.15	0.15
	D	3	4	3	0.16	0.15	0.15	0.15
	D	3	5	1	0.16	0.16	0.16	0.16
	D	3	5	2	0.16	0.15	0.16	0.16
	D	3	5	3	0.15	0.16	0.16	0.16
Columbian	E	1	1	1	0.17	0.17	0.17	0.17
	E	1	1	2	0.18	0.18	0.18	0.18
	E	1	1	3	0.18	0.18	0.18	0.18
	E	1	2	1	0.18	0.18	0.18	0.18
	E	1	2	2	0.18	0.17	0.17	0.17
	E	1	2	3	0.18	0.18	0.18	0.18
	E	1	3	1	0.18	0.18	0.18	0.18
	E	1	3	2	0.17	0.17	0.17	0.17
	E	1	3	3	0.17	0.17	0.17	0.17
	E	1	4	1	0.18	0.18	0.18	0.18
	E	1	4	2	0.17	0.17	0.17	0.17
	E	1	4	3	0.18	0.18	0.18	0.18
	E	1	5	1	0.17	0.17	0.18	0.17
	E	1	5	2	0.18	0.18	0.18	0.18
	E	1	5	3	0.17	0.17	0.17	0.17
	E	2	1	1	0.17	0.17	0.17	0.17
	E	2	1	2	0.17	0.17	0.17	0.17
	E	2	1	3	0.17	0.17	0.17	0.17
	E	2	2	1	0.17	0.17	0.17	0.17
	E	2	2	2	0.18	0.18	0.18	0.18
	E	2	2	3	0.18	0.18	0.18	0.18
	E	2	3	1	0.18	0.17	0.17	0.17
	E	2	3	2	0.18	0.18	0.17	0.18
	E	2	3	3	0.17	0.17	0.17	0.17

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	E	2	4	1	0.17	0.17	0.17	0.17
	E	2	4	2	0.18	0.18	0.18	0.18
	E	2	4	3	0.18	0.18	0.18	0.18
	E	2	5	1	0.18	0.17	0.18	0.18
	E	2	5	2	0.17	0.17	0.17	0.17
	E	2	5	3	0.17	0.17	0.17	0.17
	E	3	1	1	0.18	0.18	0.18	0.18
	E	3	1	2	0.18	0.18	0.18	0.18
	E	3	1	3	0.18	0.18	0.18	0.18
	E	3	2	1	0.18	0.18	0.18	0.18
	E	3	2	2	0.18	0.18	0.18	0.18
	E	3	2	3	0.18	0.18	0.18	0.18
	E	3	3	1	0.18	0.18	0.18	0.18
	E	3	3	2	0.18	0.18	0.18	0.18
	E	3	3	3	0.17	0.17	0.17	0.17
	E	3	4	1	0.17	0.17	0.18	0.17
	E	3	4	2	0.17	0.17	0.17	0.17
	E	3	4	3	0.17	0.17	0.17	0.17
	E	3	5	1	0.18	0.17	0.18	0.18
	E	3	5	2	0.18	0.18	0.18	0.18
	E	3	5	3	0.18	0.18	0.17	0.18
Business Source	F	1	1	1	0.16	0.16	0.16	0.16
	F	1	1	2	0.16	0.16	0.16	0.16
	F	1	1	3	0.16	0.16	0.15	0.16
	F	1	2	1	0.16	0.16	0.16	0.16
	F	1	2	2	0.15	0.15	0.15	0.15
	F	1	2	3	0.16	0.16	0.16	0.16
	F	1	3	1	0.15	0.15	0.16	0.15
	F	1	3	2	0.15	0.15	0.15	0.15
	F	1	3	3	0.15	0.15	0.15	0.15
	F	1	4	1	0.15	0.15	0.15	0.15
	F	1	4	2	0.15	0.15	0.15	0.15
	F	1	4	3	0.15	0.15	0.15	0.15
	F	1	5	1	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	F	1	5	2	0.15	0.15	0.15	0.15
	F	1	5	3	0.15	0.15	0.15	0.15
	F	2	1	1	0.16	0.16	0.16	0.16
	F	2	1	2	0.16	0.15	0.15	0.15
	F	2	1	3	0.16	0.16	0.15	0.16
	F	2	2	1	0.16	0.16	0.16	0.16
	F	2	2	2	0.15	0.15	0.15	0.15
	F	2	2	3	0.16	0.16	0.16	0.16
	F	2	3	1	0.16	0.16	0.16	0.16
	F	2	3	2	0.16	0.16	0.16	0.16
	F	2	3	3	0.15	0.15	0.15	0.15
	F	2	4	1	0.15	0.15	0.15	0.15
	F	2	4	2	0.16	0.16	0.16	0.16
	F	2	4	3	0.16	0.15	0.15	0.15
	F	2	5	1	0.15	0.15	0.15	0.15
	F	2	5	2	0.15	0.15	0.15	0.15
	F	2	5	3	0.15	0.15	0.15	0.15
	F	3	1	1	0.15	0.15	0.15	0.15
	F	3	1	2	0.15	0.15	0.15	0.15
	F	3	1	3	0.15	0.15	0.15	0.15
	F	3	2	1	0.15	0.15	0.15	0.15
	F	3	2	2	0.15	0.15	0.15	0.15
	F	3	2	3	0.15	0.15	0.15	0.15
	F	3	3	1	0.15	0.15	0.15	0.15
	F	3	3	2	0.15	0.15	0.15	0.15
	F	3	3	3	0.15	0.15	0.15	0.15
	F	3	4	1	0.15	0.15	0.15	0.15
	F	3	4	2	0.15	0.15	0.15	0.15
	F	3	4	3	0.15	0.15	0.15	0.15
	F	3	5	1	0.15	0.15	0.15	0.15
	F	3	5	2	0.15	0.15	0.15	0.15
	F	3	5	3	0.15	0.15	0.15	0.15
Amazon Basics	G	1	1	1	0.15	0.15	0.15	0.15
	G	1	1	2	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	G	1	1	3	0.15	0.15	0.15	0.15
	G	1	2	1	0.15	0.15	0.15	0.15
	G	1	2	2	0.15	0.15	0.15	0.15
	G	1	2	3	0.16	0.15	0.15	0.15
	G	1	3	1	0.16	0.16	0.15	0.16
	G	1	3	2	0.15	0.15	0.15	0.15
	G	1	3	3	0.16	0.15	0.15	0.15
	G	1	4	1	0.15	0.15	0.15	0.15
	G	1	4	2	0.15	0.15	0.15	0.15
	G	1	4	3	0.15	0.15	0.15	0.15
	G	1	5	1	0.15	0.15	0.15	0.15
	G	1	5	2	0.15	0.15	0.15	0.15
	G	1	5	3	0.15	0.15	0.15	0.15
	G	2	1	1	0.15	0.15	0.15	0.15
	G	2	1	2	0.15	0.15	0.15	0.15
	G	2	1	3	0.15	0.15	0.15	0.15
	G	2	2	1	0.15	0.15	0.15	0.15
	G	2	2	2	0.15	0.15	0.15	0.15
	G	2	2	3	0.15	0.15	0.15	0.15
	G	2	3	1	0.15	0.15	0.15	0.15
	G	2	3	2	0.15	0.15	0.15	0.15
	G	2	3	3	0.15	0.15	0.15	0.15
	G	2	4	1	0.15	0.15	0.15	0.15
	G	2	4	2	0.16	0.16	0.15	0.16
	G	2	4	3	0.15	0.15	0.15	0.15
	G	2	5	1	0.15	0.15	0.15	0.15
	G	2	5	2	0.15	0.15	0.15	0.15
	G	2	5	3	0.15	0.15	0.15	0.15
	G	3	1	1	0.15	0.15	0.15	0.15
	G	3	1	2	0.15	0.15	0.15	0.15
	G	3	1	3	0.15	0.15	0.15	0.15
	G	3	2	1	0.15	0.15	0.15	0.15
	G	3	2	2	0.15	0.15	0.15	0.15
	G	3	2	3	0.15	0.15	0.15	0.15
	G	3	3	1	0.15	0.15	0.15	0.15
	G	3	3	2	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	G	3	3	3	0.15	0.15	0.15	0.15
	G	3	4	1	0.15	0.15	0.15	0.15
	G	3	4	2	0.15	0.15	0.15	0.15
	G	3	4	3	0.15	0.15	0.15	0.15
	G	3	5	1	0.15	0.15	0.15	0.15
	G	3	5	2	0.15	0.15	0.15	0.15
	G	3	5	3	0.15	0.15	0.15	0.15
Check-O-Matic	H	1	1	1	0.15	0.15	0.15	0.15
	H	1	1	2	0.15	0.14	0.14	0.14
	H	1	1	3	0.15	0.15	0.15	0.15
	H	1	2	1	0.15	0.15	0.15	0.15
	H	1	2	2	0.15	0.14	0.14	0.14
	H	1	2	3	0.15	0.15	0.15	0.15
	H	1	3	1	0.15	0.15	0.15	0.15
	H	1	3	2	0.15	0.15	0.15	0.15
	H	1	3	3	0.15	0.16	0.16	0.16
	H	1	4	1	0.15	0.15	0.15	0.15
	H	1	4	2	0.15	0.15	0.15	0.15
	H	1	4	3	0.15	0.15	0.15	0.15
	H	1	5	1	0.15	0.15	0.15	0.15
	H	1	5	2	0.15	0.15	0.15	0.15
	H	1	5	3	0.15	0.15	0.15	0.15
	H	2	1	1	0.15	0.15	0.15	0.15
	H	2	1	2	0.15	0.15	0.15	0.15
	H	2	1	3	0.16	0.15	0.15	0.15
	H	2	2	1	0.15	0.15	0.15	0.15
	H	2	2	2	0.15	0.15	0.15	0.15
	H	2	2	3	0.15	0.15	0.15	0.15
	H	2	3	1	0.15	0.15	0.15	0.15
	H	2	3	2	0.15	0.15	0.15	0.15
	H	2	3	3	0.15	0.15	0.15	0.15
	H	2	4	1	0.15	0.15	0.15	0.15
	H	2	4	2	0.15	0.15	0.15	0.15
	H	2	4	3	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	H	2	5	1	0.15	0.15	0.15	0.15
	H	2	5	2	0.14	0.14	0.14	0.14
	H	2	5	3	0.15	0.15	0.15	0.15
	H	3	1	1	0.15	0.15	0.15	0.15
	H	3	1	2	0.15	0.15	0.15	0.15
	H	3	1	3	0.15	0.15	0.15	0.15
	H	3	2	1	0.15	0.15	0.15	0.15
	H	3	2	2	0.15	0.15	0.15	0.15
	H	3	2	3	0.15	0.15	0.15	0.15
	H	3	3	1	0.15	0.15	0.15	0.15
	H	3	3	2	0.15	0.15	0.15	0.15
	H	3	3	3	0.15	0.15	0.15	0.15
	H	3	4	1	0.15	0.15	0.15	0.15
	H	3	4	2	0.15	0.15	0.15	0.15
	H	3	4	3	0.15	0.15	0.15	0.15
	H	3	5	1	0.15	0.15	0.15	0.15
	H	3	5	2	0.15	0.15	0.15	0.15
	H	3	5	3	0.15	0.15	0.15	0.15
Mead	I	1	1	1	0.14	0.14	0.14	0.14
	I	1	1	2	0.14	0.14	0.14	0.14
	I	1	1	3	0.14	0.14	0.14	0.14
	I	1	2	1	0.14	0.14	0.14	0.14
	I	1	2	2	0.14	0.14	0.14	0.14
	I	1	2	3	0.15	0.15	0.14	0.15
	I	1	3	1	0.14	0.14	0.14	0.14
	I	1	3	2	0.13	0.14	0.13	0.13
	I	1	3	3	0.13	0.13	0.13	0.13
	I	1	4	1	0.13	0.13	0.13	0.13
	I	1	4	2	0.13	0.13	0.13	0.13
	I	1	4	3	0.13	0.13	0.13	0.13
	I	1	5	1	0.14	0.14	0.14	0.14
	I	1	5	2	0.13	0.13	0.13	0.13
	I	1	5	3	0.14	0.14	0.14	0.14
	I	2	1	1	0.14	0.14	0.14	0.14
	I	2	1	2	0.14	0.14	0.14	0.14

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	I	2	1	3	0.14	0.14	0.14	0.14
	I	2	2	1	0.14	0.14	0.14	0.14
	I	2	2	2	0.14	0.14	0.14	0.14
	I	2	2	3	0.14	0.14	0.14	0.14
	I	2	3	1	0.14	0.14	0.15	0.14
	I	2	3	2	0.14	0.14	0.14	0.14
	I	2	3	3	0.13	0.13	0.14	0.13
	I	2	4	1	0.14	0.14	0.14	0.14
	I	2	4	2	0.14	0.14	0.14	0.14
	I	2	4	3	0.14	0.13	0.13	0.13
	I	2	5	1	0.14	0.14	0.14	0.14
	I	2	5	2	0.14	0.14	0.14	0.14
	I	2	5	3	0.14	0.14	0.14	0.14
	I	3	1	1	0.14	0.14	0.14	0.14
	I	3	1	2	0.13	0.13	0.13	0.13
	I	3	1	3	0.14	0.14	0.14	0.14
	I	3	2	1	0.14	0.14	0.14	0.14
	I	3	2	2	0.14	0.13	0.13	0.13
	I	3	2	3	0.14	0.14	0.14	0.14
	I	3	3	1	0.14	0.14	0.14	0.14
	I	3	3	2	0.13	0.13	0.13	0.13
	I	3	3	3	0.14	0.14	0.14	0.14
	I	3	4	1	0.13	0.13	0.13	0.13
	I	3	4	2	0.13	0.13	0.13	0.13
	I	3	4	3	0.14	0.14	0.14	0.14
	I	3	5	1	0.14	0.14	0.14	0.14
	I	3	5	2	0.14	0.14	0.14	0.14
	I	3	5	3	0.14	0.14	0.14	0.14
Jam	J	1	1	1	0.16	0.16	0.16	0.16
	J	1	1	2	0.15	0.15	0.15	0.15
	J	1	1	3	0.15	0.15	0.15	0.15
	J	1	2	1	0.16	0.16	0.16	0.16
	J	1	2	2	0.15	0.15	0.15	0.15
	J	1	2	3	0.15	0.16	0.15	0.15
	J	1	3	1	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	J	1	3	2	0.15	0.15	0.15	0.15
	J	1	3	3	0.16	0.15	0.15	0.15
	J	1	4	1	0.15	0.15	0.16	0.15
	J	1	4	2	0.15	0.15	0.15	0.15
	J	1	4	3	0.15	0.15	0.15	0.15
	J	1	5	1	0.16	0.16	0.15	0.16
	J	1	5	2	0.15	0.15	0.15	0.15
	J	1	5	3	0.15	0.15	0.15	0.15
	J	2	1	1	0.16	0.15	0.15	0.15
	J	2	1	2	0.15	0.15	0.15	0.15
	J	2	1	3	0.15	0.15	0.14	0.15
	J	2	2	1	0.14	0.14	0.14	0.14
	J	2	2	2	0.15	0.14	0.14	0.14
	J	2	2	3	0.15	0.15	0.15	0.15
	J	2	3	1	0.15	0.15	0.15	0.15
	J	2	3	2	0.15	0.15	0.15	0.15
	J	2	3	3	0.14	0.14	0.14	0.14
	J	2	4	1	0.15	0.15	0.15	0.15
	J	2	4	2	0.15	0.14	0.14	0.14
	J	2	4	3	0.14	0.14	0.14	0.14
	J	2	5	1	0.15	0.14	0.14	0.14
	J	2	5	2	0.14	0.14	0.14	0.14
	J	2	5	3	0.15	0.15	0.15	0.15
	J	3	1	1	0.15	0.15	0.15	0.15
	J	3	1	2	0.14	0.14	0.14	0.14
	J	3	1	3	0.15	0.15	0.15	0.15
	J	3	2	1	0.16	0.16	0.16	0.16
	J	3	2	2	0.15	0.15	0.15	0.15
	J	3	2	3	0.15	0.15	0.15	0.15
	J	3	3	1	0.15	0.15	0.15	0.15
	J	3	3	2	0.15	0.15	0.15	0.15
	J	3	3	3	0.15	0.16	0.15	0.15
	J	3	4	1	0.15	0.15	0.15	0.15
	J	3	4	2	0.16	0.15	0.15	0.15
	J	3	4	3	0.15	0.15	0.15	0.15
	J	3	5	1	0.15	0.15	0.15	0.15

Brand	Brand #	Box #	Env. #	Spot #	Thickness 1 (mm)	Thickness 2 (mm)	Thickness 3 (mm)	Thickness Average (mm)
	J	3	5	2	0.15	0.15	0.15	0.15
	J	3	5	3	0.15	0.15	0.15	0.15

Table 33. Thickness measurement results obtained for every envelope analyzed from every brand

APPENDIX X

Weight measurements for all brands

Brand	Brand #	Box #	Envelope #	Weight (g)
Staples	A	1	1	19
	A	1	2	20
	A	1	3	20
	A	1	4	19
	A	1	5	19
	A	2	1	19
	A	2	2	20
	A	2	3	20
	A	2	4	20
	A	2	5	20
	A	3	1	20
	A	3	2	19
	A	3	3	20
	A	3	4	20
	A	3	5	19
W.B.Mason	B	1	1	17
	B	1	2	17
	B	1	3	17
	B	1	4	17
	B	1	5	17
	B	2	1	17
	B	2	2	17
	B	2	3	17
	B	2	4	17
	B	2	5	17
	B	3	1	17
	B	3	2	17
	B	3	3	17
	B	3	4	17
	B	3	5	16
Office Depot	C	1	1	17

Brand	Brand #	Box #	Envelope #	Weight (g)
	C	1	2	17
	C	1	3	17
	C	1	4	17
	C	1	5	17
	C	2	1	17
	C	2	2	16
	C	2	3	16
	C	2	4	17
	C	2	5	16
	C	3	1	17
	C	3	2	17
	C	3	3	16
	C	3	4	16
	C	3	5	17
Quality Park	D	1	1	17
	D	1	2	17
	D	1	3	17
	D	1	4	17
	D	1	5	16
	D	2	1	18
	D	2	2	17
	D	2	3	18
	D	2	4	18
	D	2	5	17
	D	3	1	17
	D	3	2	16
	D	3	3	17
	D	3	4	17
	D	3	5	17
Columbian	E	1	1	18
	E	1	2	19
	E	1	3	19
	E	1	4	19
	E	1	5	19
	E	2	1	20

Brand	Brand #	Box #	Envelope #	Weight (g)
	E	2	2	19
	E	2	3	19
	E	2	4	19
	E	2	5	19
	E	3	1	19
	E	3	2	19
	E	3	3	20
	E	3	4	18
	E	3	5	19
Business Source	F	1	1	17
	F	1	2	17
	F	1	3	16
	F	1	4	17
	F	1	5	16
	F	2	1	17
	F	2	2	17
	F	2	3	17
	F	2	4	17
	F	2	5	17
	F	3	1	16
	F	3	2	17
	F	3	3	17
	F	3	4	17
	F	3	5	16
Amazon Basics	G	1	1	17
	G	1	2	16
	G	1	3	17
	G	1	4	17
	G	1	5	16
	G	2	1	17
	G	2	2	16
	G	2	3	17
	G	2	4	16
	G	2	5	17
	G	3	1	17

Brand	Brand #	Box #	Envelope #	Weight (g)
	G	3	2	17
	G	3	3	17
	G	3	4	17
	G	3	5	17
Check-O-Matic	H	1	1	17
	H	1	2	17
	H	1	3	18
	H	1	4	17
	H	1	5	18
	H	2	1	17
	H	2	2	17
	H	2	3	18
	H	2	4	18
	H	2	5	17
	H	3	1	18
	H	3	2	17
	H	3	3	18
	H	3	4	17
	H	3	5	17
Mead	I	1	1	16
	I	1	2	14
	I	1	3	16
	I	1	4	14
	I	1	5	15
	I	2	1	16
	I	2	2	15
	I	2	3	16
	I	2	4	15
	I	2	5	15
	I	3	1	16
	I	3	2	14
	I	3	3	16
	I	3	4	15
	I	3	5	15

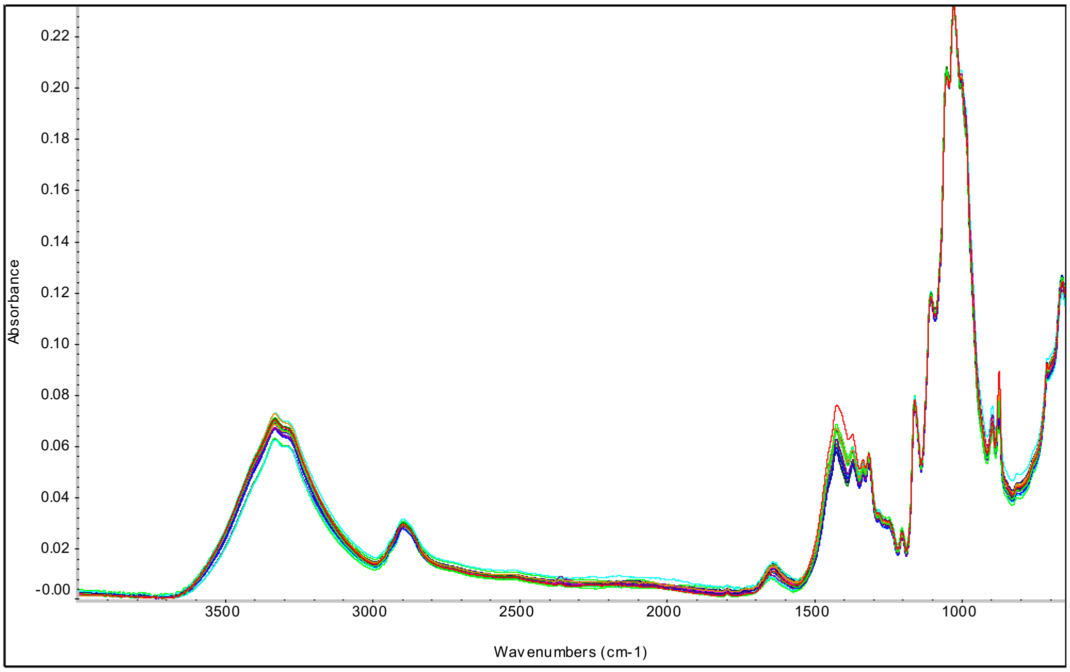
Brand	Brand #	Box #	Envelope #	Weight (g)
Jam	J	1	1	16
	J	1	2	17
	J	1	3	17
	J	1	4	16
	J	1	5	17
	J	2	1	16
	J	2	2	17
	J	2	3	17
	J	2	4	17
	J	2	5	16
	J	3	1	16
	J	3	2	17
	J	3	3	17
	J	3	4	17
	J	3	5	16

Table 34. Weight measurement results obtained for every envelope analyzed from every brand

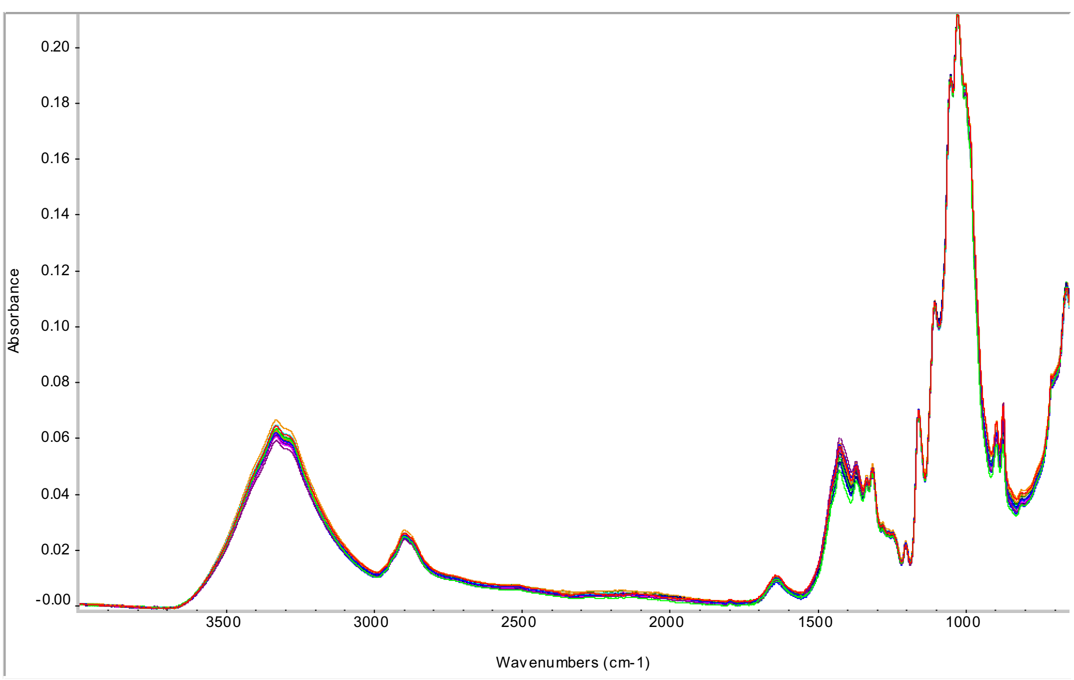
APPENDIX XI

ATR FT-IR Spectroscopy Spectra Results

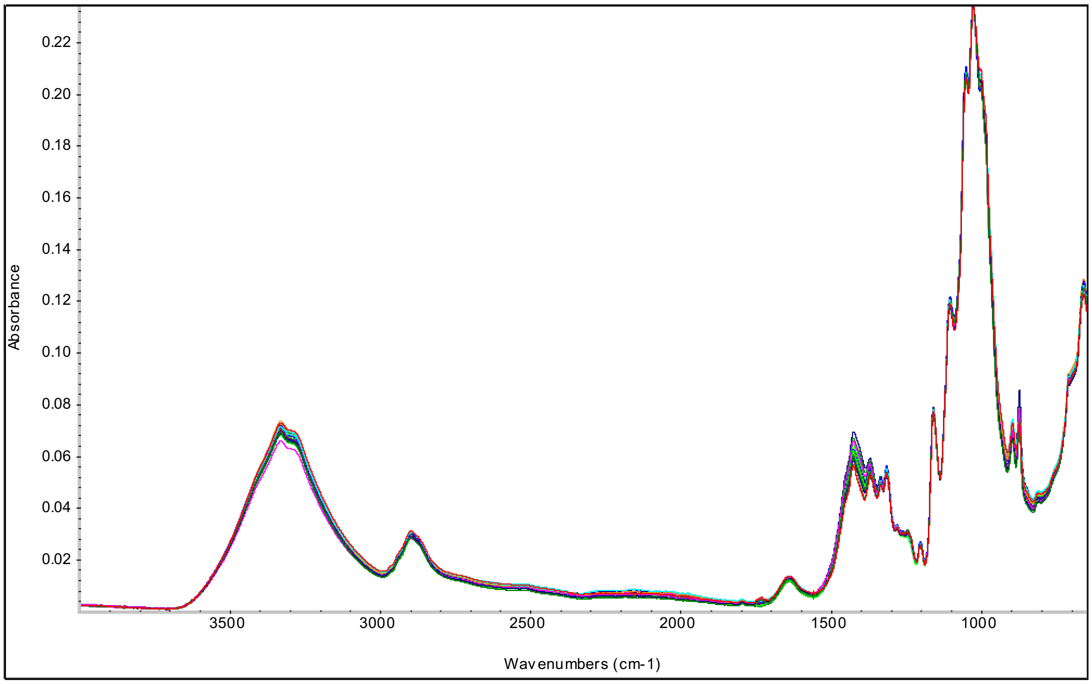
A-1 – Variation in spectra within box A-1 (5 envelopes, 4 spots)



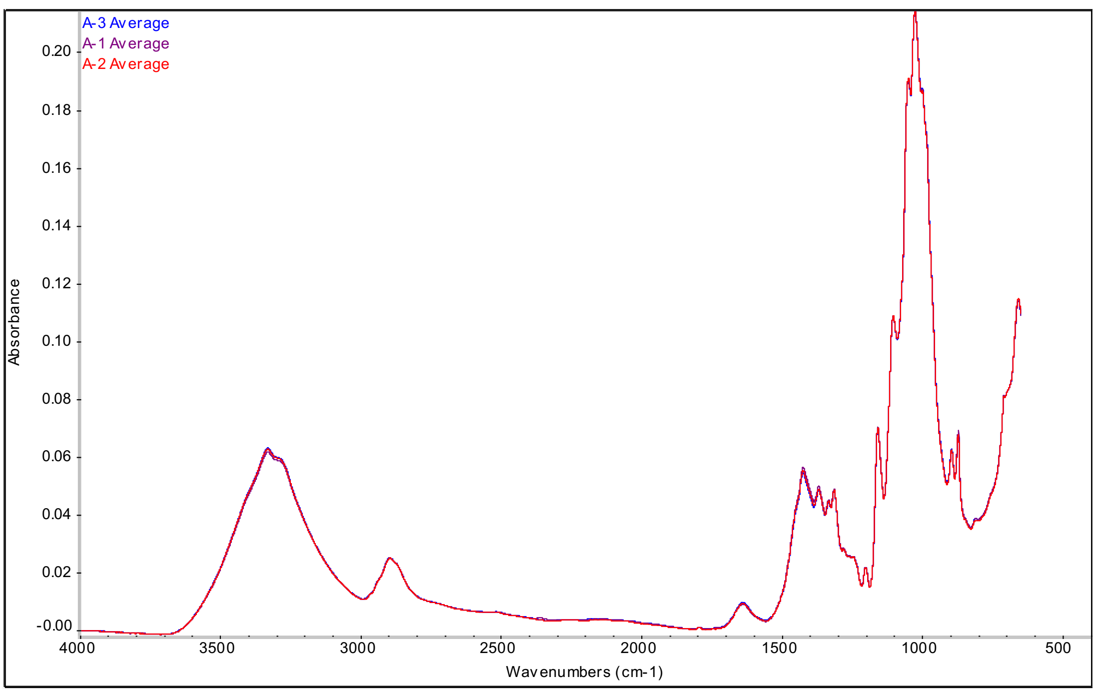
A-2 – Variation in spectra within box A-2 (5 envelopes, 4 spots)



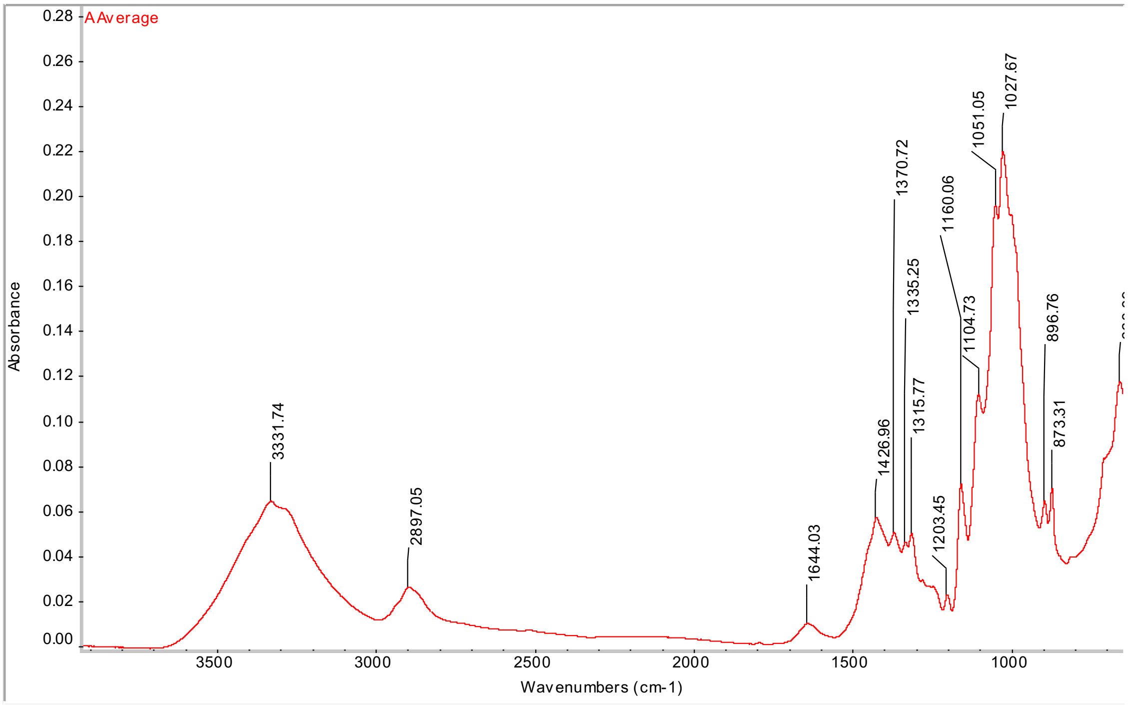
A-3 – Variation in spectra within box A-3 (5 envelopes, 4 spots)



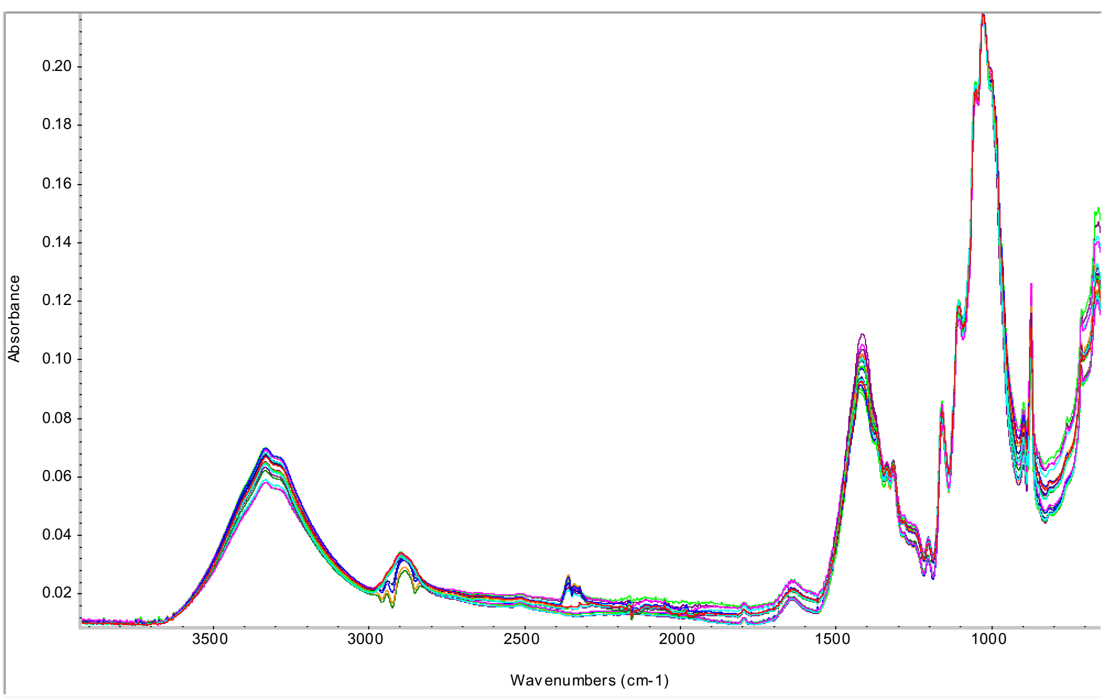
ATR-FT-IR BOX A AVERAGES



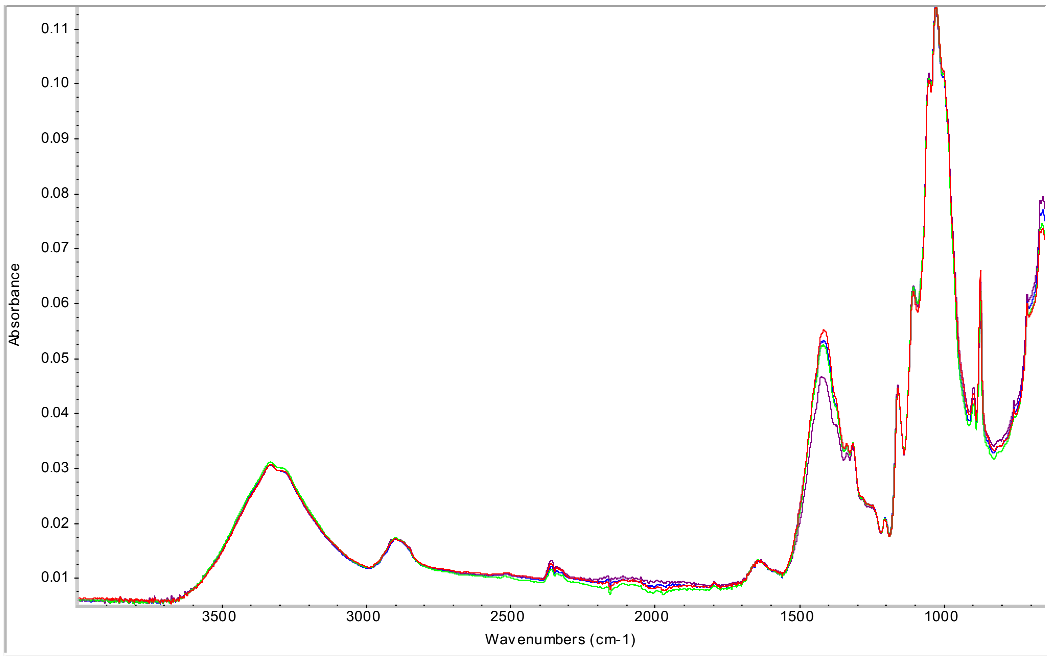
AVERAGE SPECTRA FOR BRAND A



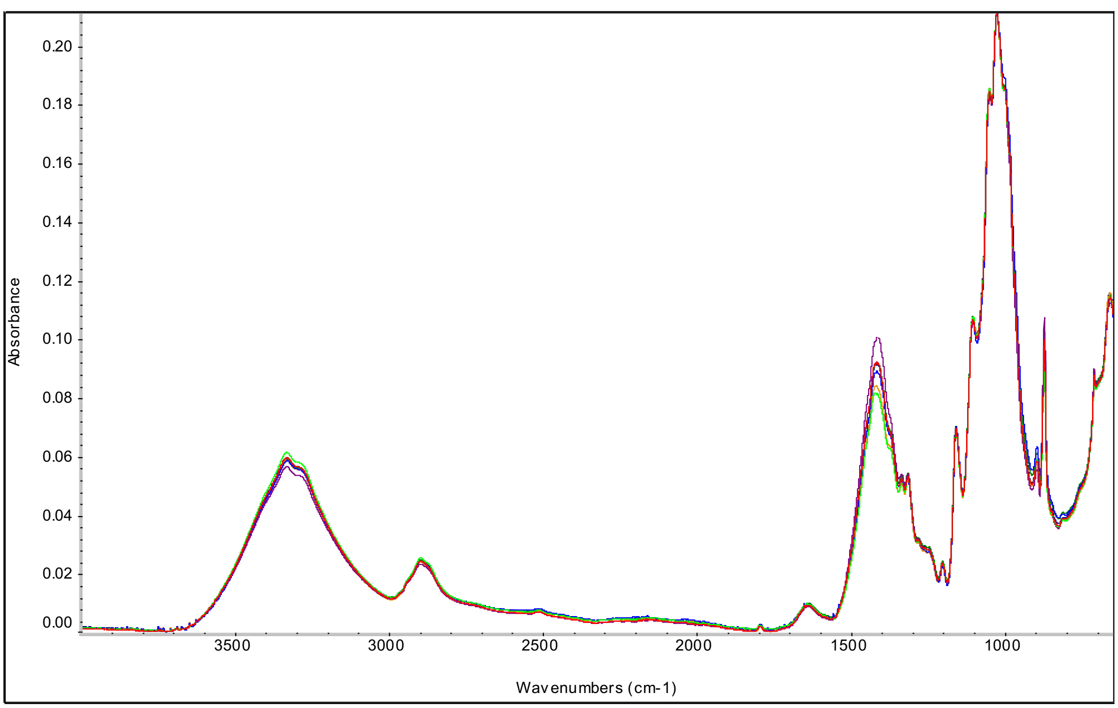
B-1 – Variation in spectra within box B-1 (5 envelopes, 4 spots)



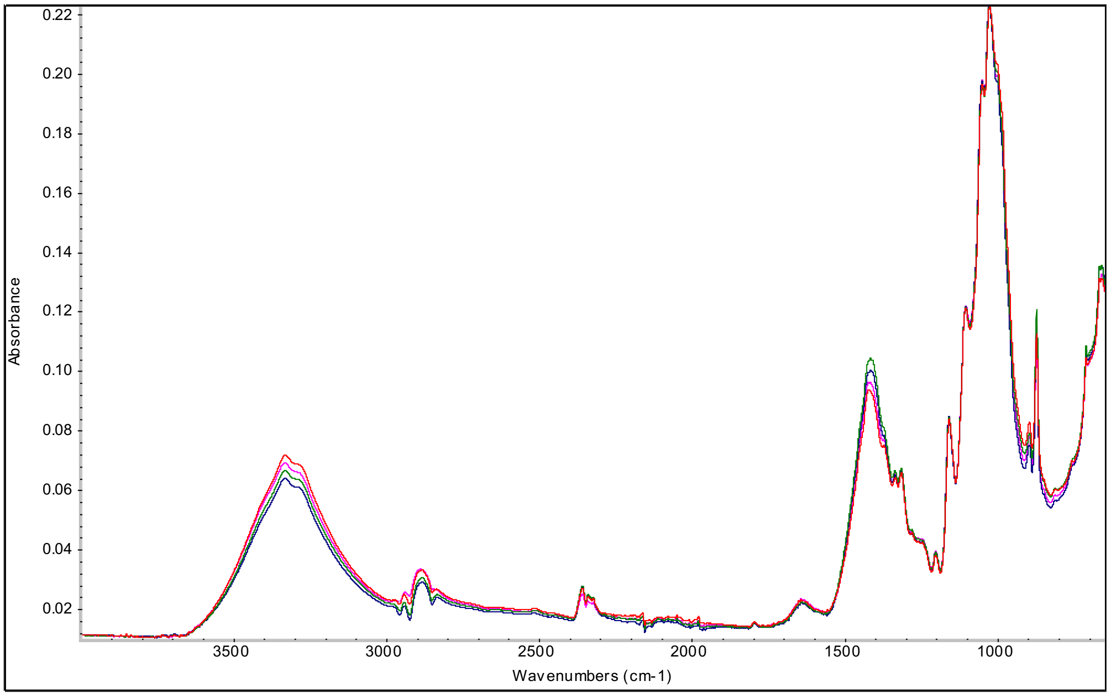
B-1-1 – Variation in spectra in envelope 1 within box 1 (4 spots)



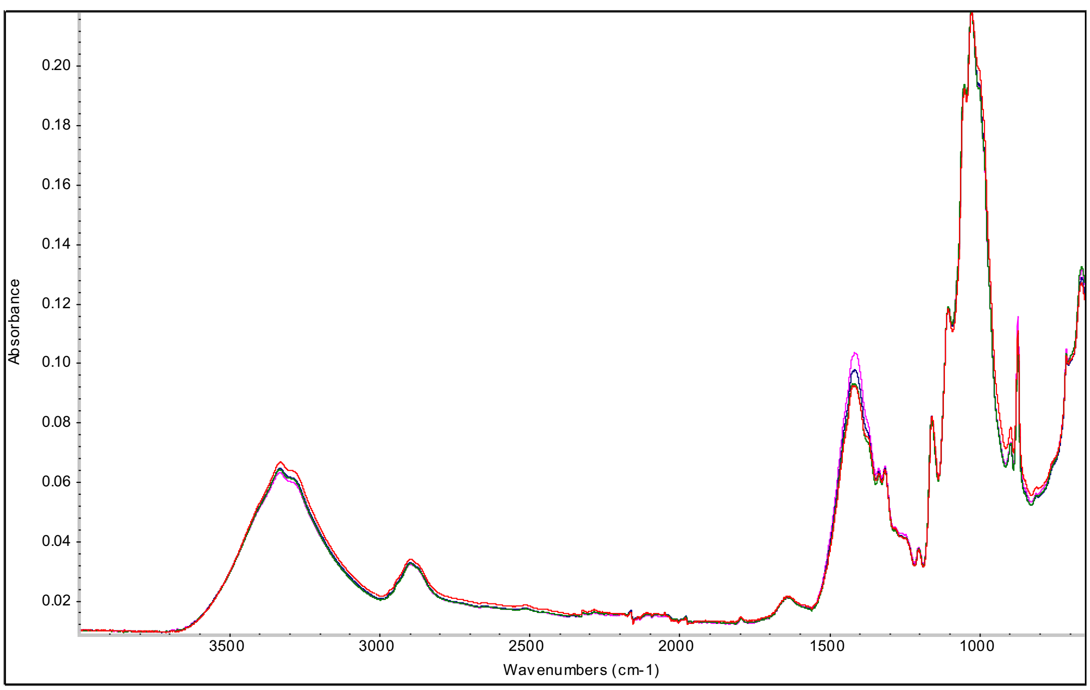
B-1-2 and B-1-3 - Variation in spectra in envelopes 2 and 3 within box 1 (4 spots)



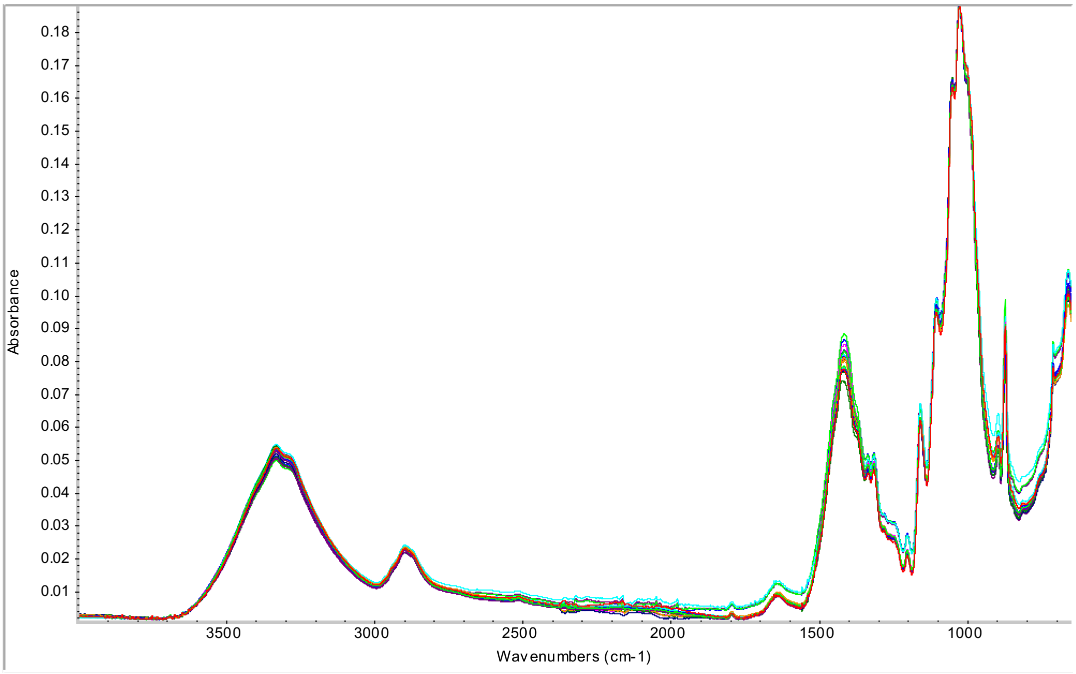
B-1-4 - Variation in spectra in envelope 4 within box 1 (4 spots)



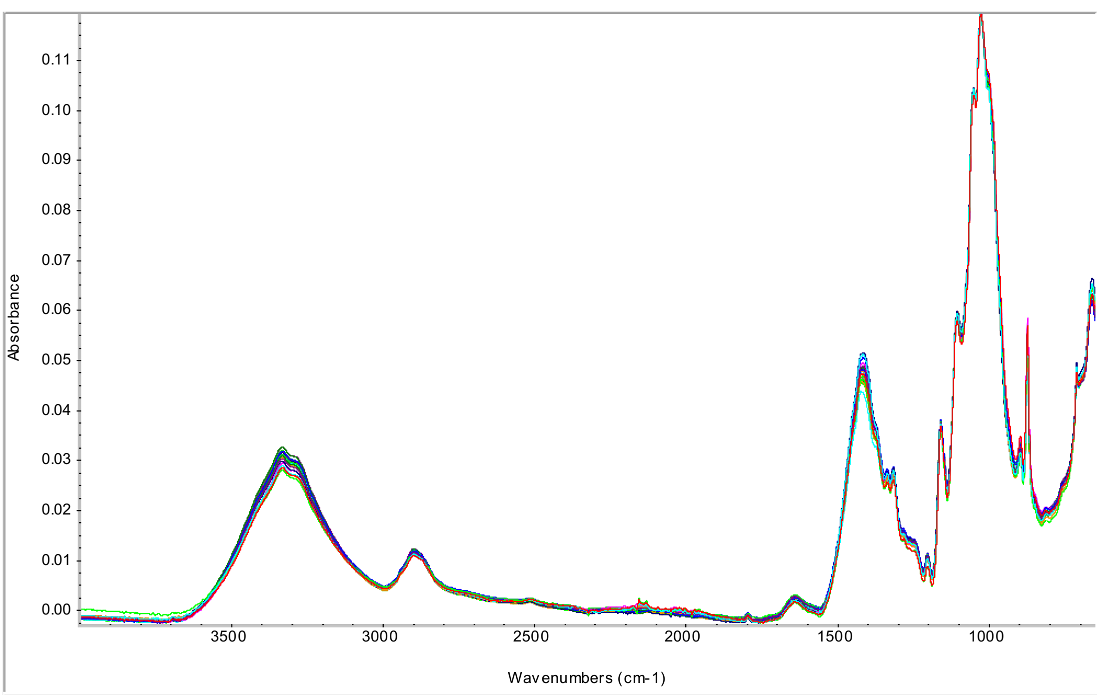
B-1-5 - Variation in spectra in envelope 5 within box 1 (4 spots)



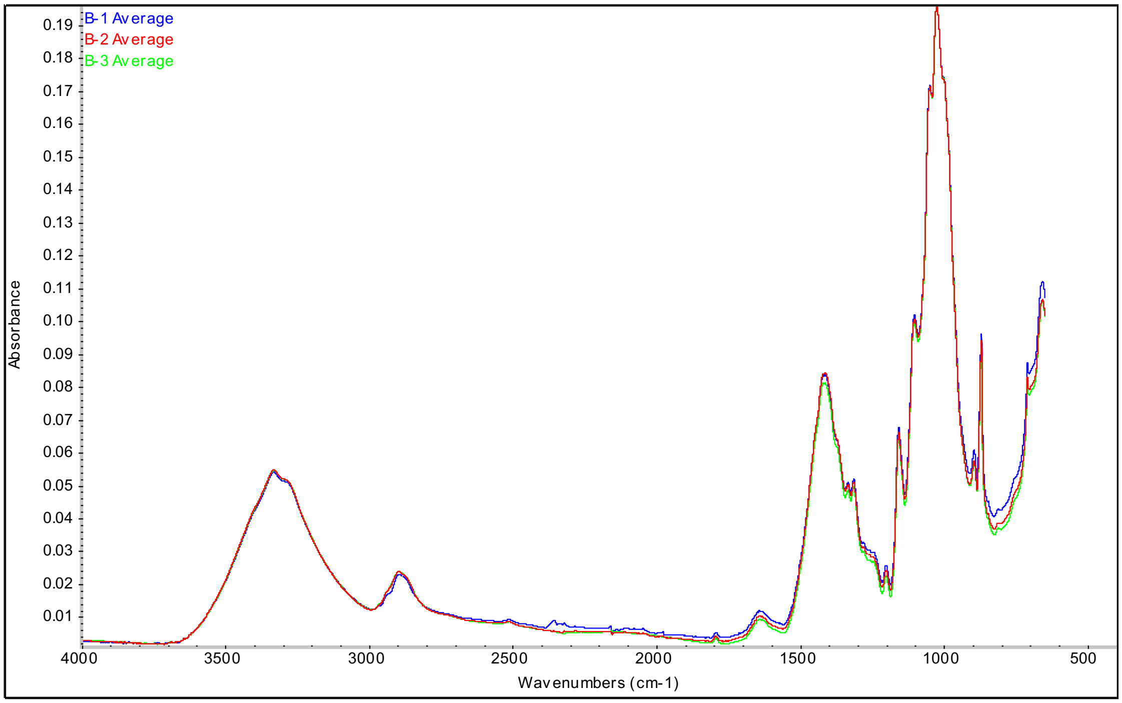
B-2 – Variation in spectra within box B-2 (5 envelopes, 4 spots)



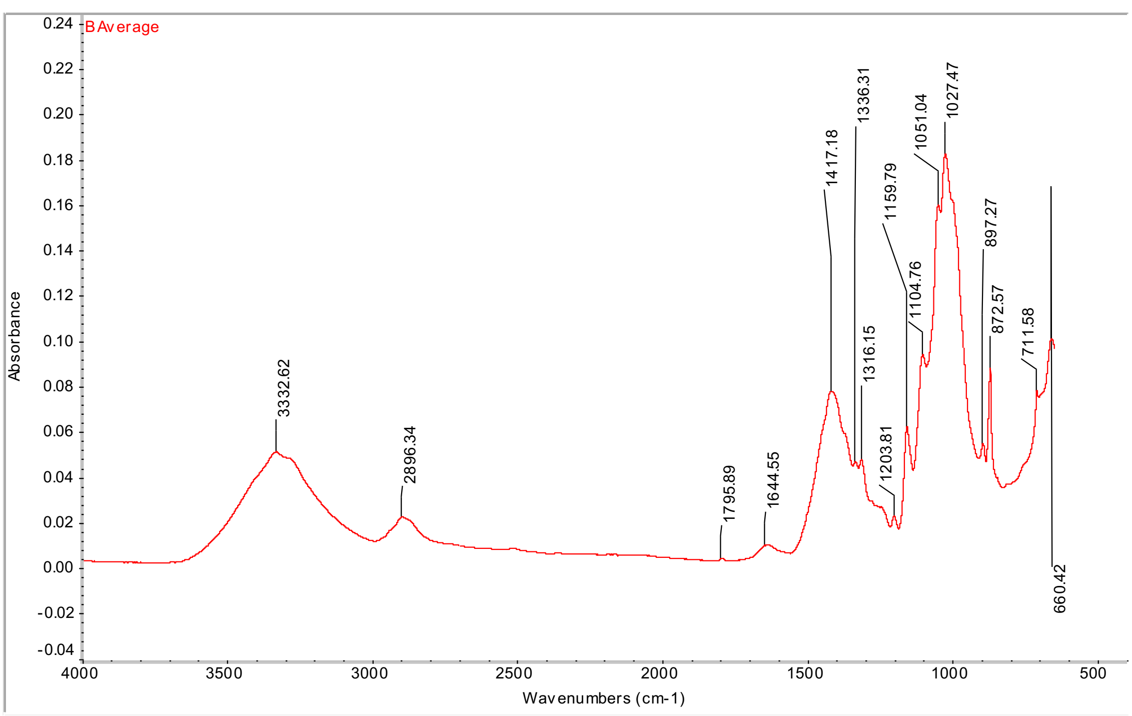
B-3 – Variation in spectra within box B-3 (5 envelopes, 4 spots)



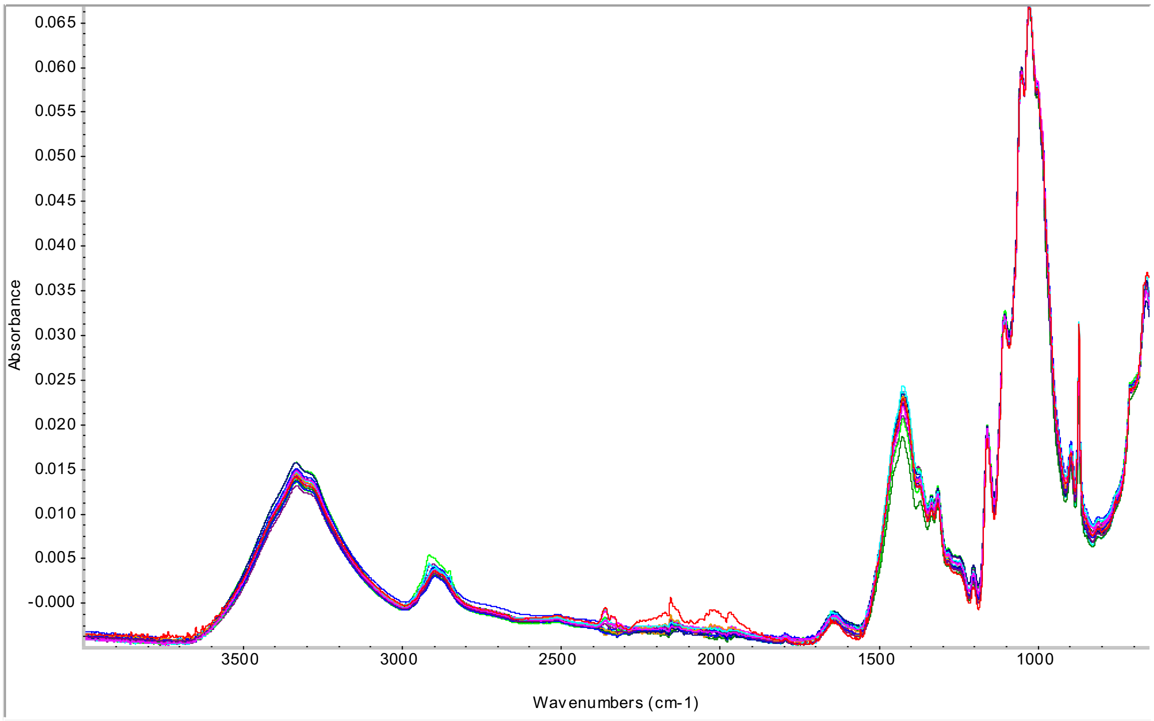
ATR-FT-IR BOX B AVERAGES (with all B-1 boxes):



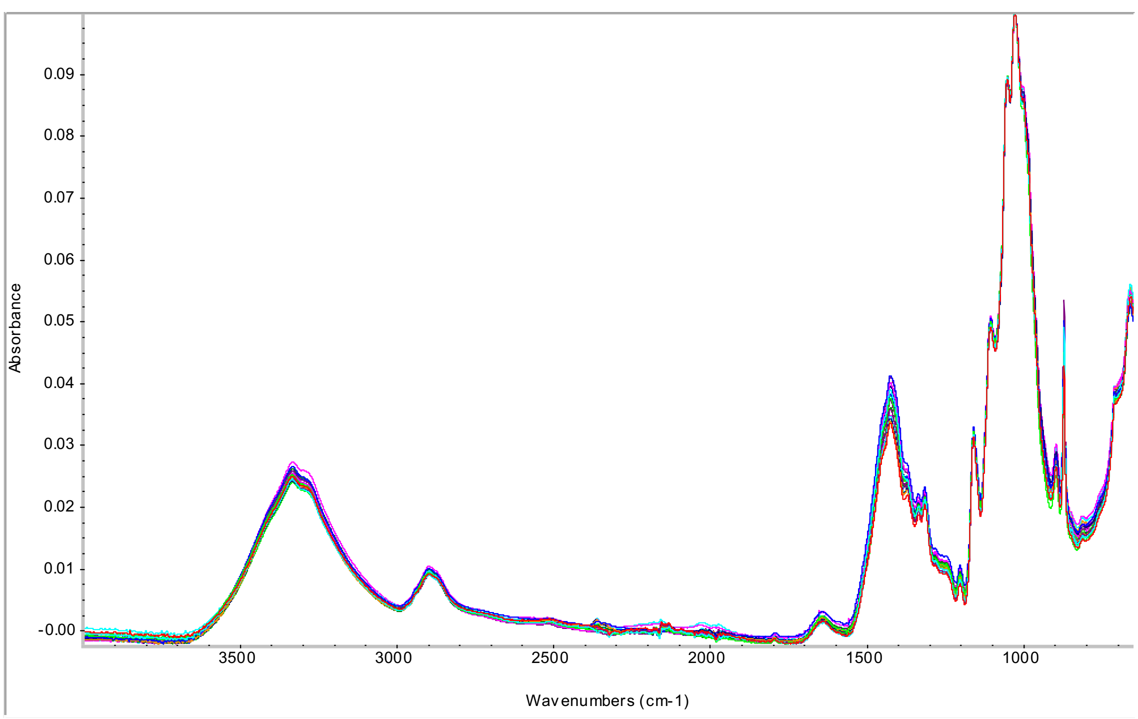
AVERAGE SPECTRA FOR BRAND B:



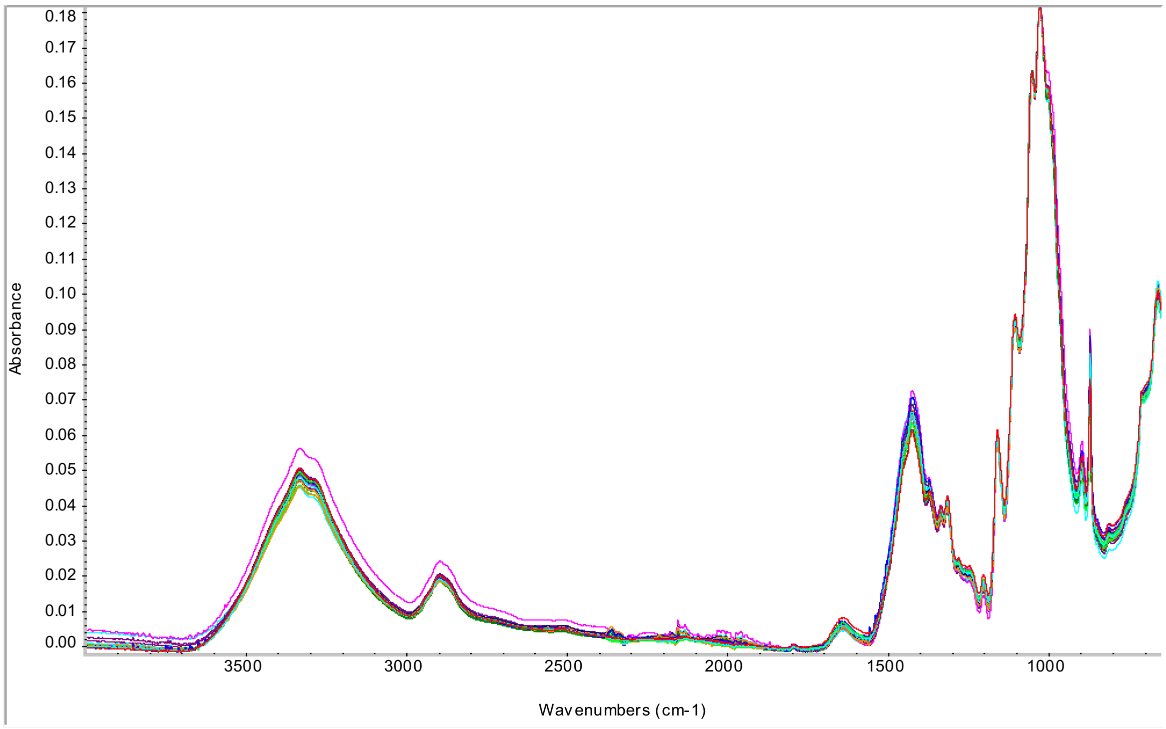
C-1 – Variation in spectra within box C-1 (5 envelopes, 4 spots)



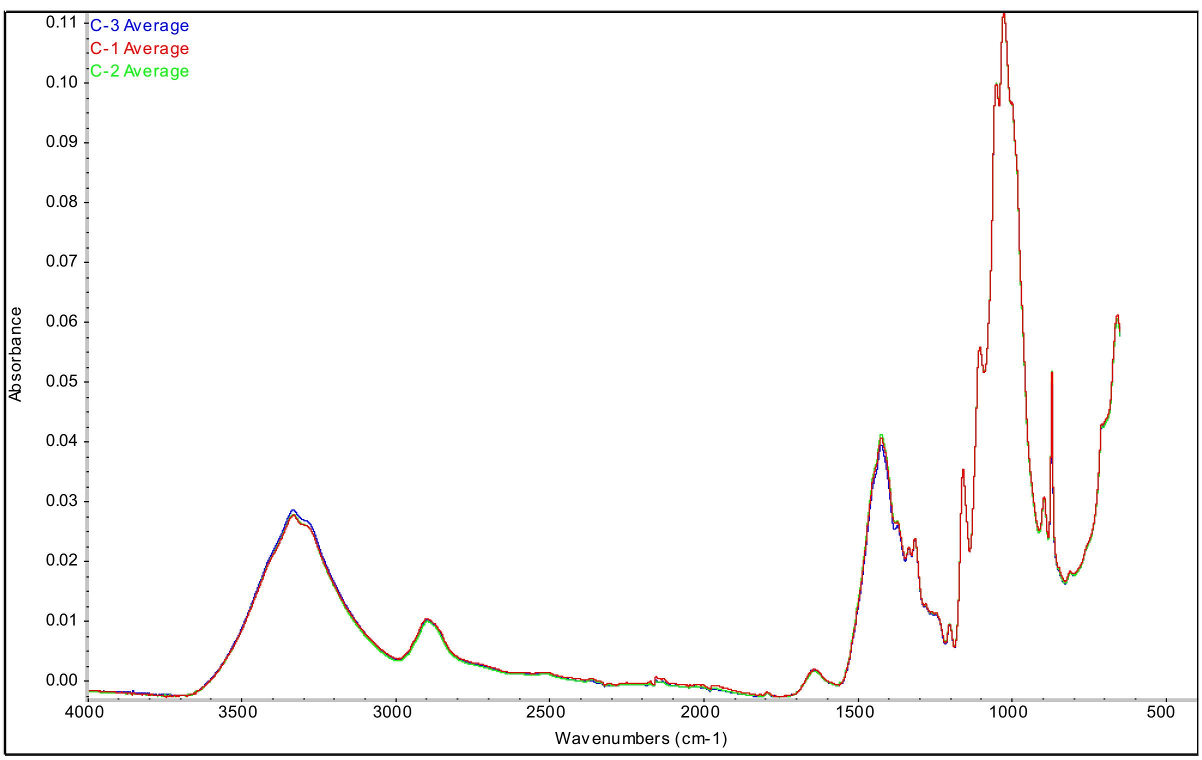
C-2 – Variation in spectra within box C-2 (5 envelopes, 4 spots)



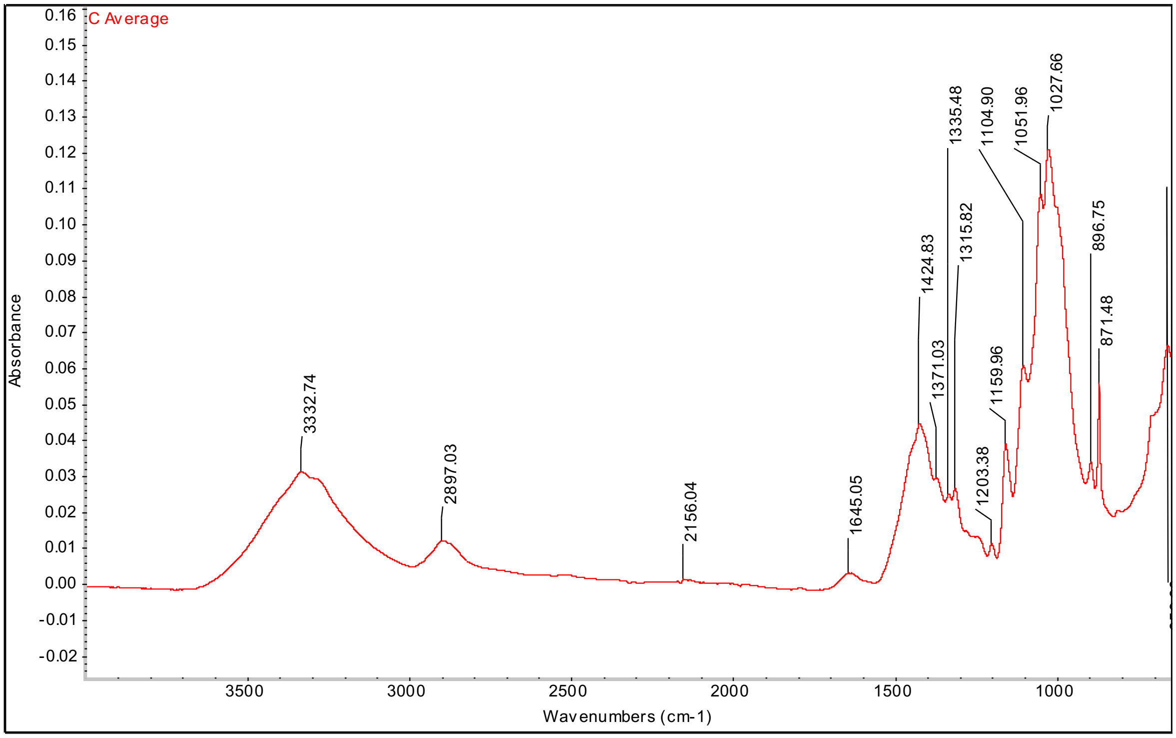
C-3 – Variation in spectra within box C-3 (5 envelopes, 4 spots)



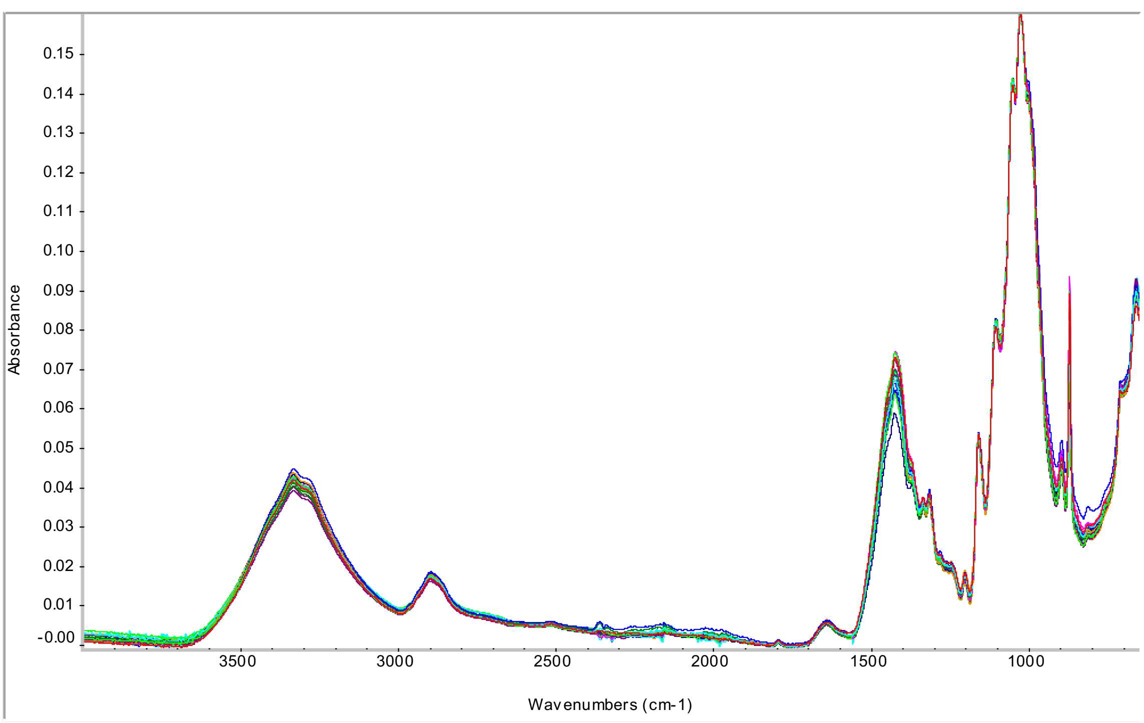
ATR-FT-IR BOX C AVERAGES:



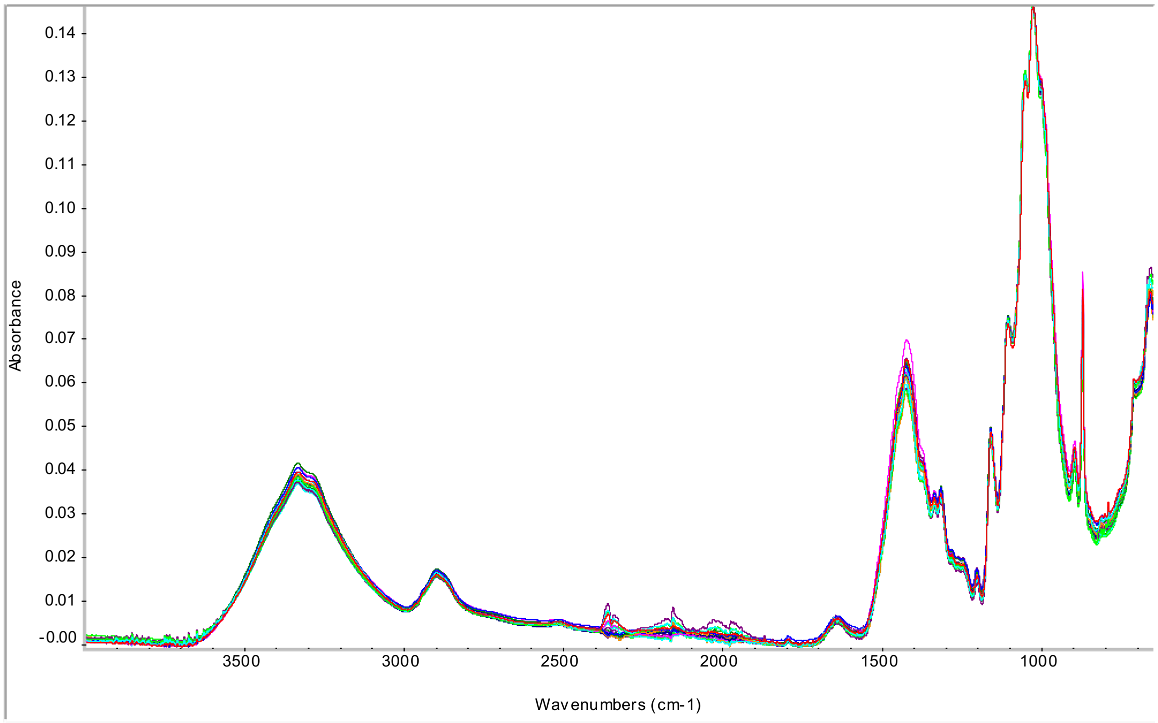
AVERAGE SPECTRA FOR BRAND C:



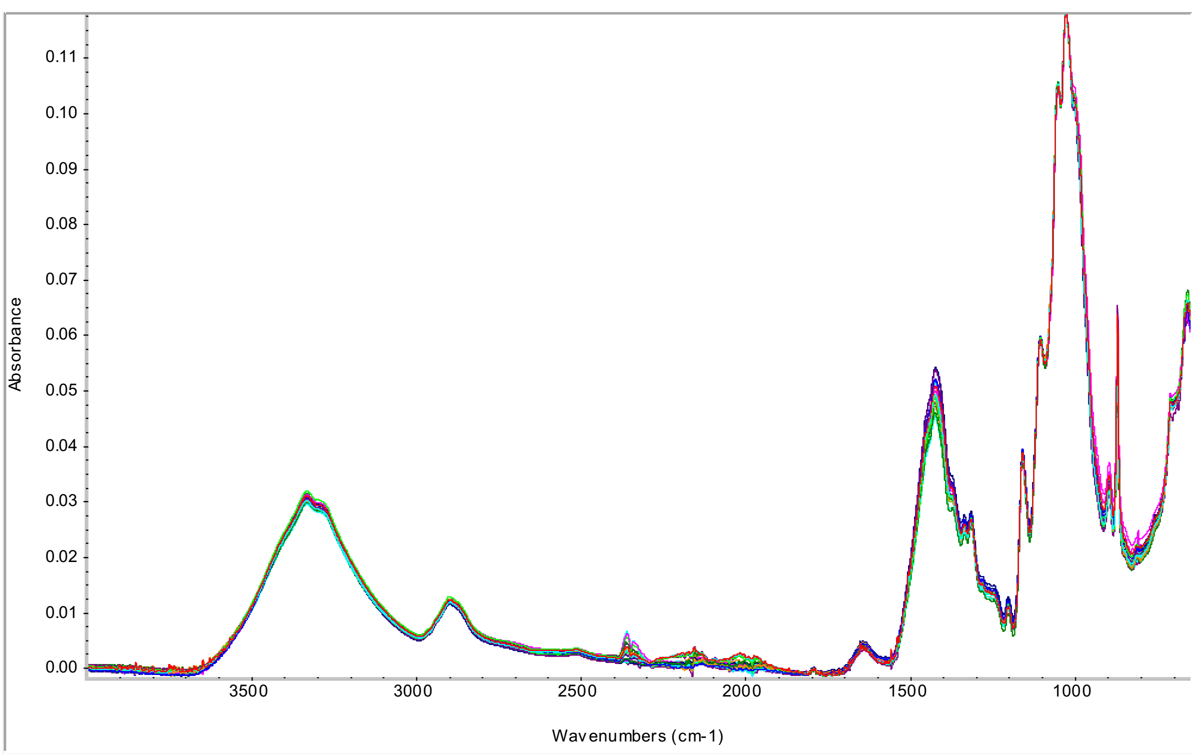
D-1 – Variation in spectra within box D-1 (5 envelopes, 4 spots)



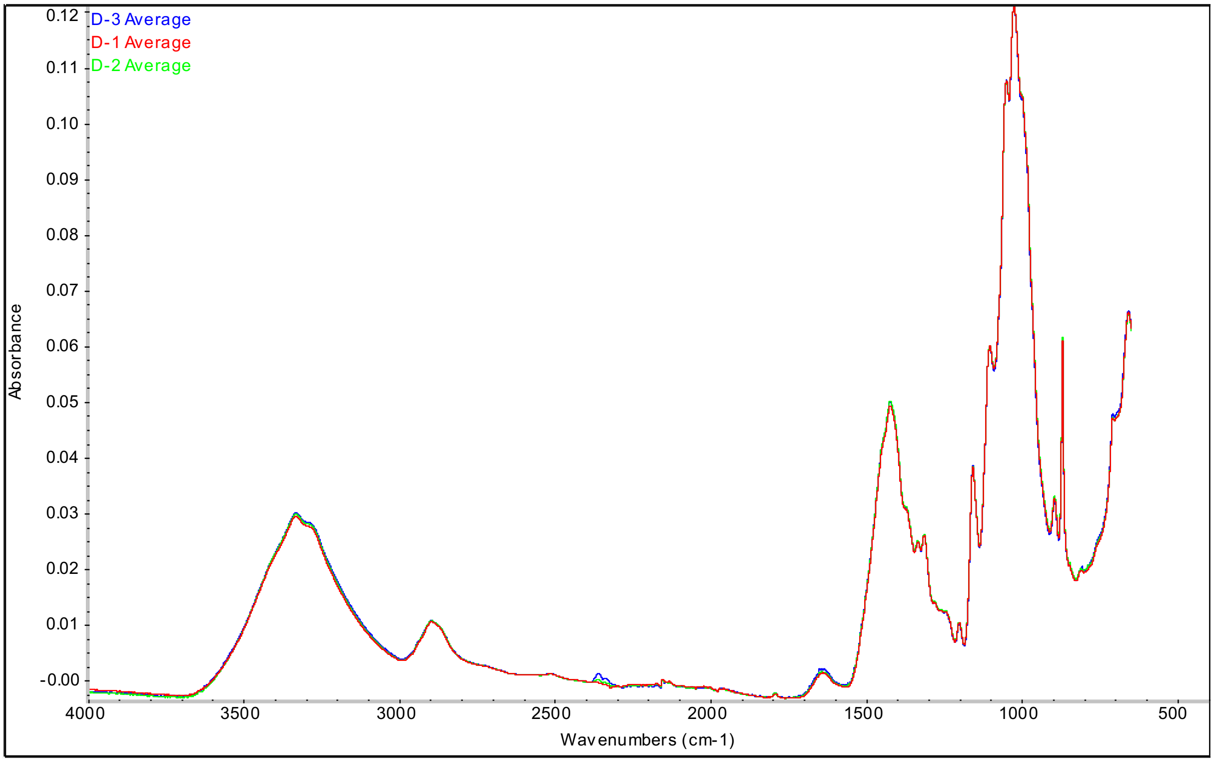
D-2 – Variation in spectra within box D-2 (5 envelopes, 4 spots)



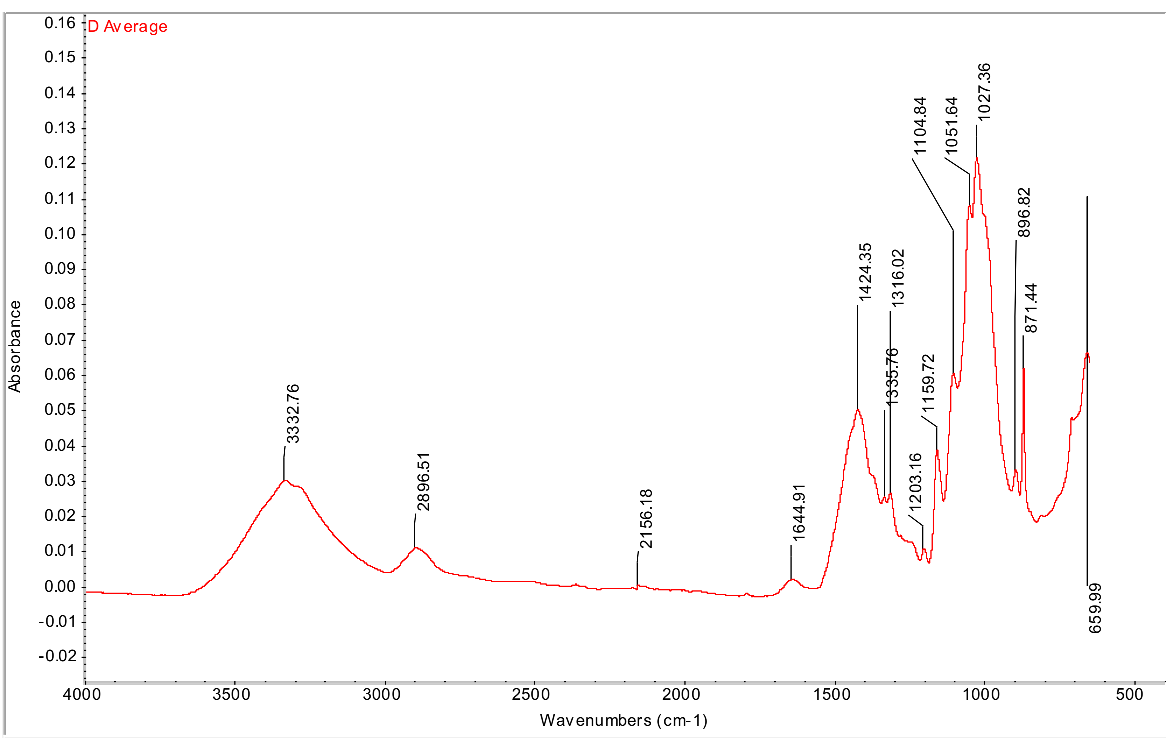
D-3 – Variation in spectra within box D-3 (5 envelopes, 4 spots)



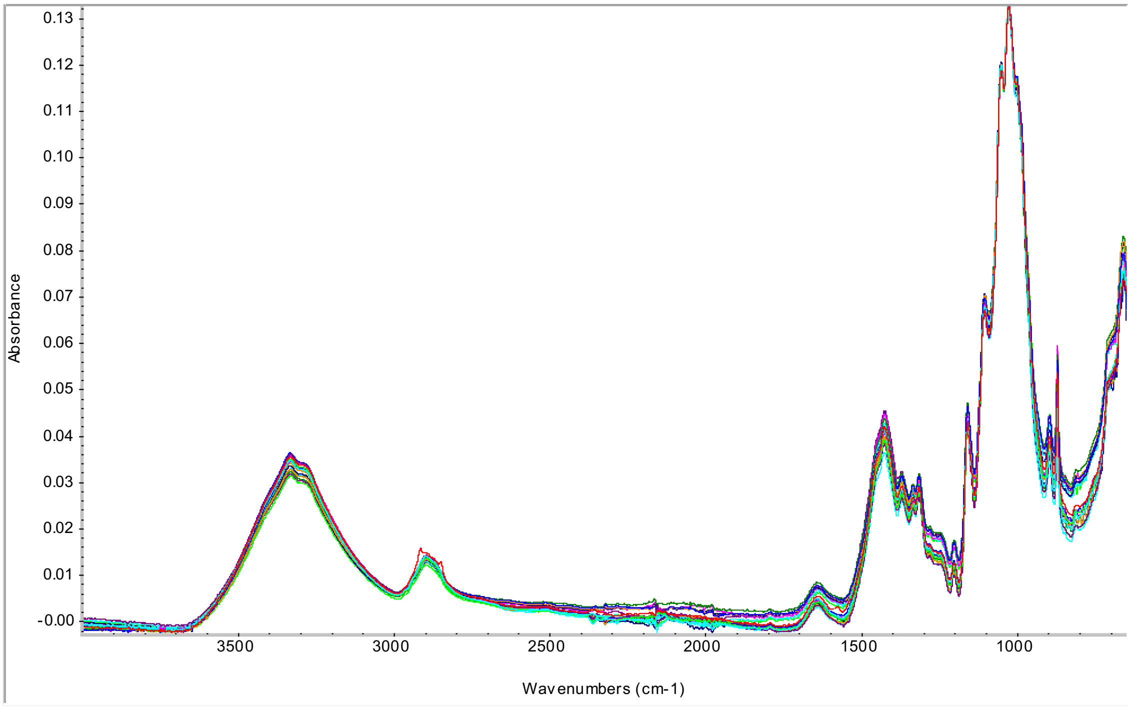
ATR-FT-IR BOX D AVERAGES:



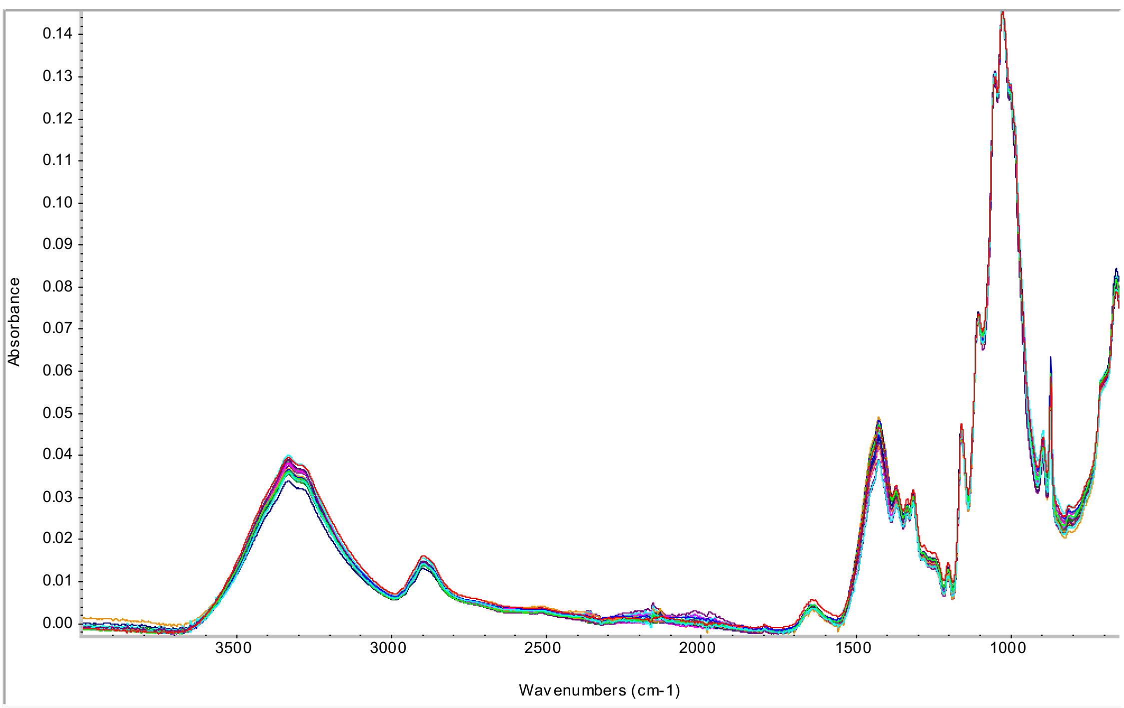
AVERAGE SPECTRA FOR BRAND D:



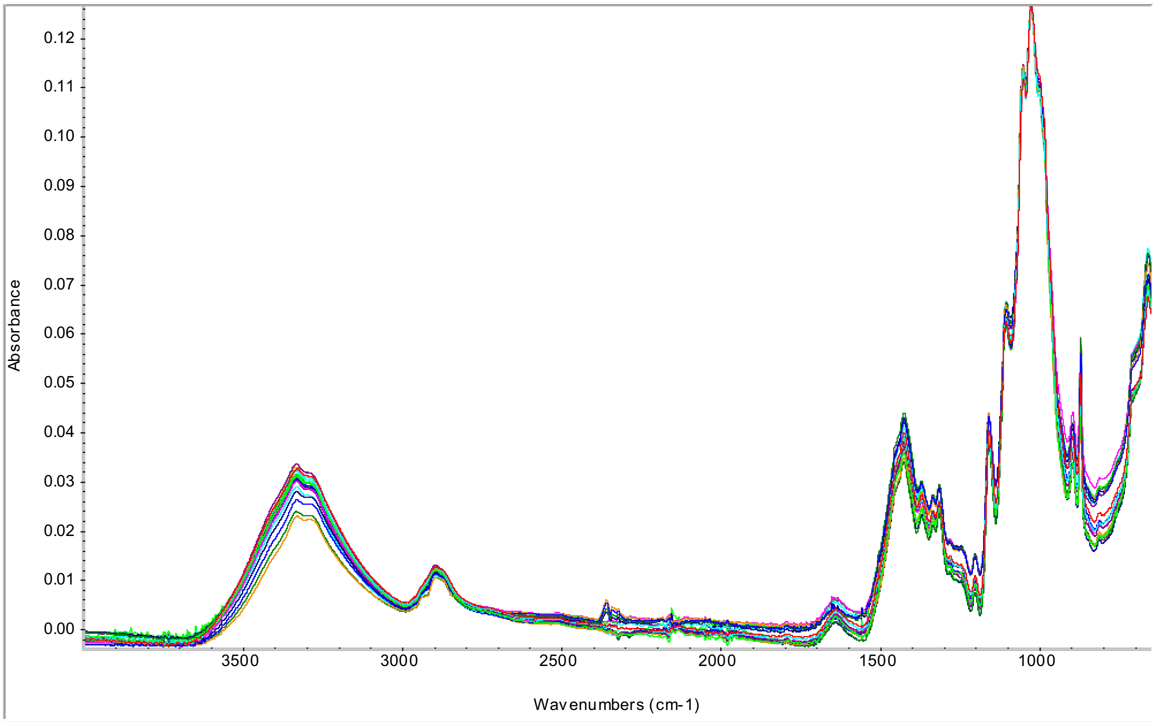
E-1 – Variation in spectra within box E-1 (5 envelopes, 4 spots)



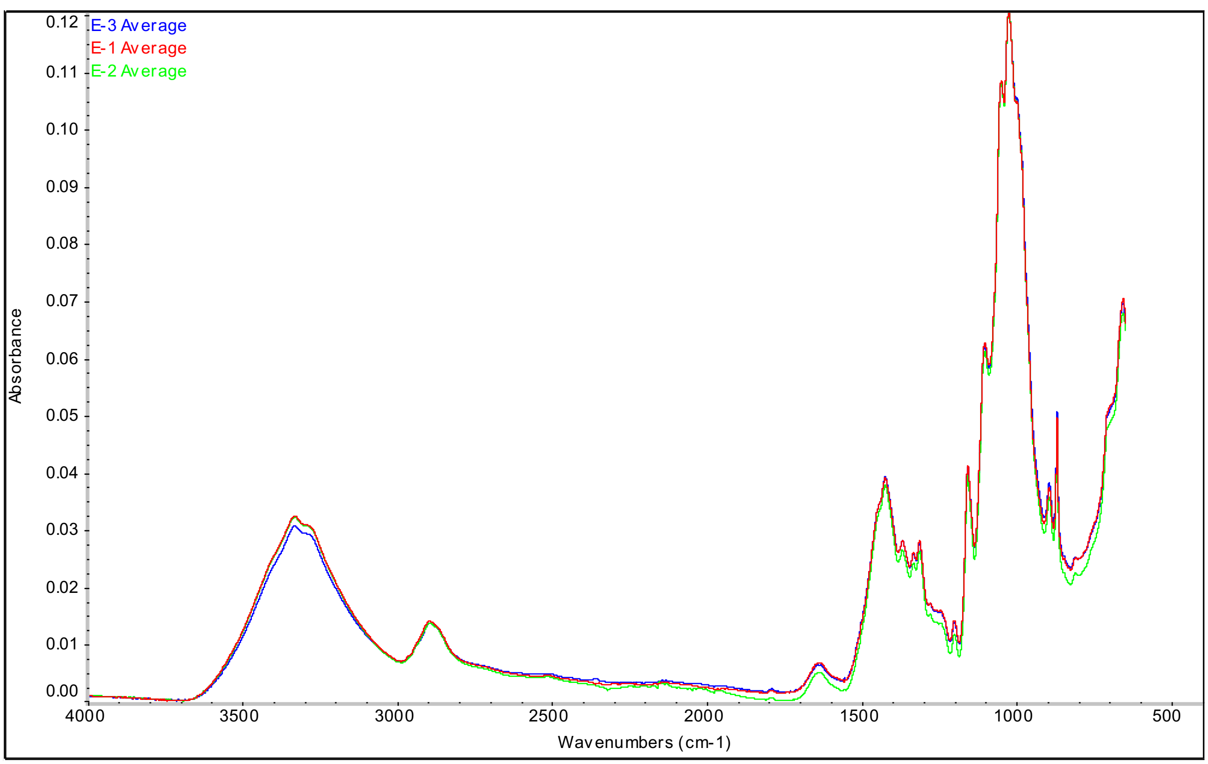
E-2 – Variation in spectra within box E-2 (5 envelopes, 4 spots)



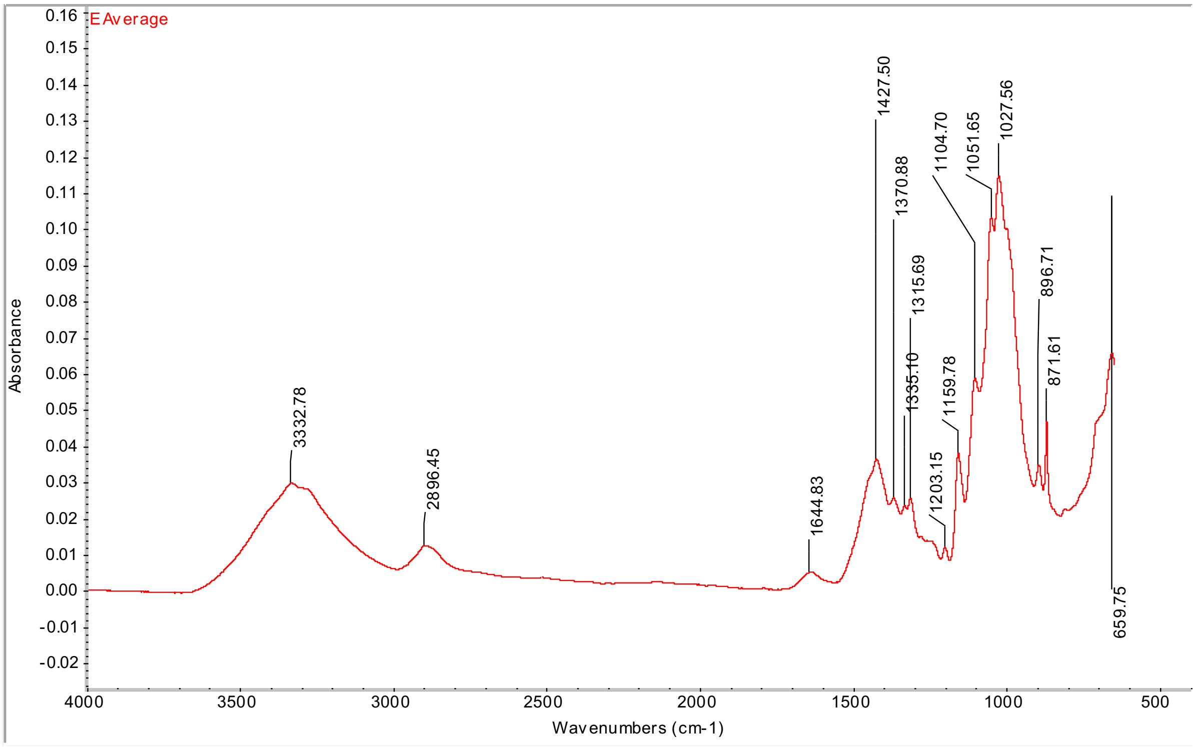
E-3 – Variation in spectra within box E-3 (5 envelopes, 4 spots)



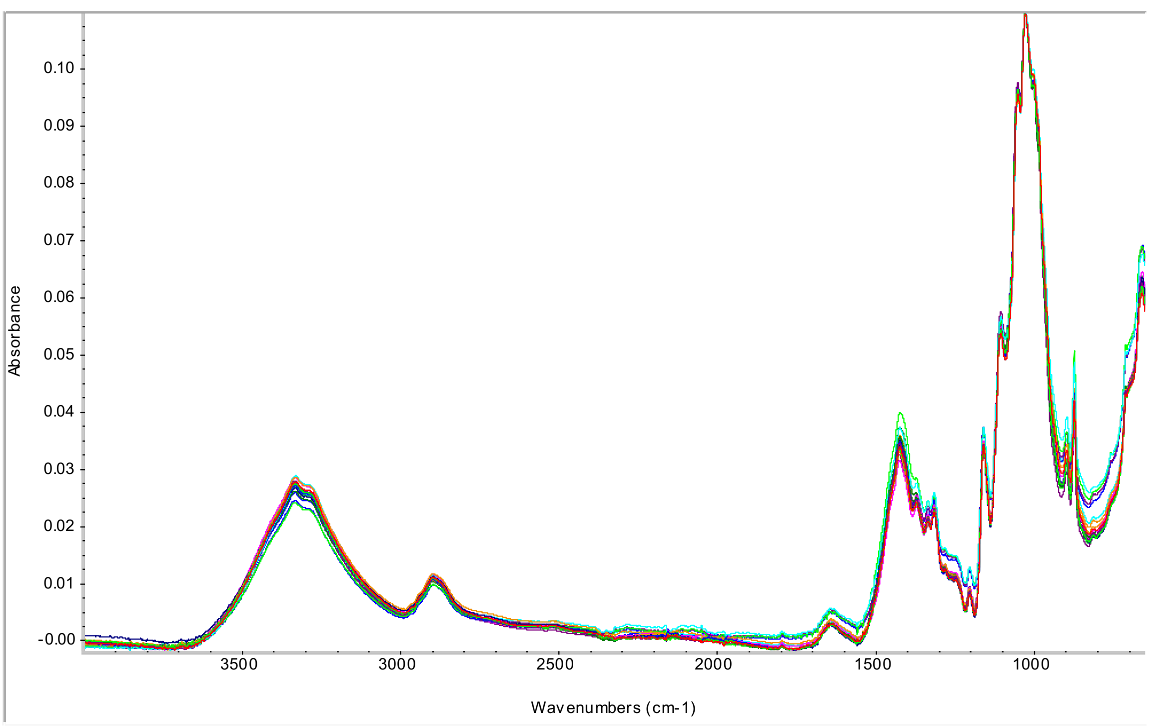
ATR-FT-IR BOX E AVERAGES:



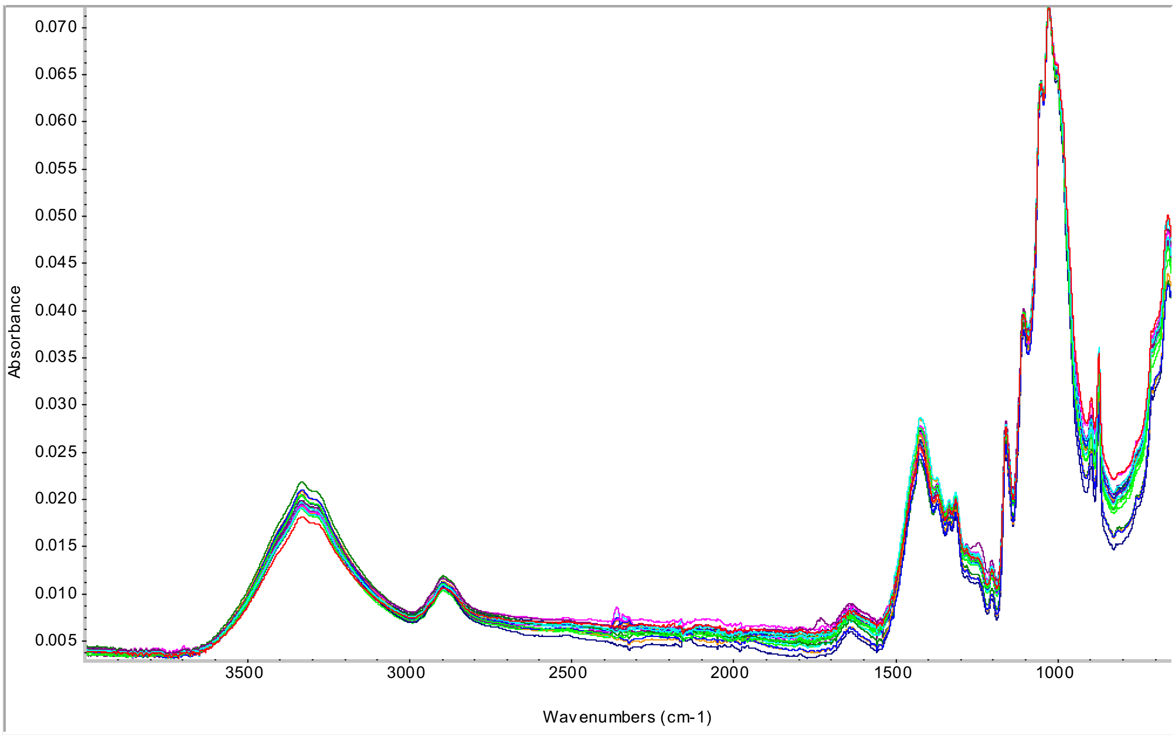
AVERAGE SPECTRA FOR BRAND E:



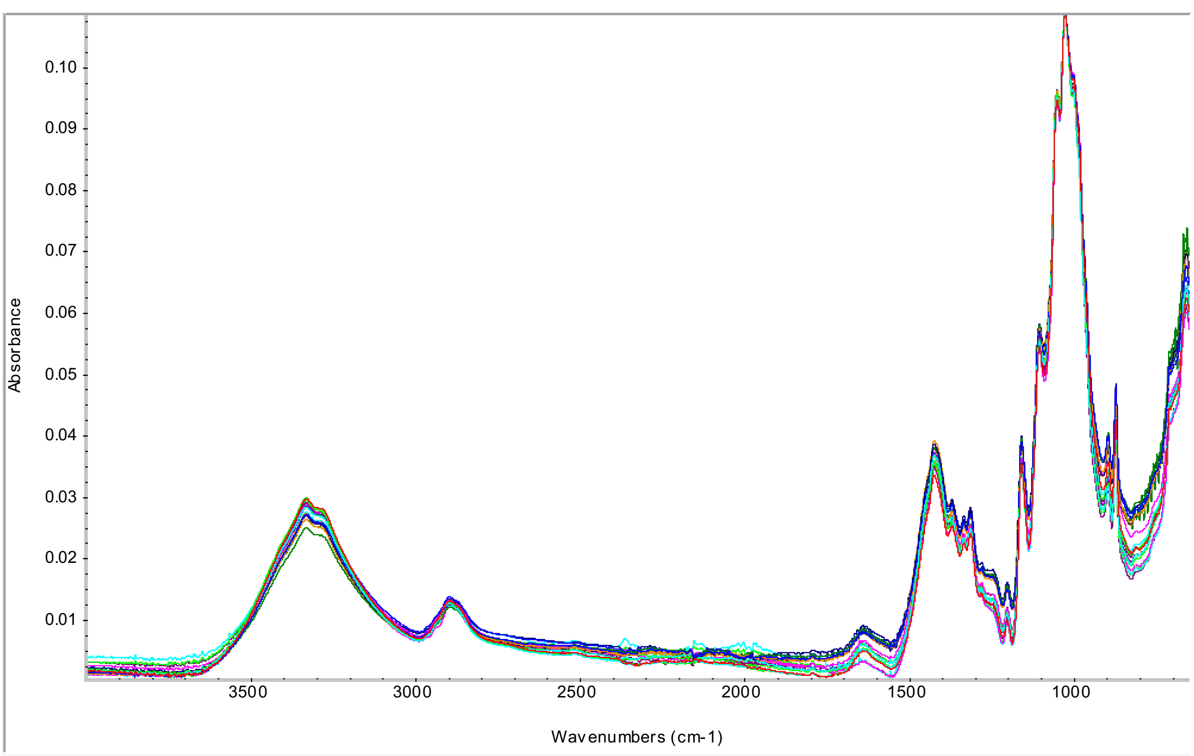
F-1 – Variation in spectra within box F-1 (5 envelopes, 4 spots)



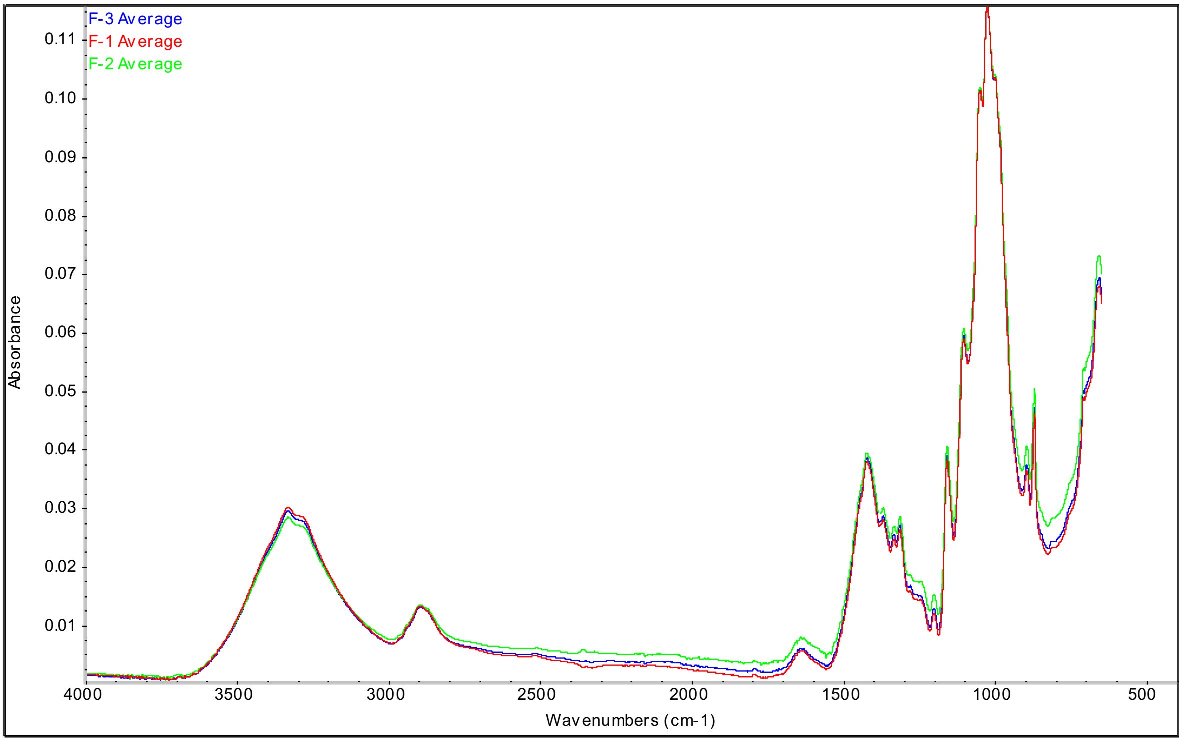
F-2 – Variation in spectra within box F-2 (5 envelopes, 4 spots)



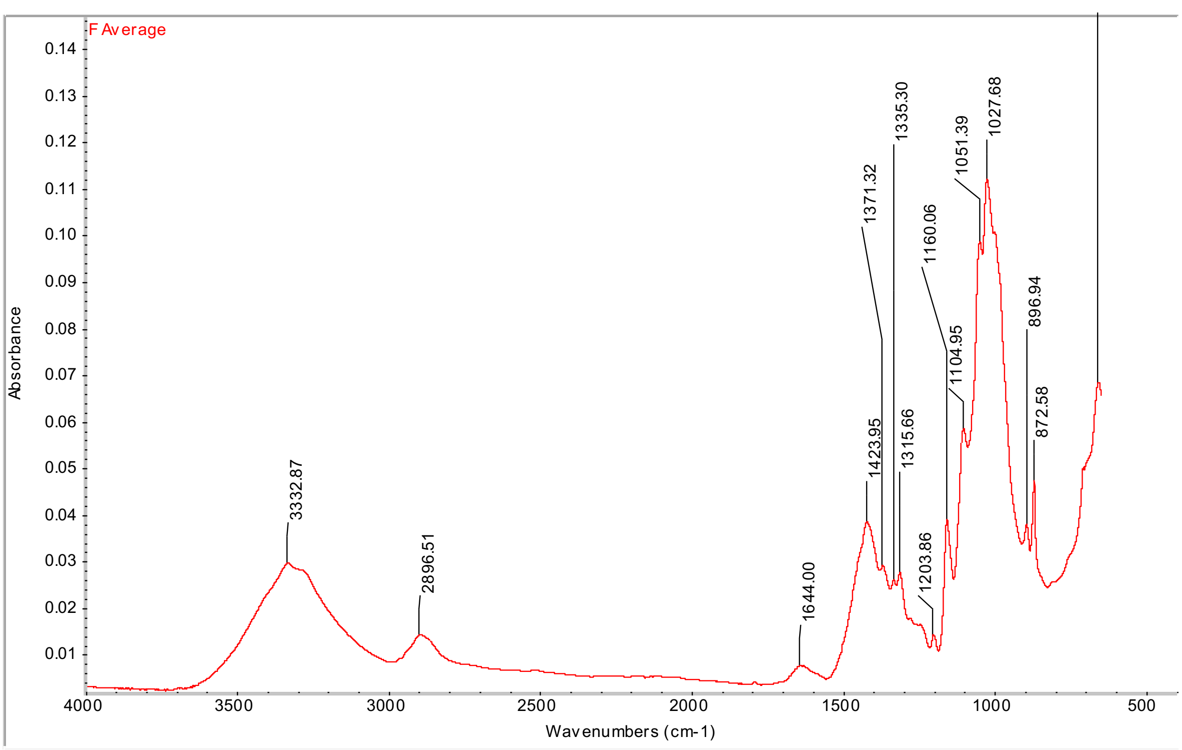
F-3 – Variation in spectra within box F-3 (5 envelopes, 4 spots)



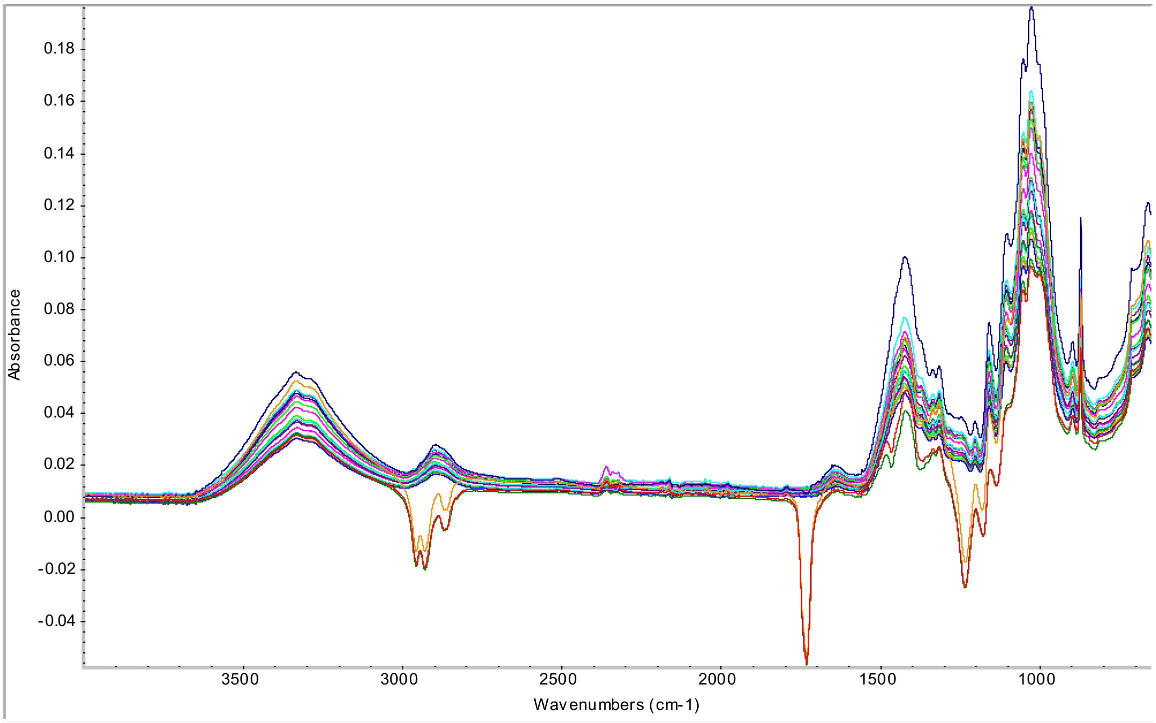
ATR-FT-IR BOX F AVERAGES:



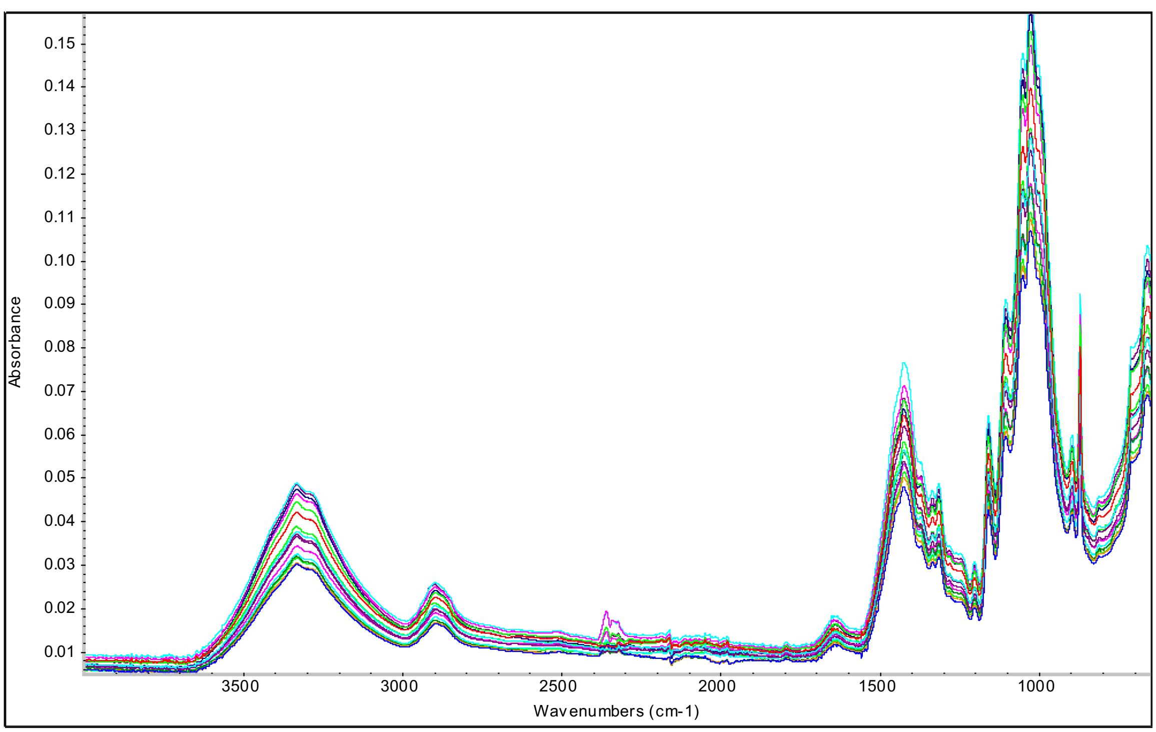
AVERAGE SPECTRA FOR BRAND F:



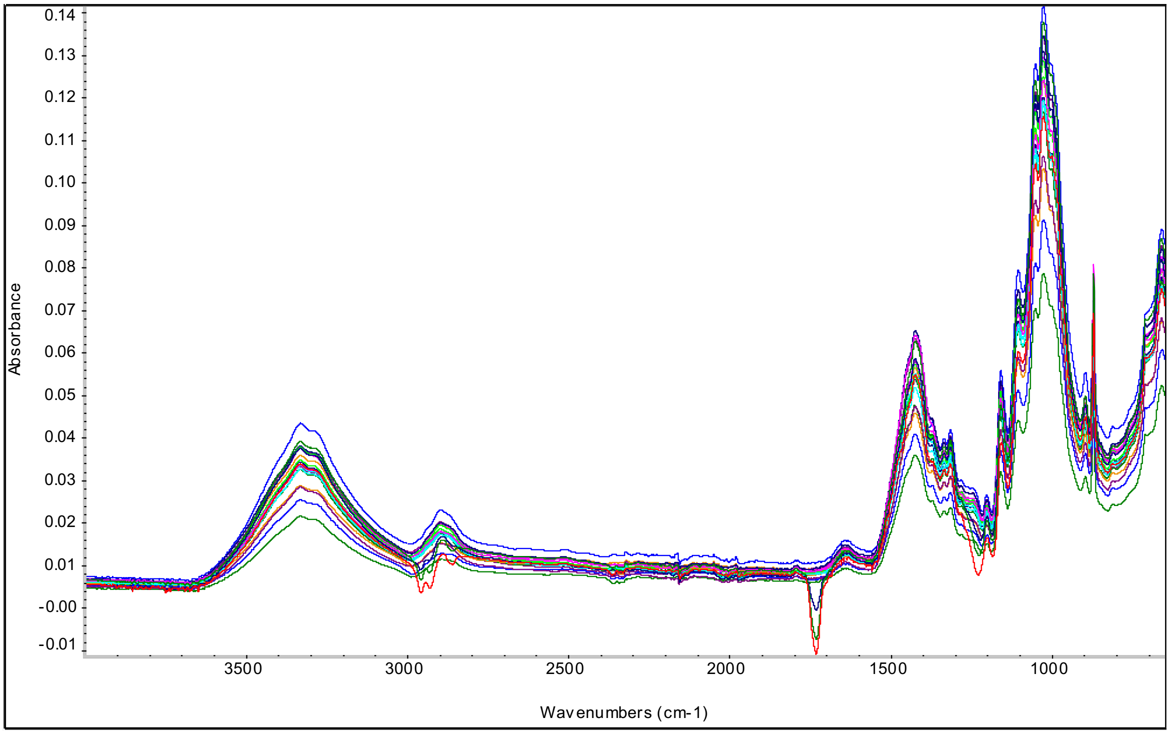
G-1 – Variation in spectra within box G-1 (5 envelopes, 4 spots)



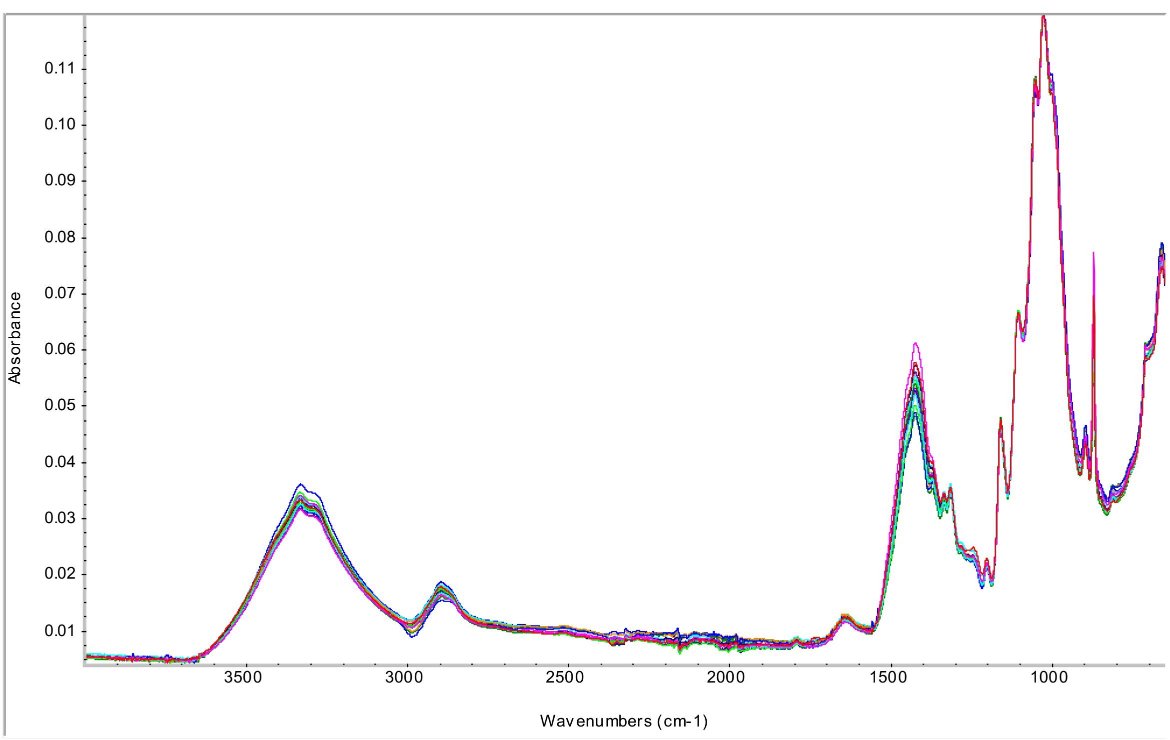
G-1 – Variation in spectra within box G-1 (5 envelopes, 4 spots) without outliers G-1-2-1, G-1-2-2, G-1-2-3, G-1-2-4, G-1-2-5



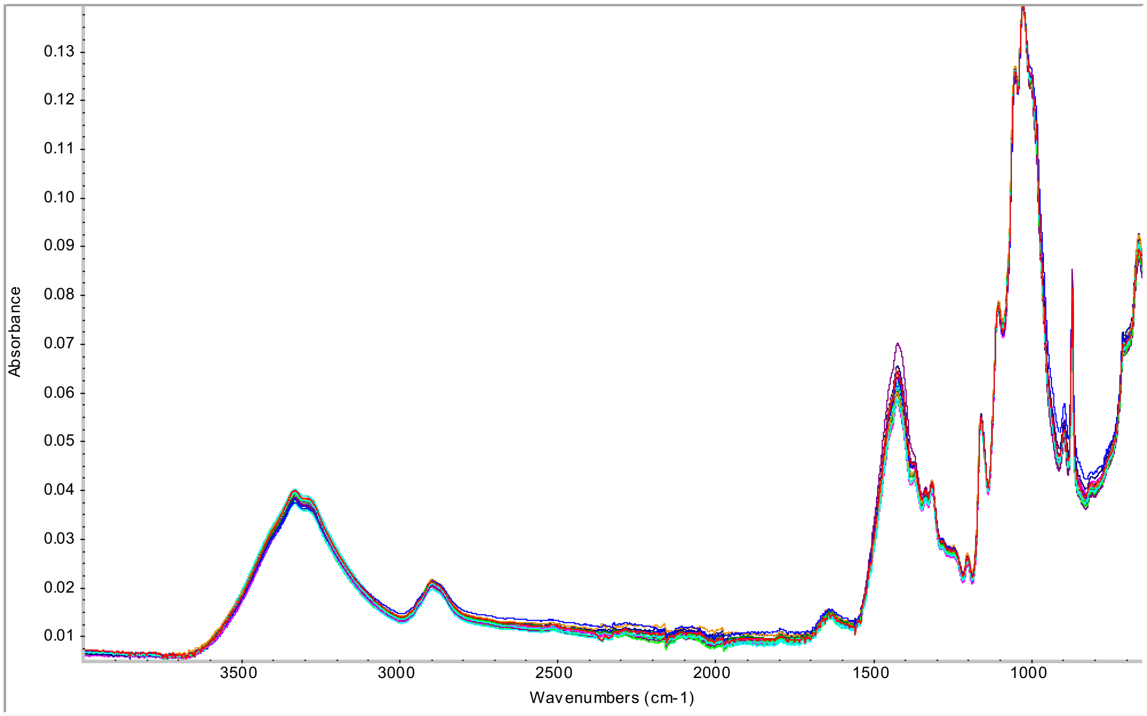
G-2 – Variation in spectra within box G-2 (5 envelopes, 4 spots)



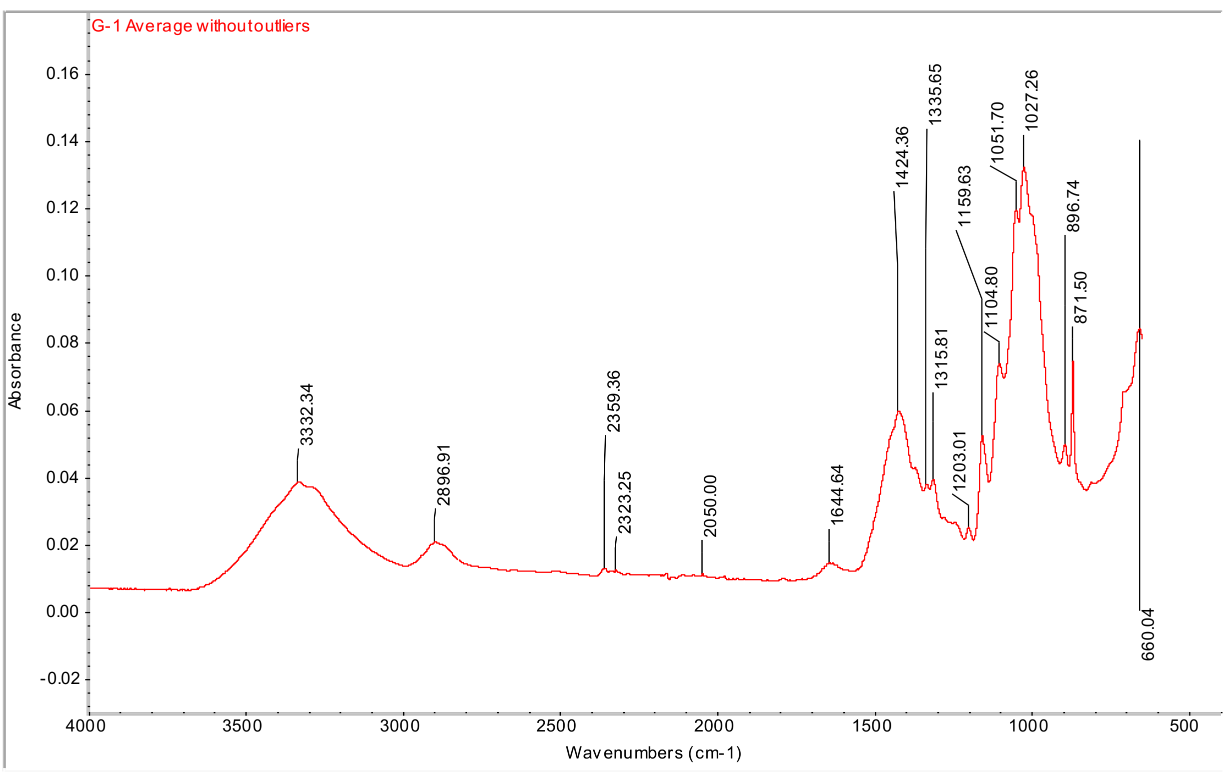
G-2 – Variation in spectra within box G-2 (5 envelopes, 4 spots) without outliers G-2-1-2, G-2-1-3, G-2-1-4.

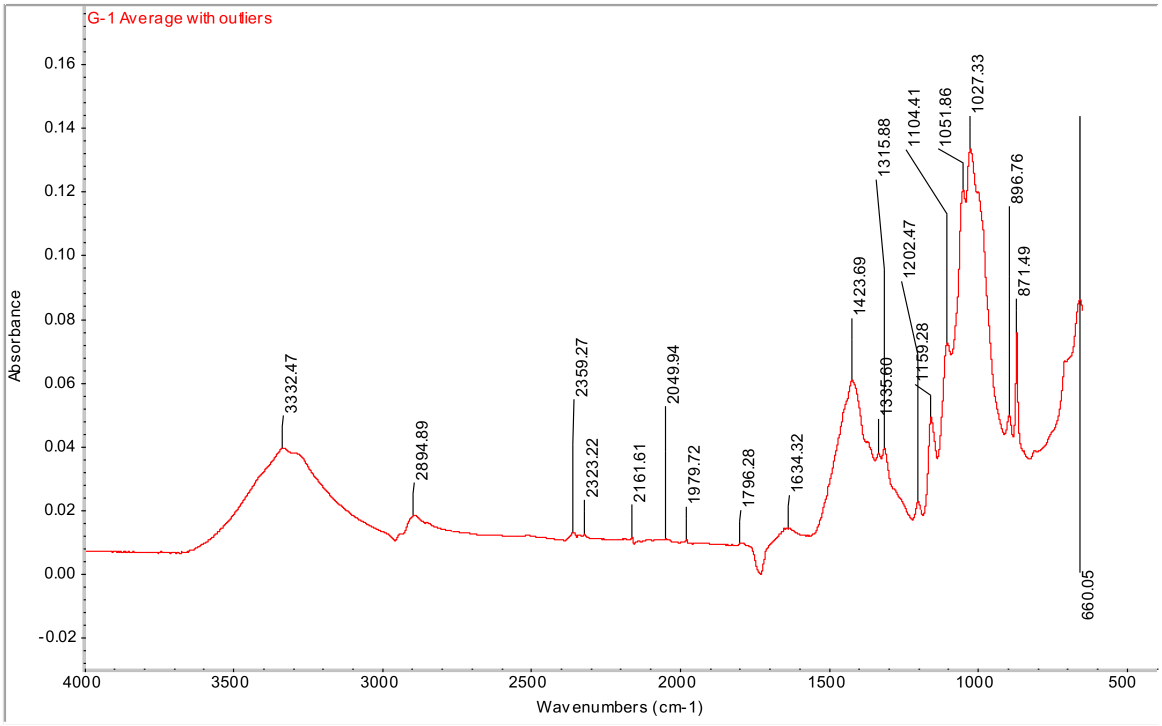


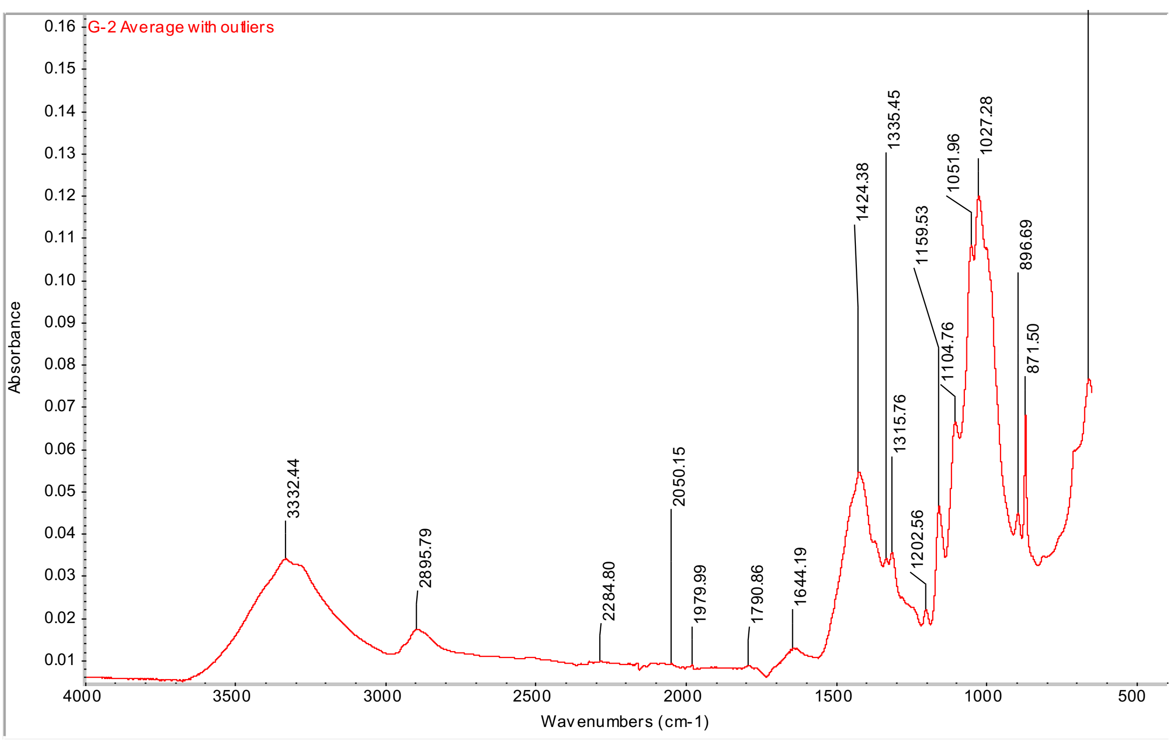
G-3 – Variation in spectra within box G-3 (5 envelopes, 4 spots)

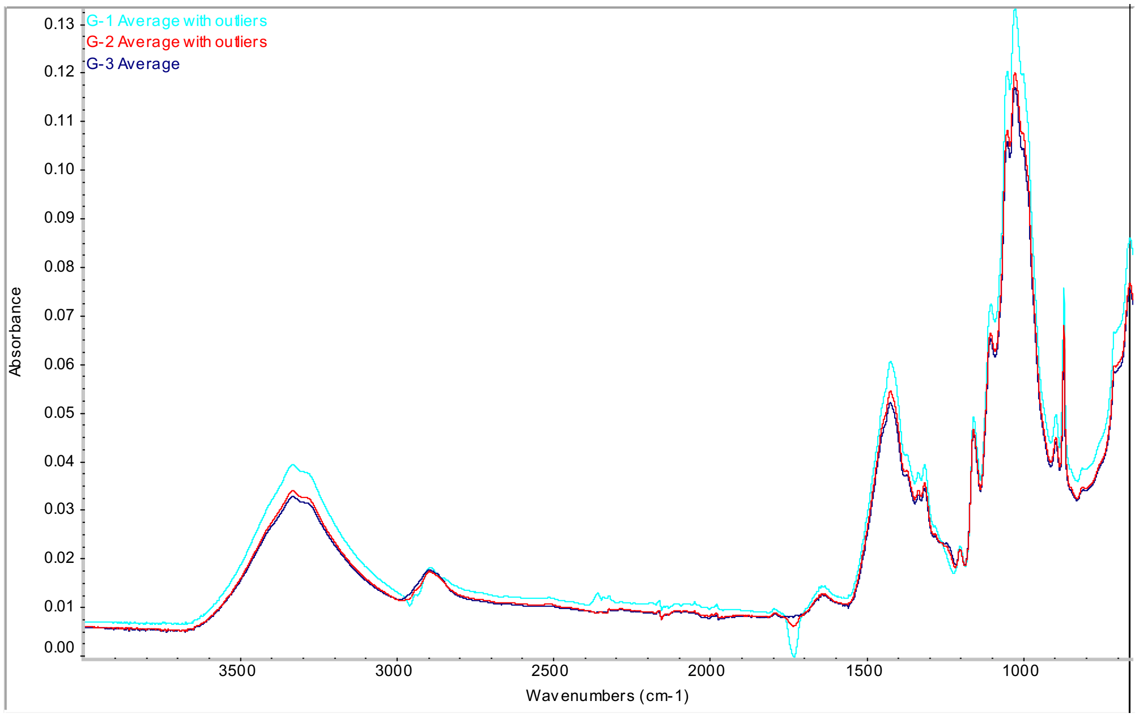


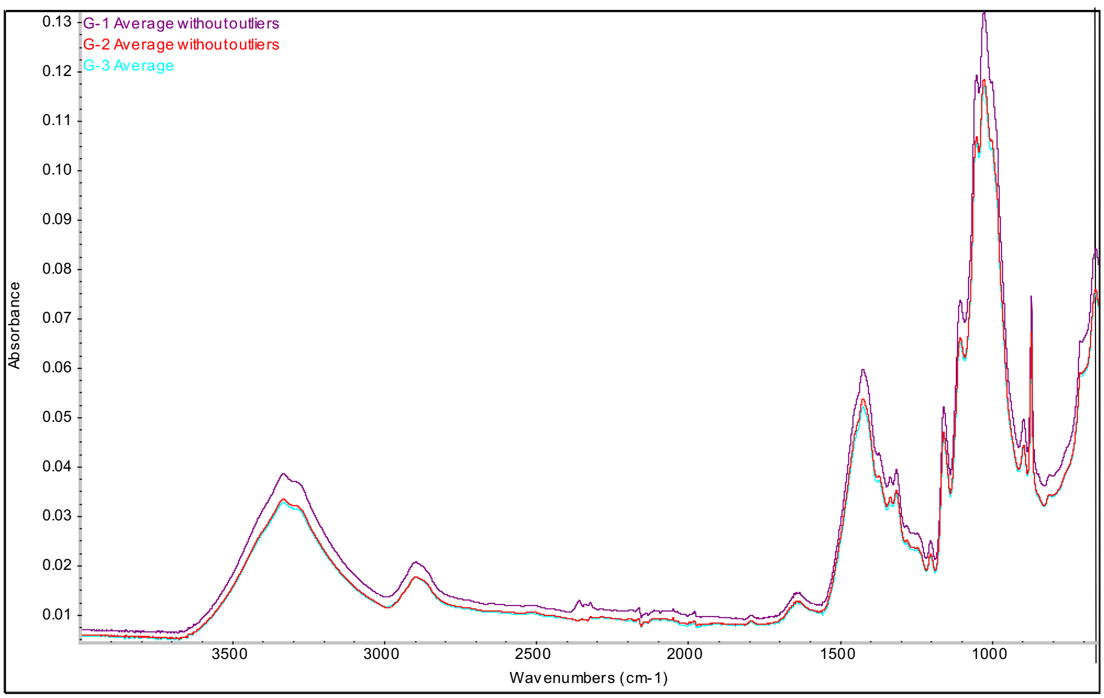
ATR-FT-IR BOX G AVERAGES:



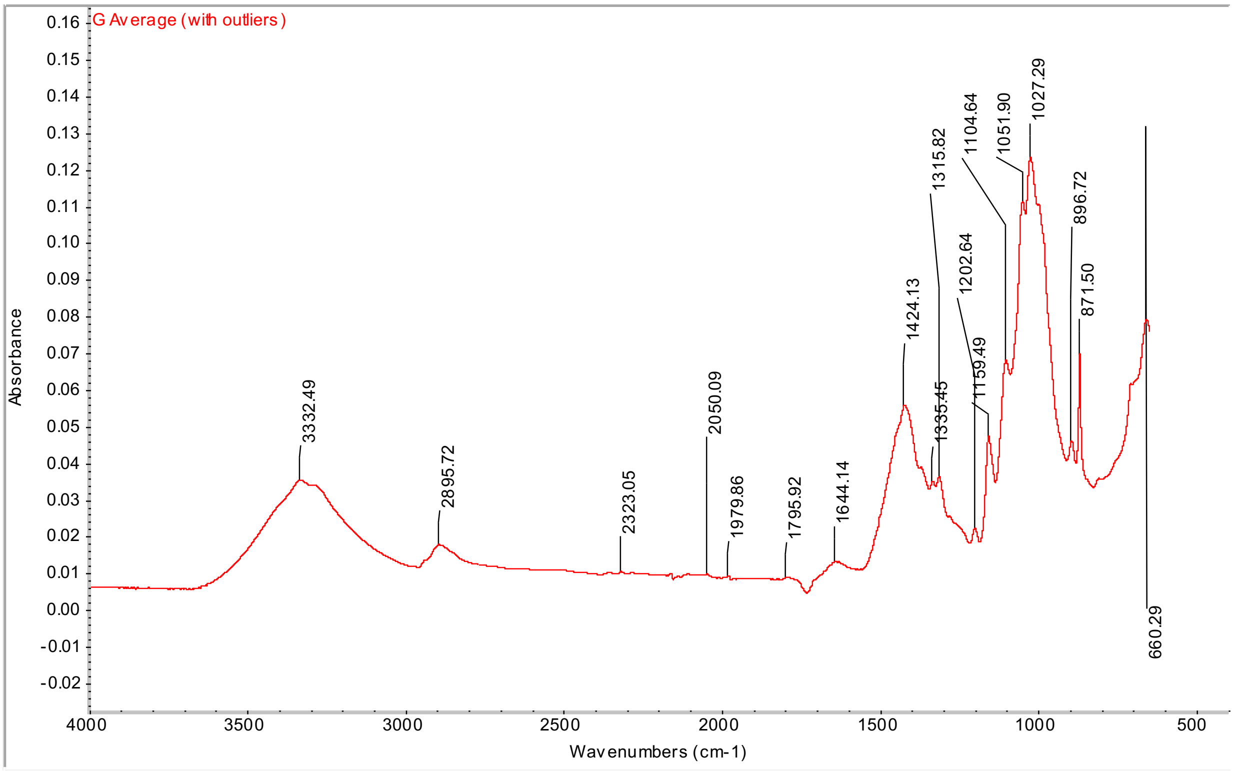

G-1 Average with outliers
Absorbance
Wavenumbers (cm-1)
3332.47
2894.89
2359.27
2323.22
2161.61
2049.94
1979.72
1796.28
1634.32
1423.69
1335.60
1315.88
1202.47
1159.28
1104.41
1051.86
1027.33
896.76
871.49
660.05

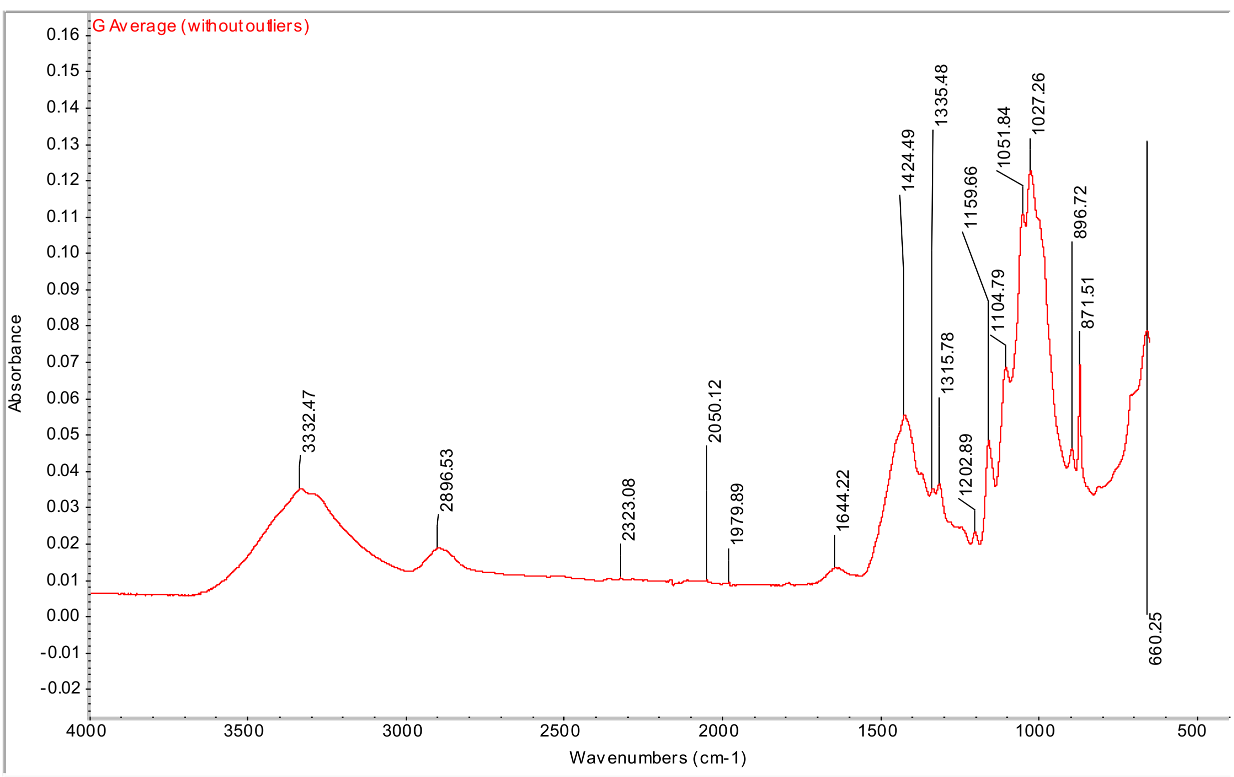

G-2 Average with outliers
Absorbance
Wavenumbers (cm-1)
3332.44
2895.79
2284.80
2050.15
1979.99
1790.86
1644.19
1424.38
1335.45
1315.76
1202.56
1159.53
1104.76
1051.96
1027.28
896.69
871.50


G-1 Average with outliers
G-2 Average with outliers
G-3 Average
Absorbance
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
3500
3000
2500
2000
1500
1000
Wavenumbers (cm-1)

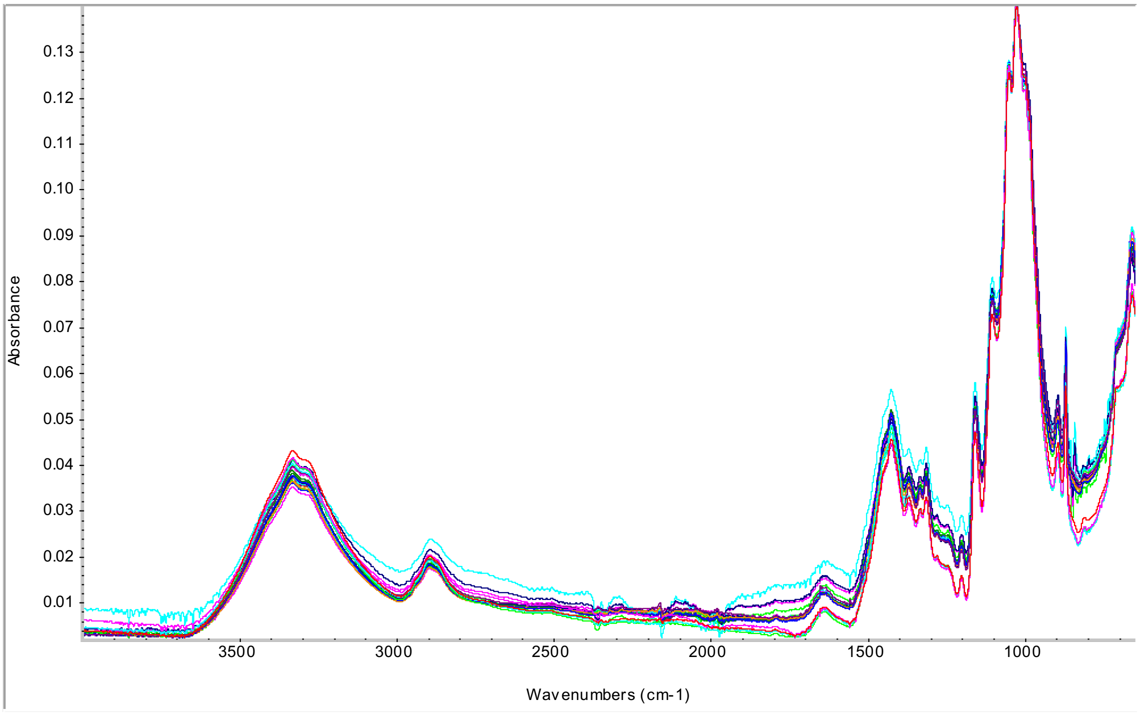

G-1 Average without outliers
G-2 Average without outliers
G-3 Average
Absorbance
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
3500
3000
2500
2000
1500
1000
Wavenumbers (cm-1)

AVERAGE SPECTRA FOR BRAND G:

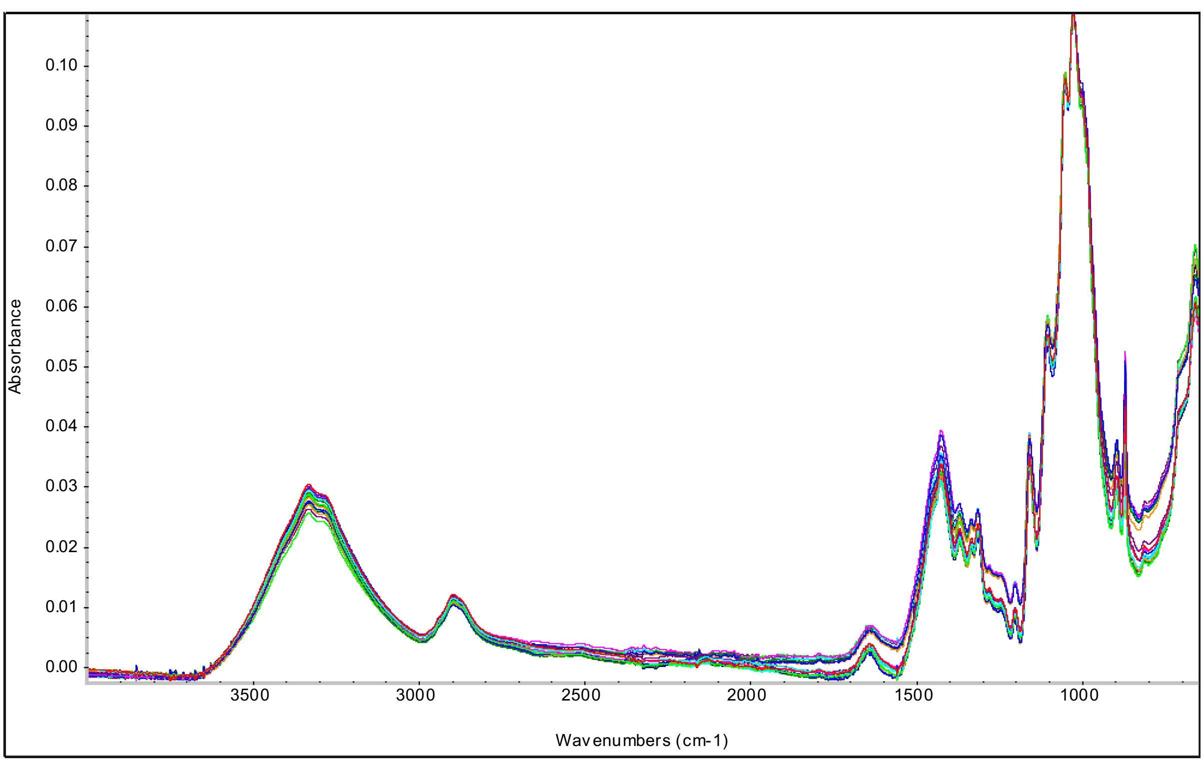




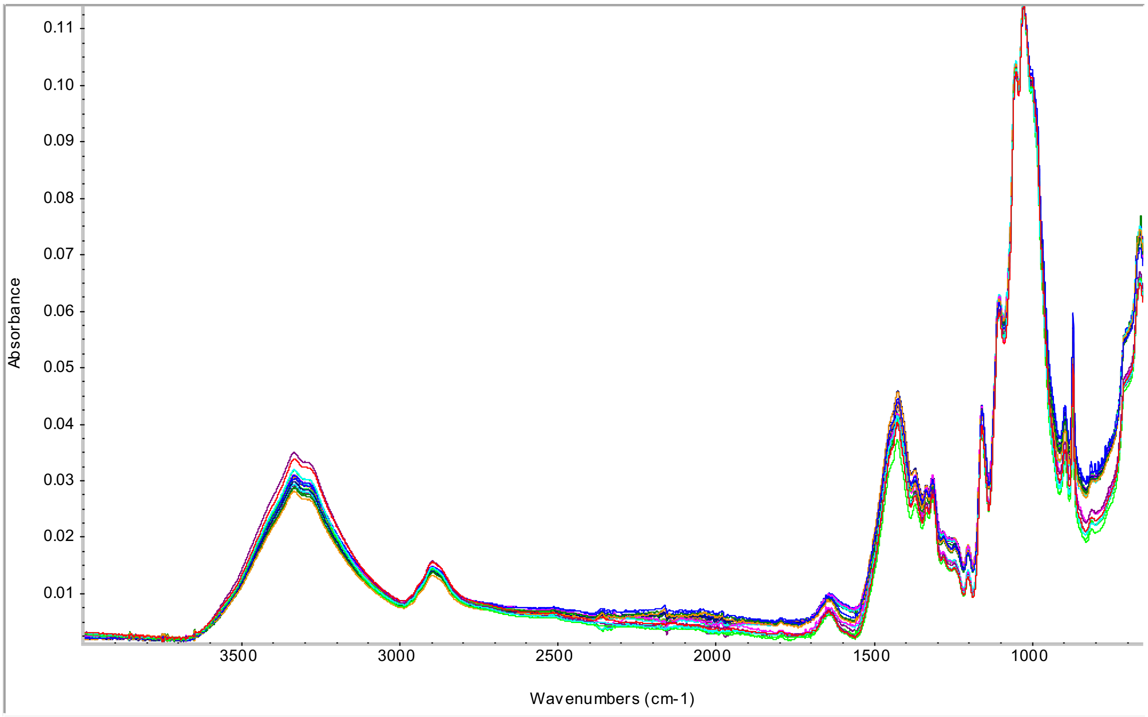
H-1 – Variation in spectra within box H-1 (5 envelopes, 4 spots)



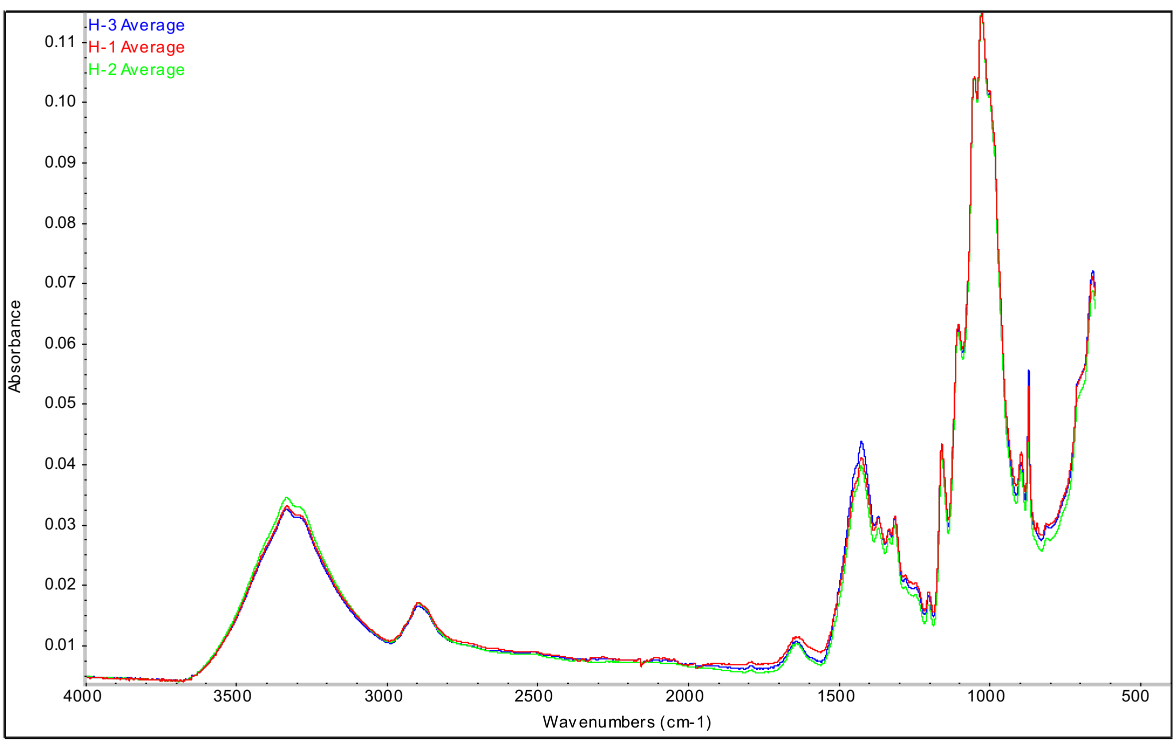
H-2 – Variation in spectra within box H-2 (5 envelopes, 4 spots)



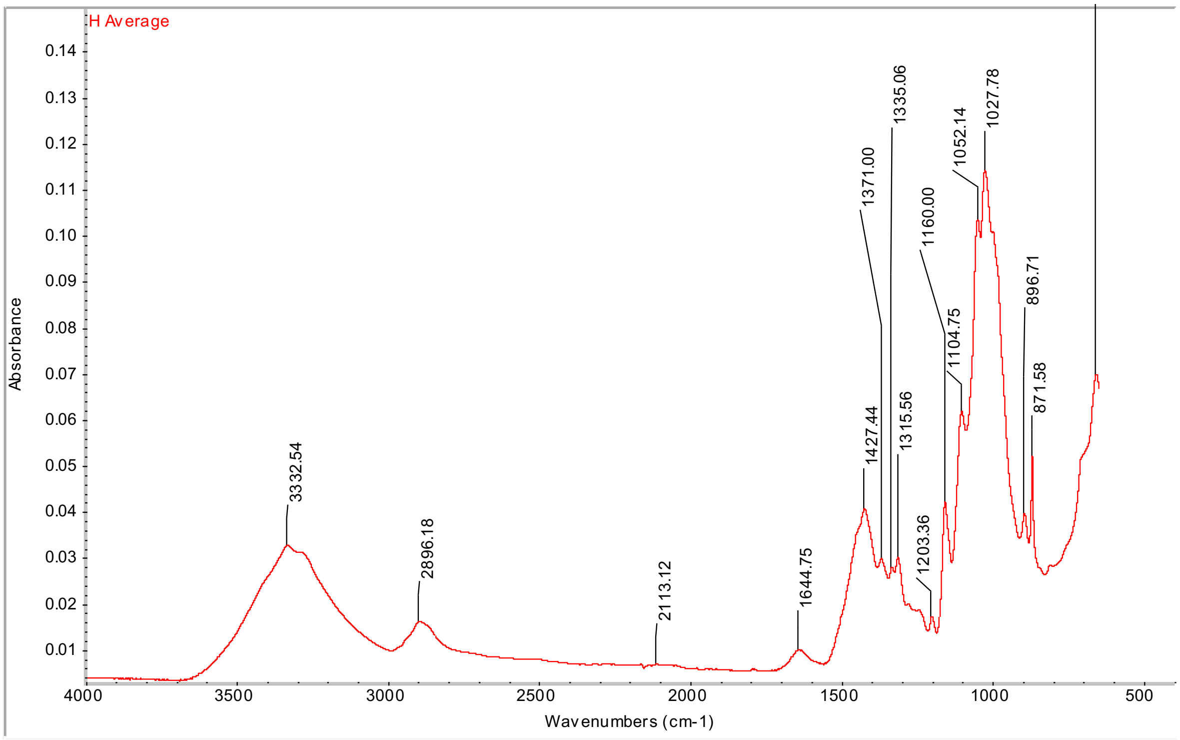
H-3 – Variation in spectra within box H-3 (5 envelopes, 4 spots)



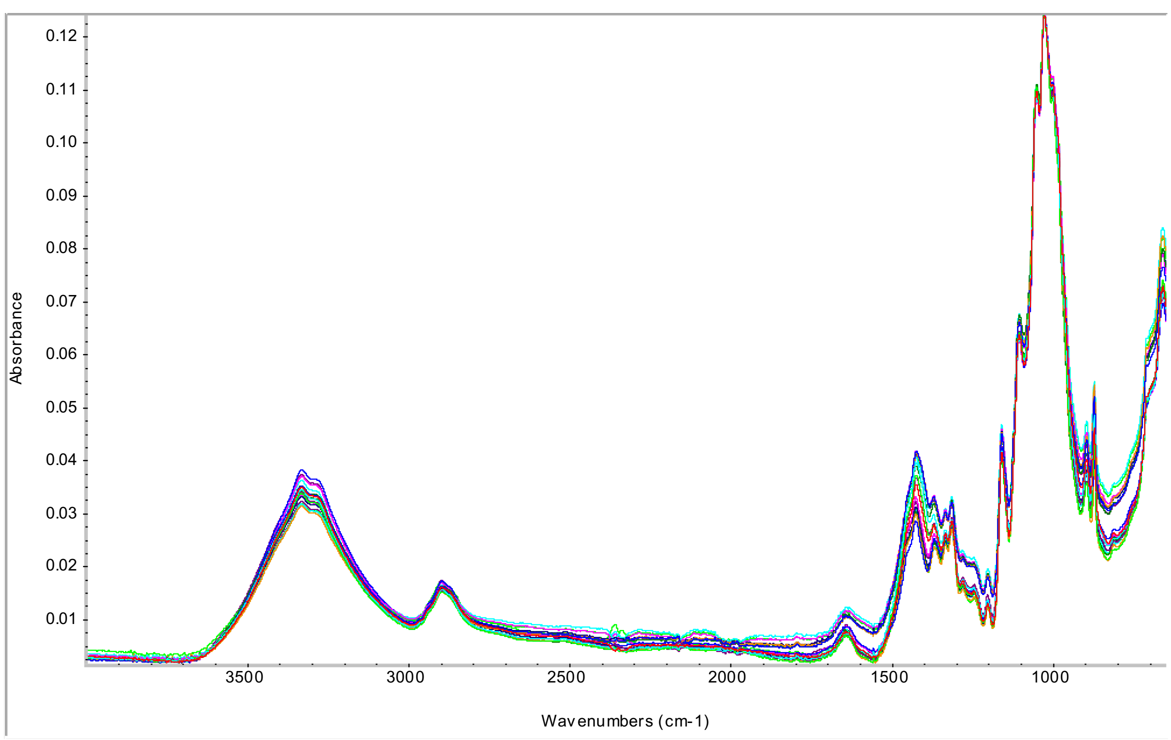
ATR-FT-IR BOX H AVERAGES:



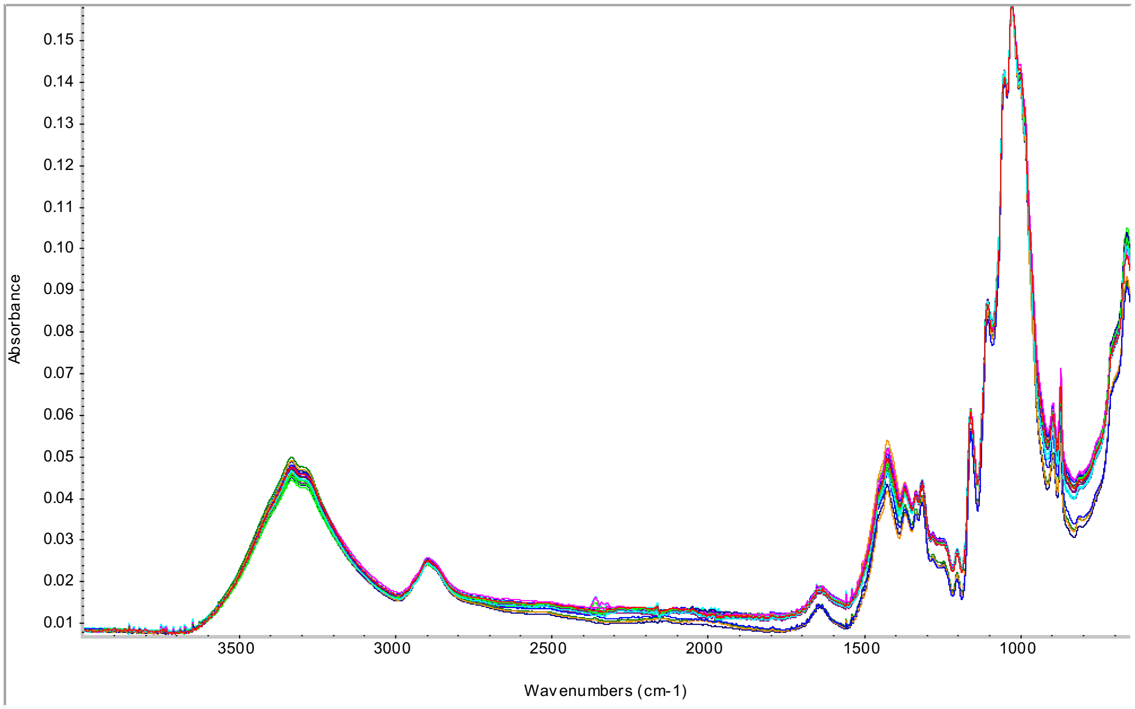
AVERAGE SPECTRA FOR BRAND H:



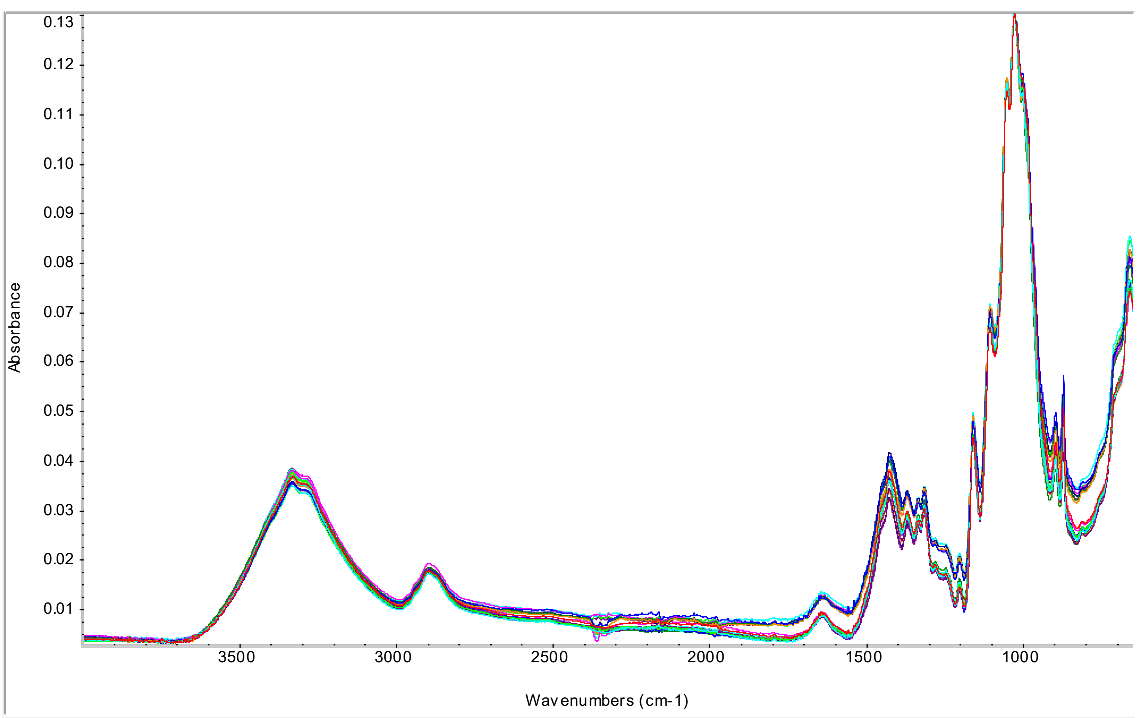
I-1 – Variation in spectra within box I-1 (5 envelopes, 4 spots)



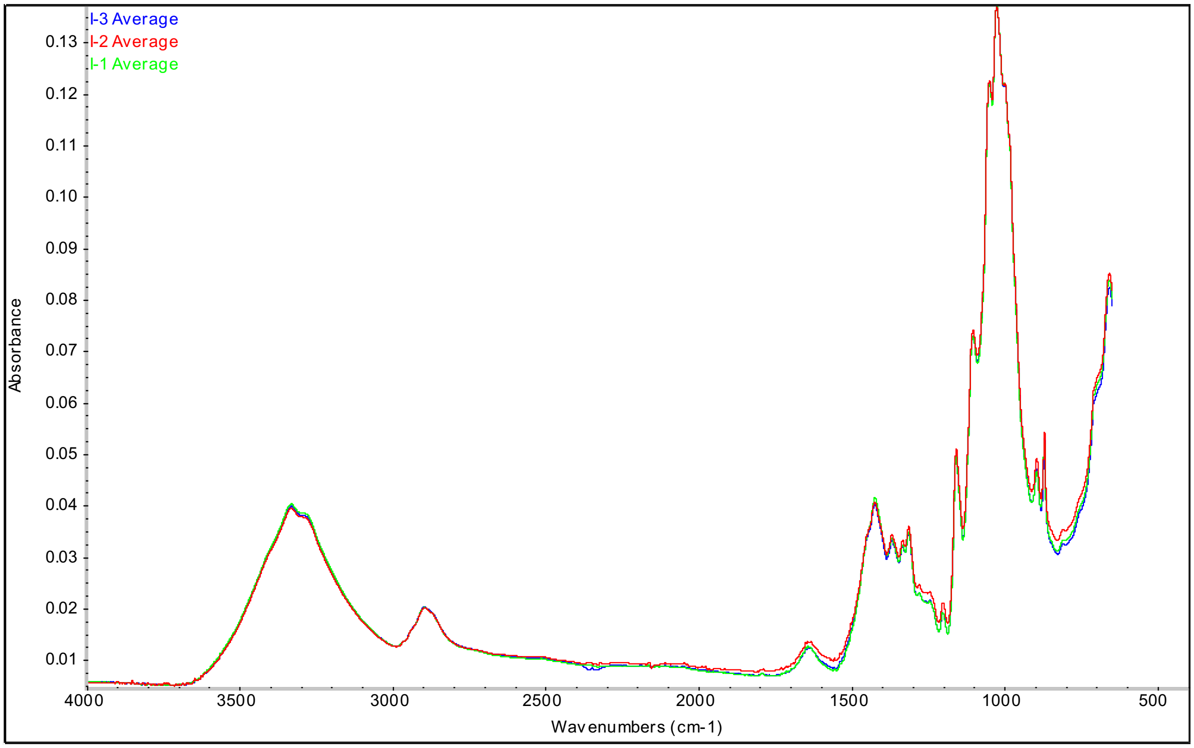
I-2 – Variation in spectra within box I-2 (5 envelopes, 4 spots)

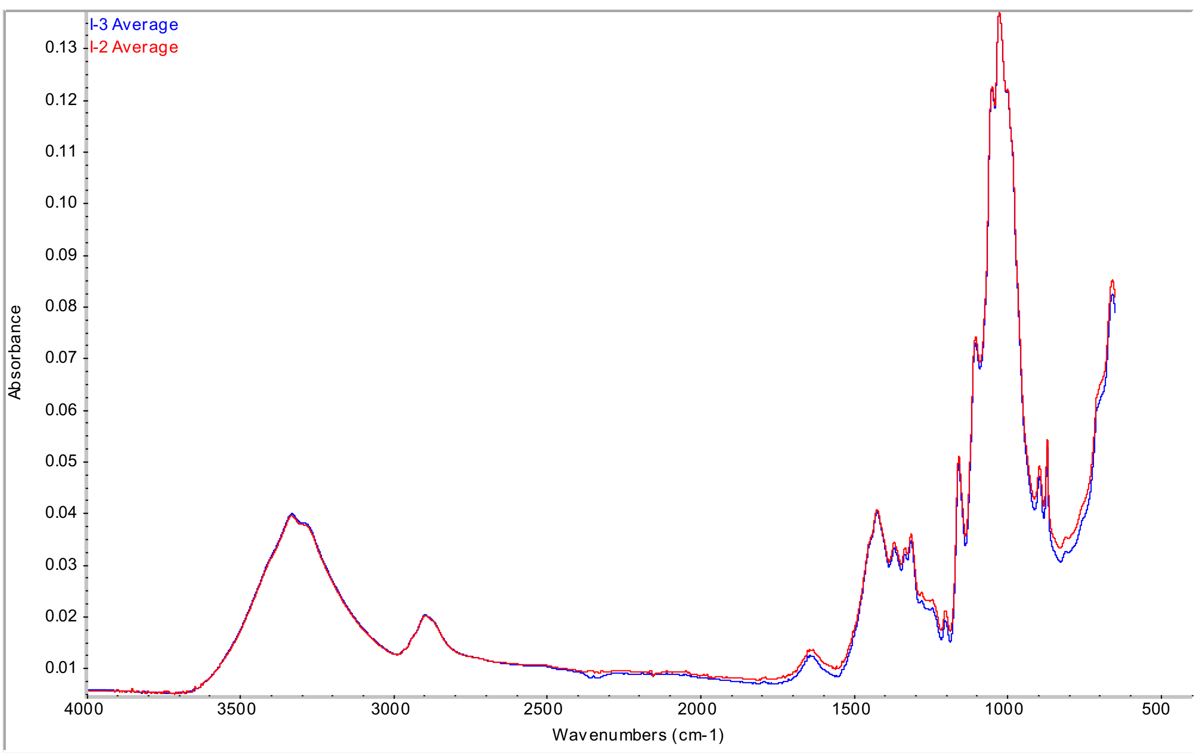


I-3 – Variation in spectra within box I-3 (5 envelopes, 4 spots)

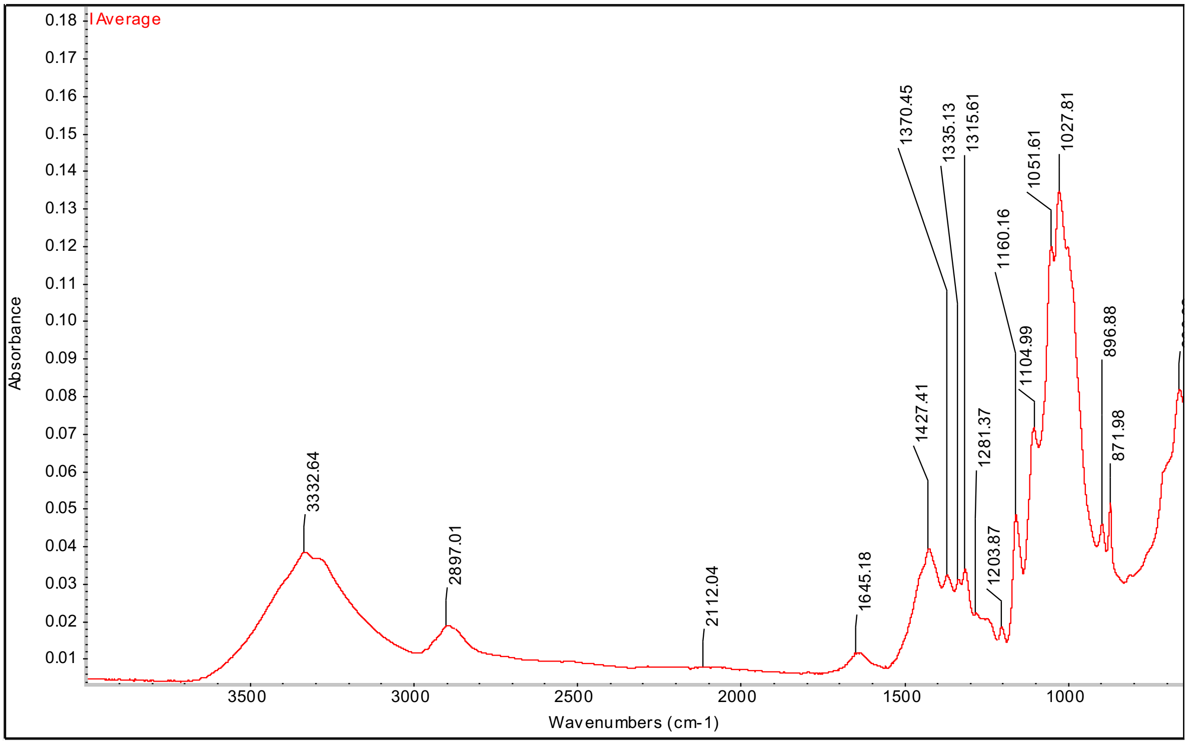


ATR-FT-IR BOX I AVERAGES:

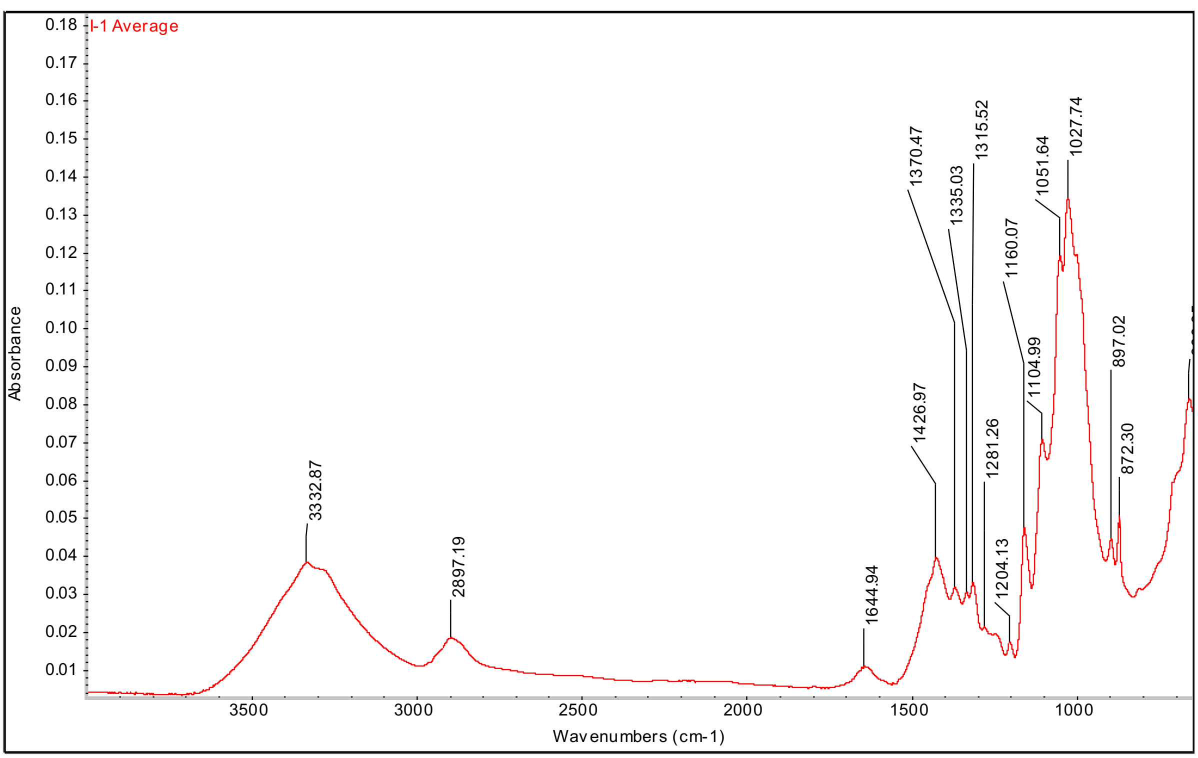


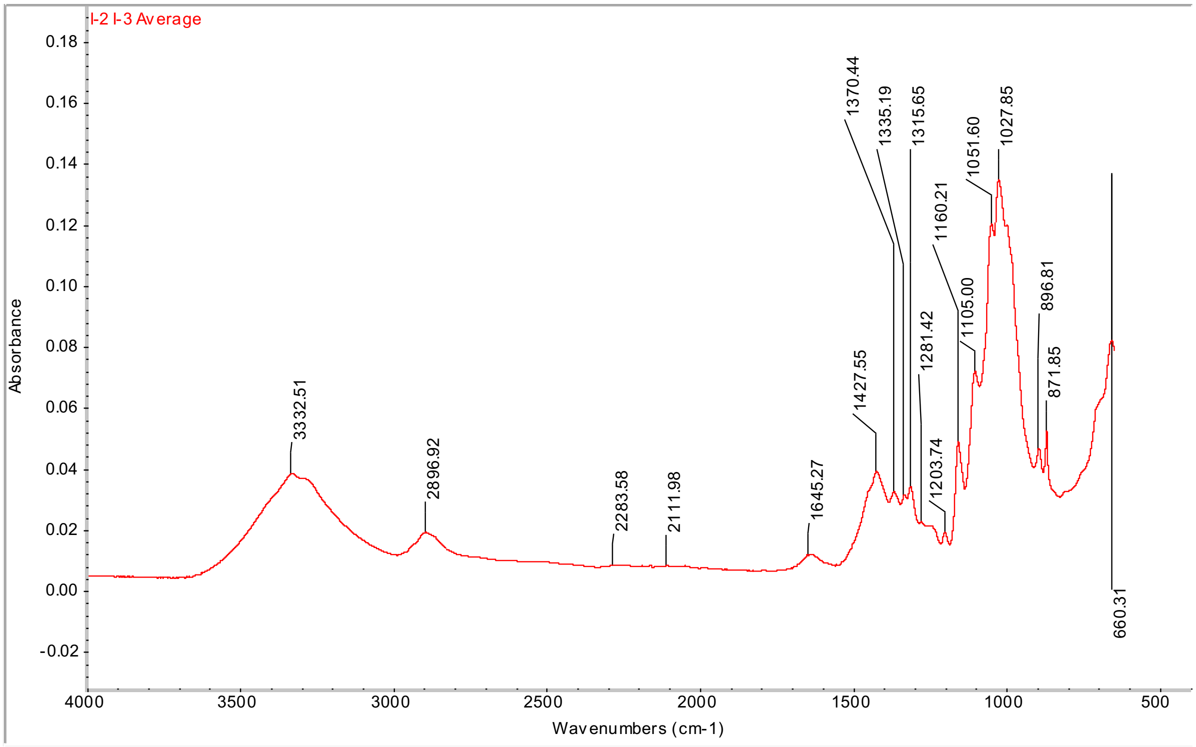


AVERAGE SPECTRA FOR BRAND I (all boxes):

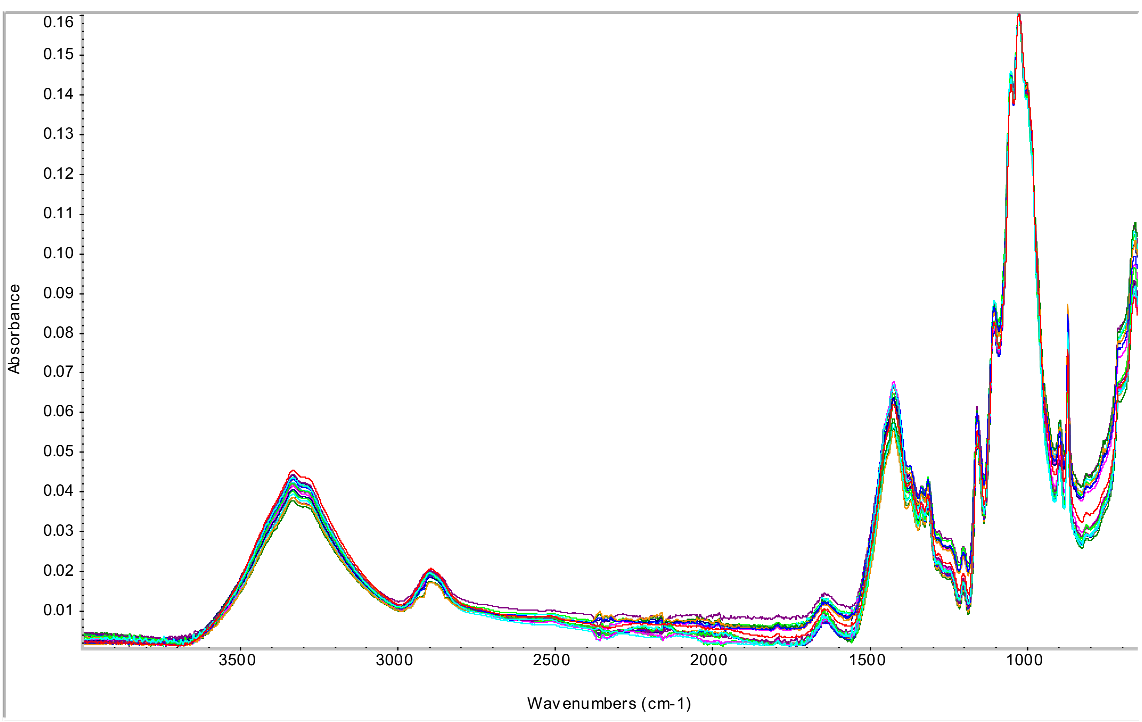


BRAND AVERAGES (separating I into 2):

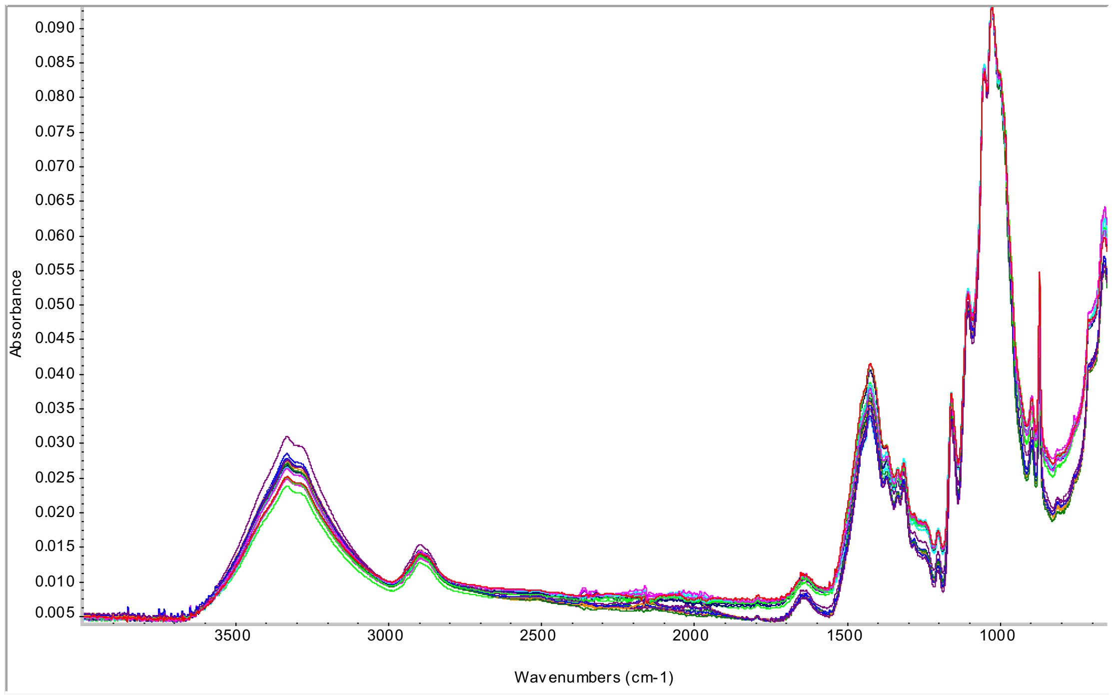




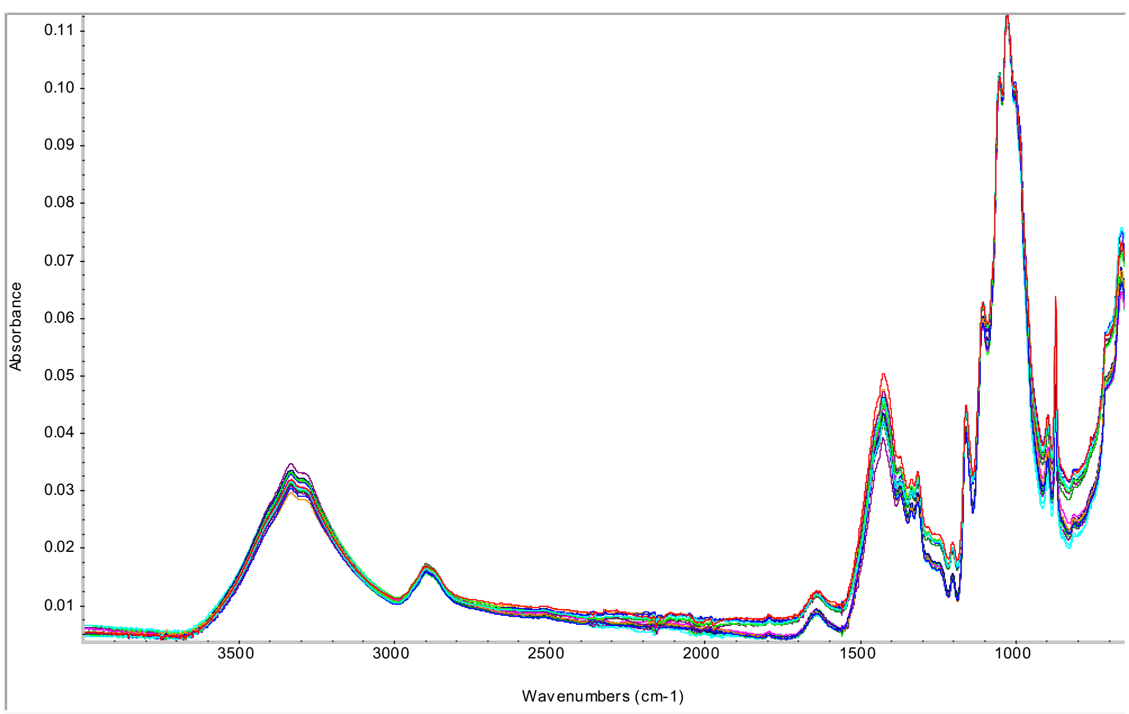
J-1 – Variation in spectra within box J-1 (5 envelopes, 4 spots)



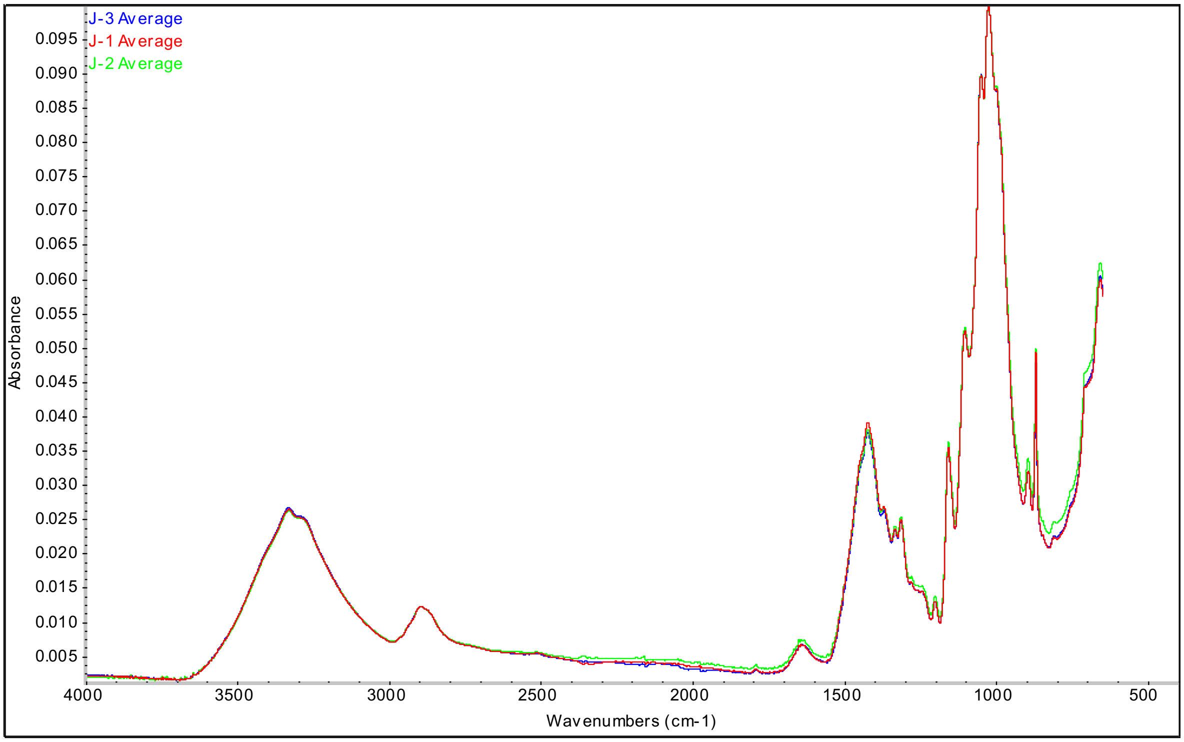
J-2 – Variation in spectra within box J-2 (5 envelopes, 4 spots)



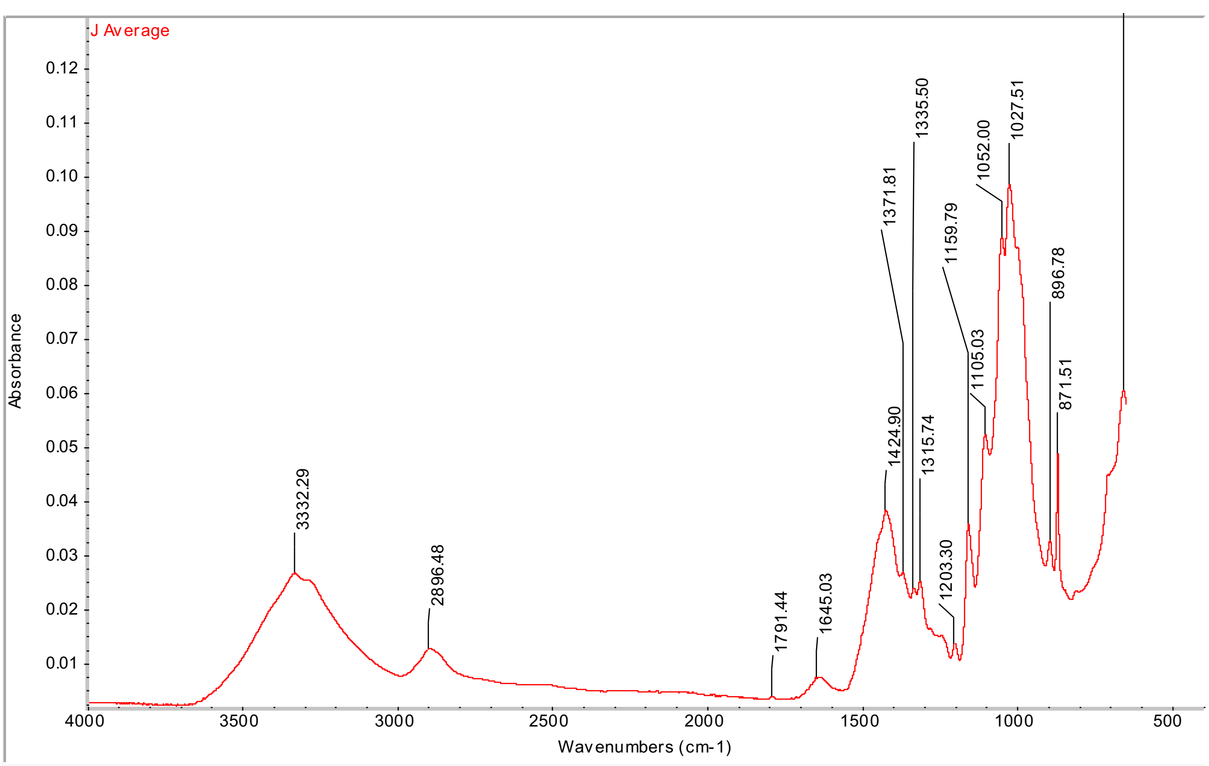
J-3 – Variation in spectra within box J-3 (5 envelopes, 4 spots)



ATR-FT-IR BOX J AVERAGES:

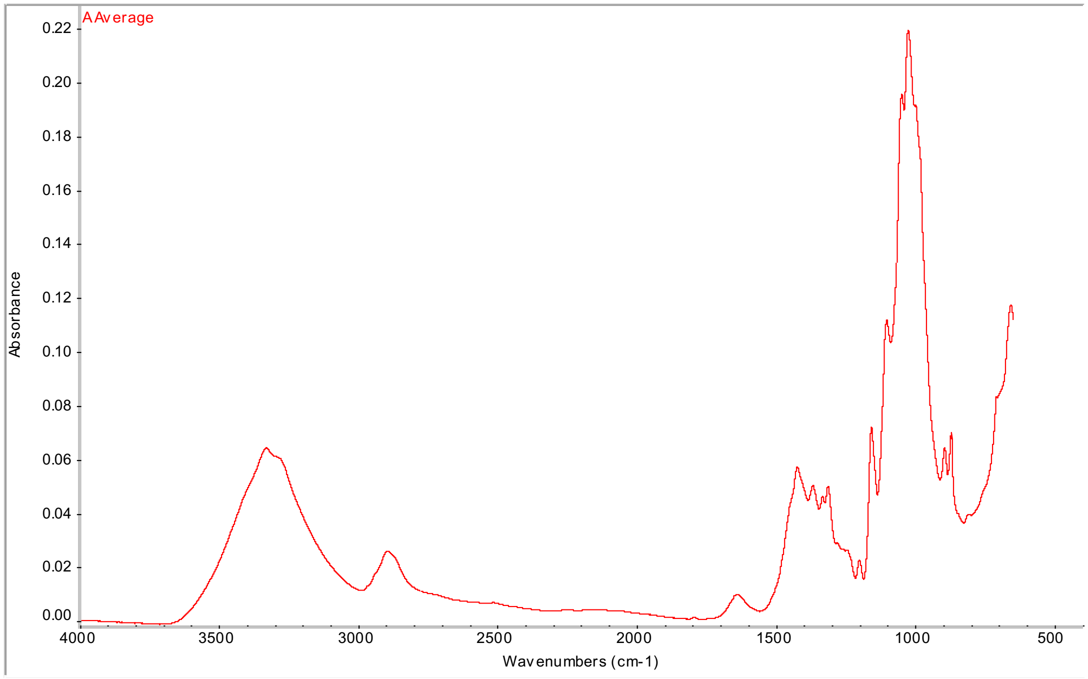


AVERAGE SPECTRA FOR BRAND J:

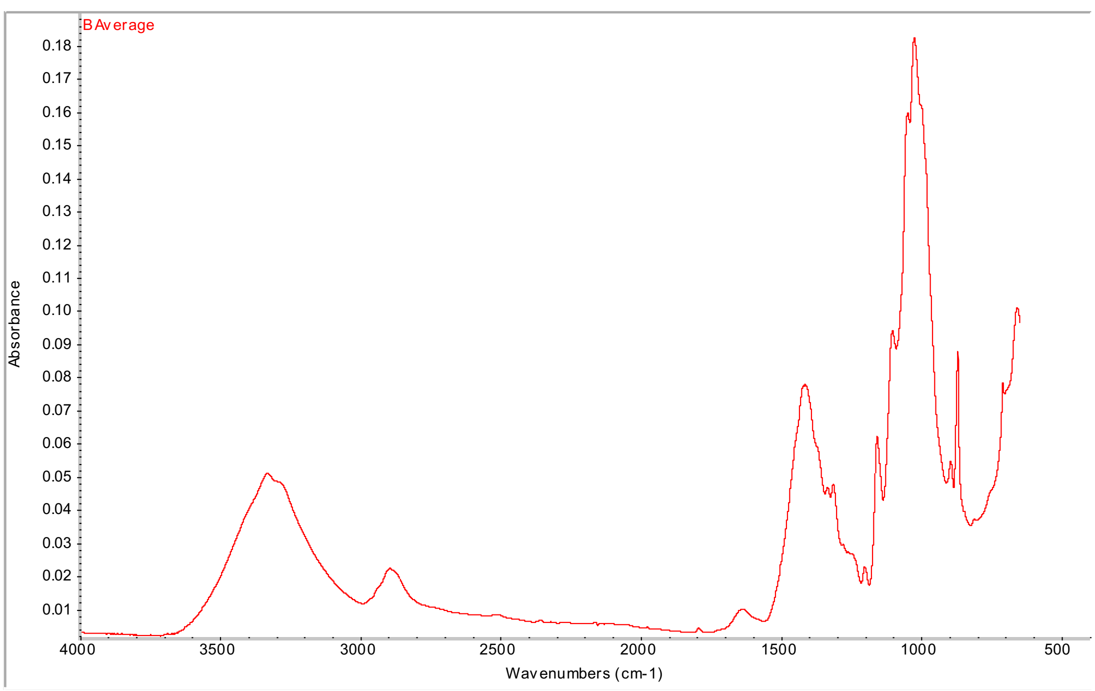


SPECTRAL AVERAGE BY GROUPS:

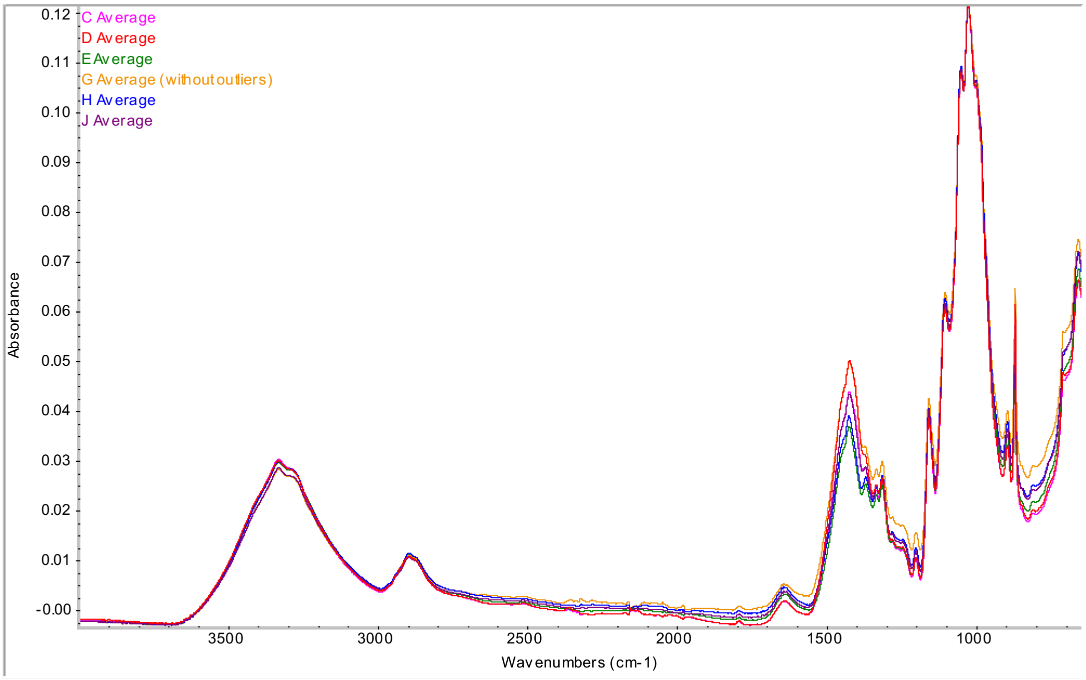
Brand A:



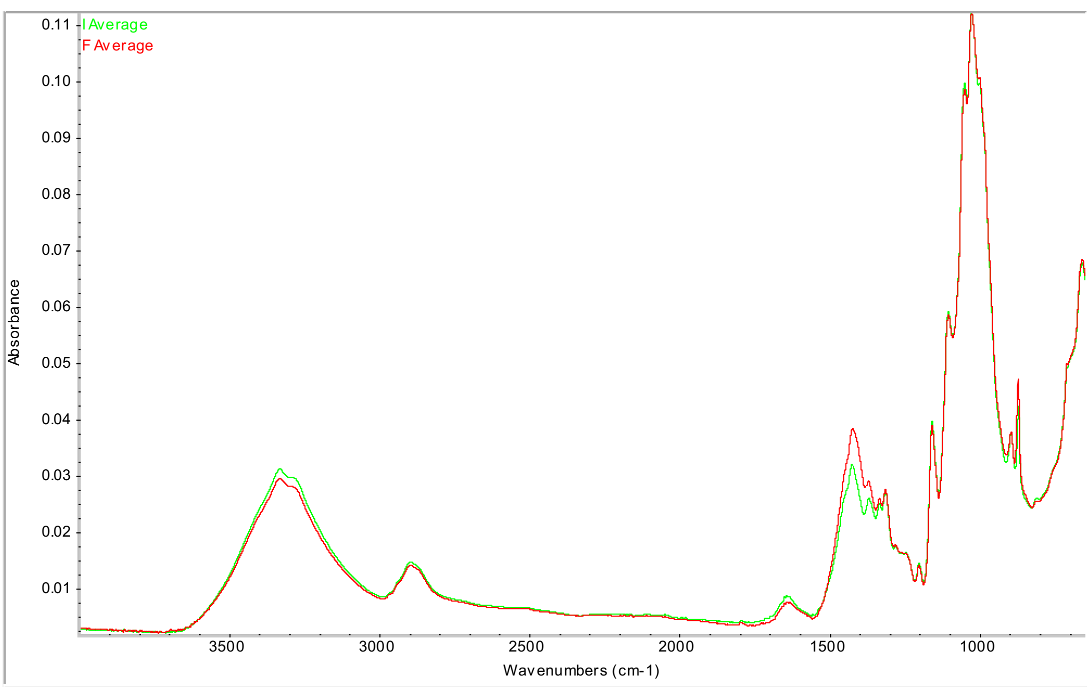
Brand B:



Brands C, D, E, G, H, J:



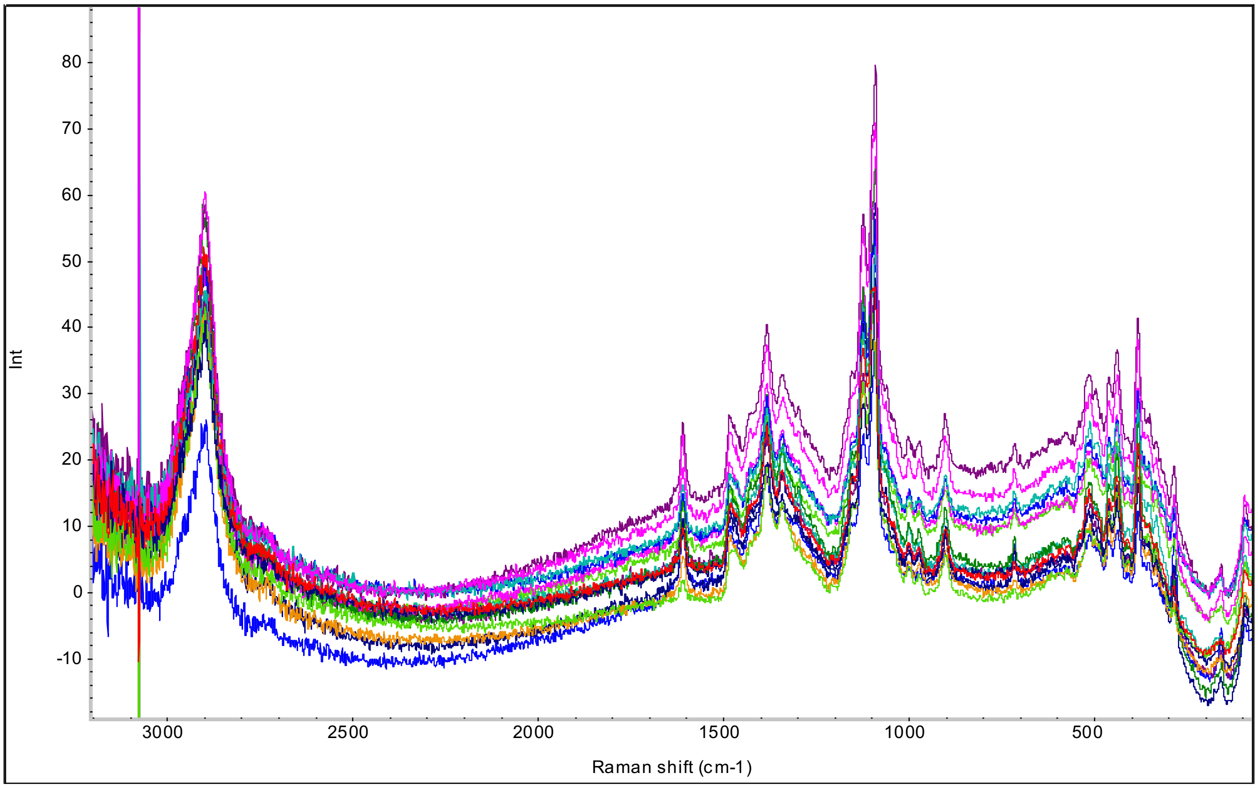
Brands I, F:



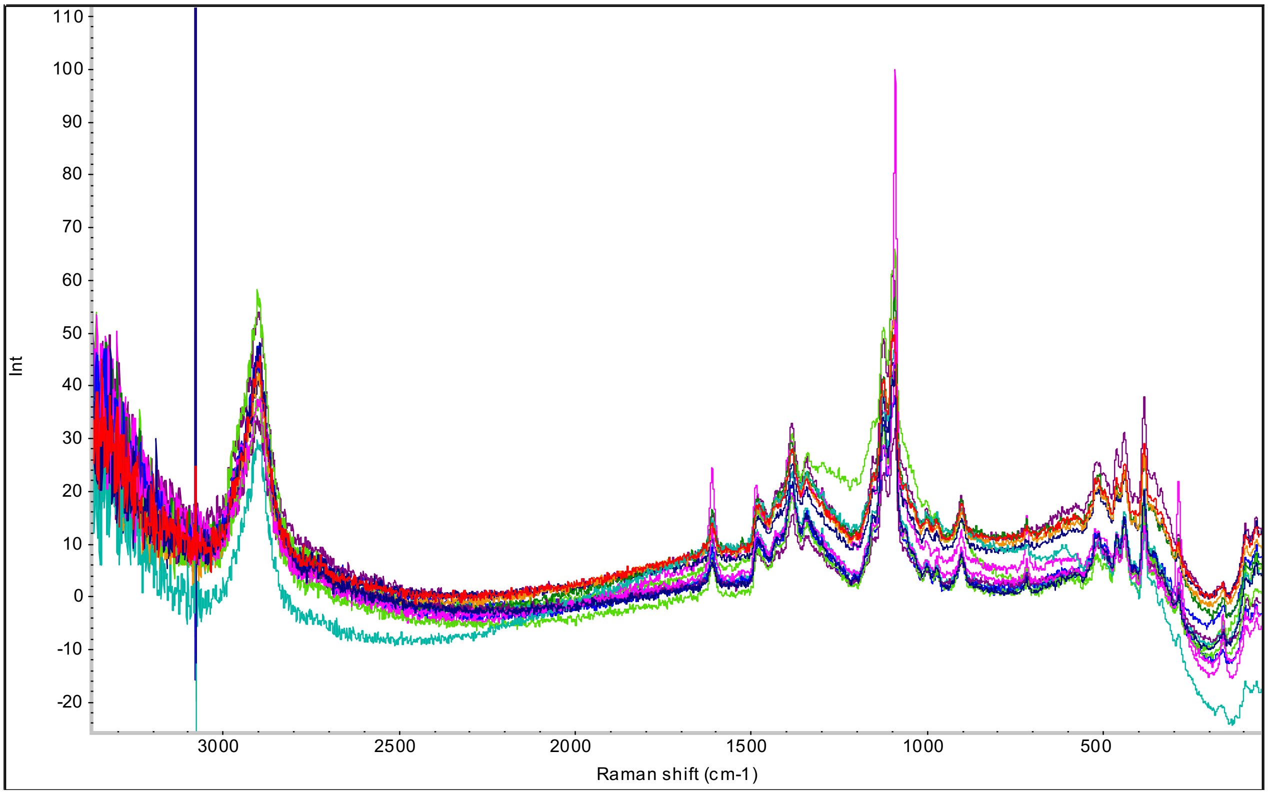
APPENDIX XII

Raman Spectroscopy Spectra Results

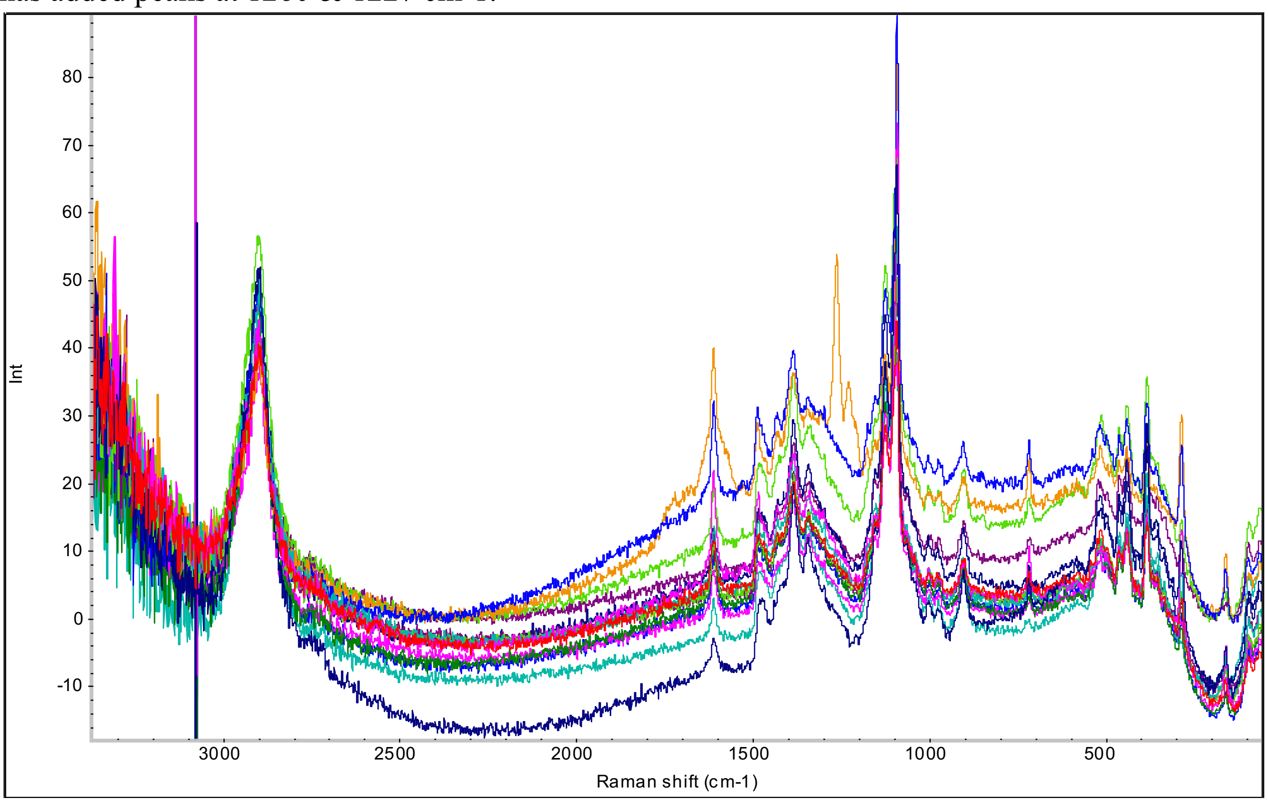
A-1 – Variation in spectra within box A-1 (5 envelopes, 3 spots)



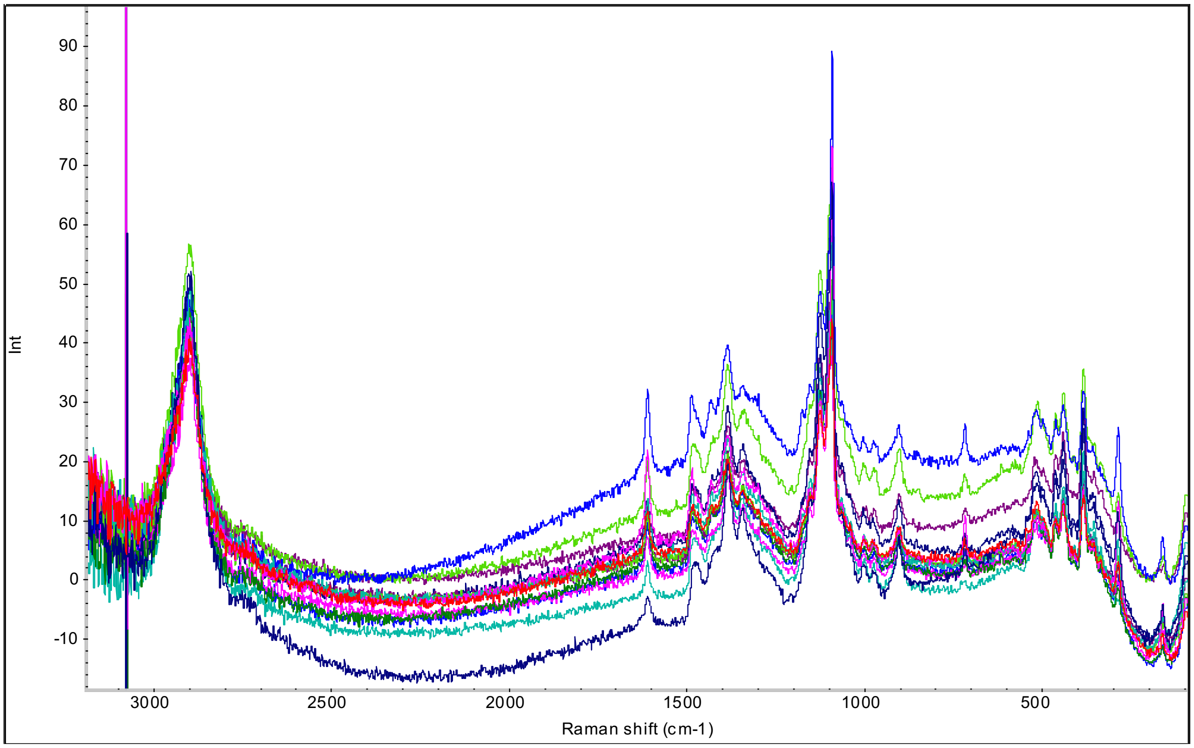
A-2 – Variation in spectra within box A-2 (5 envelopes, 3 spots)



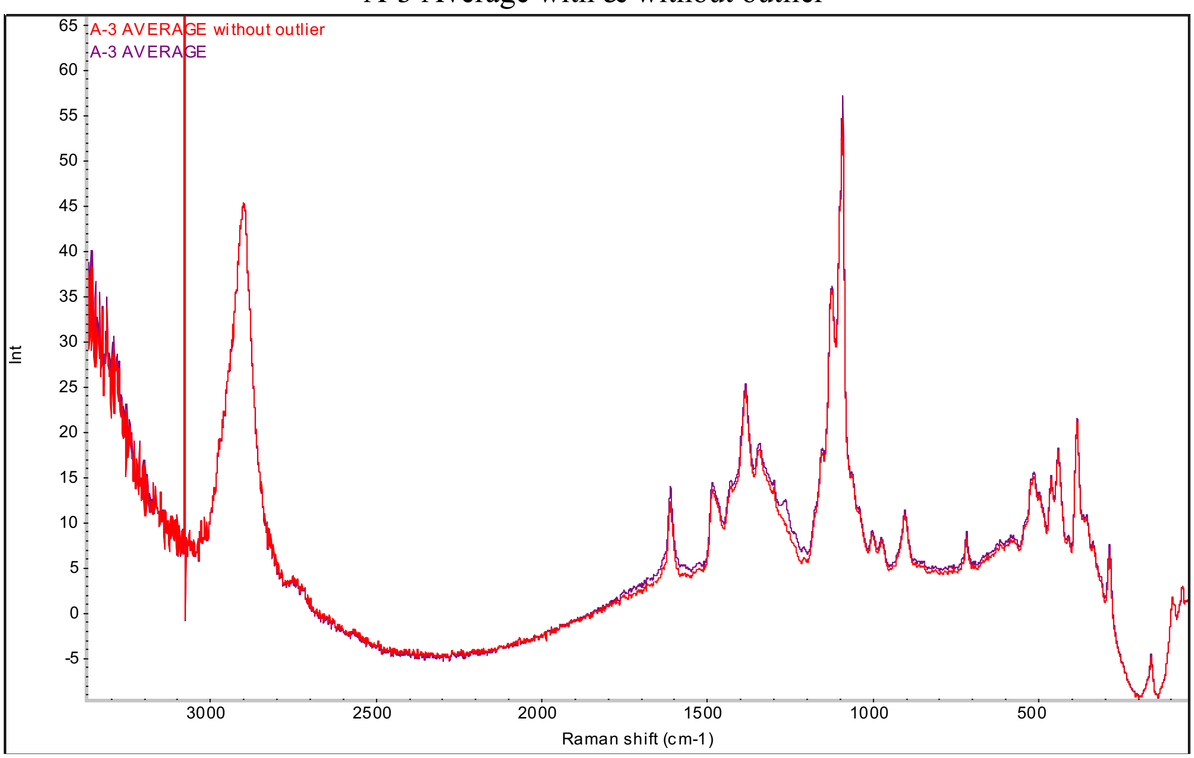
A-3 – Variation in spectra within box A-3 (5 envelopes, 3 spots). One outlier spectrum, A-3-3-2, has added peaks at 1260 & 1227 cm-1.



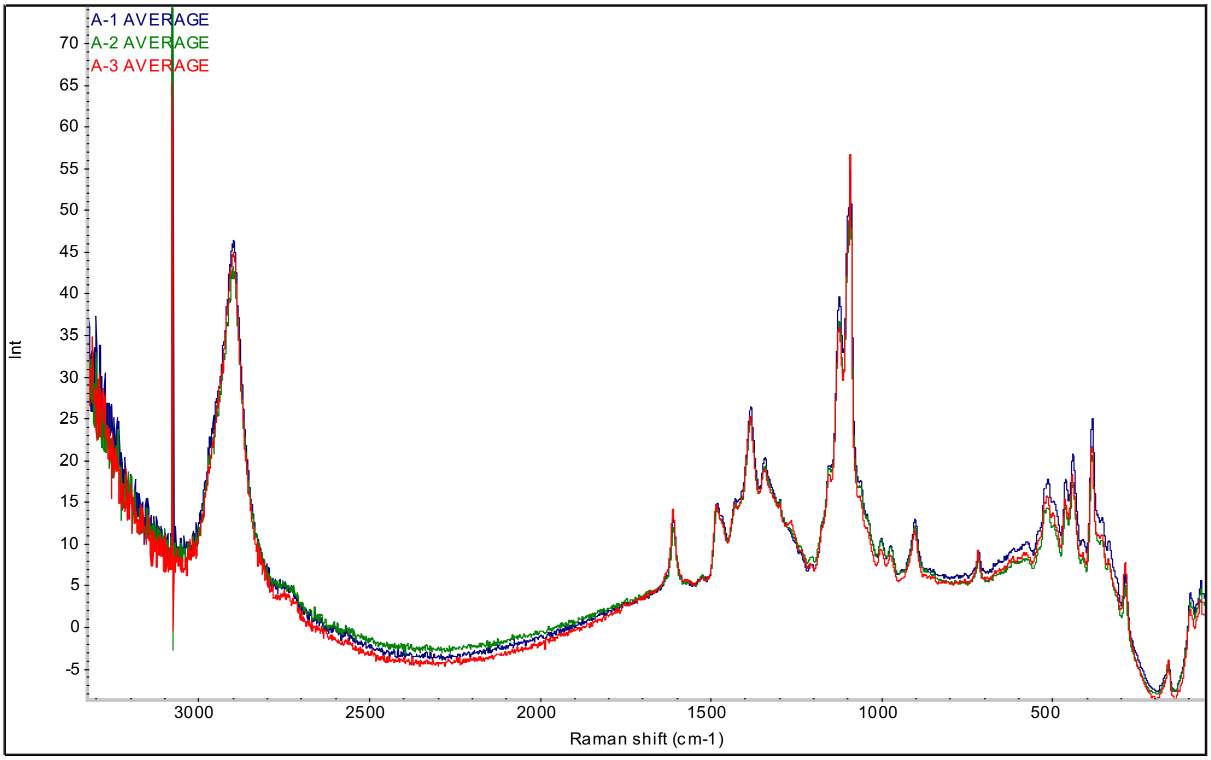
A-3 – Variation in spectra within box A-3 (5 envelopes, 3 spots). One outlier was removed (A-3-3-2).

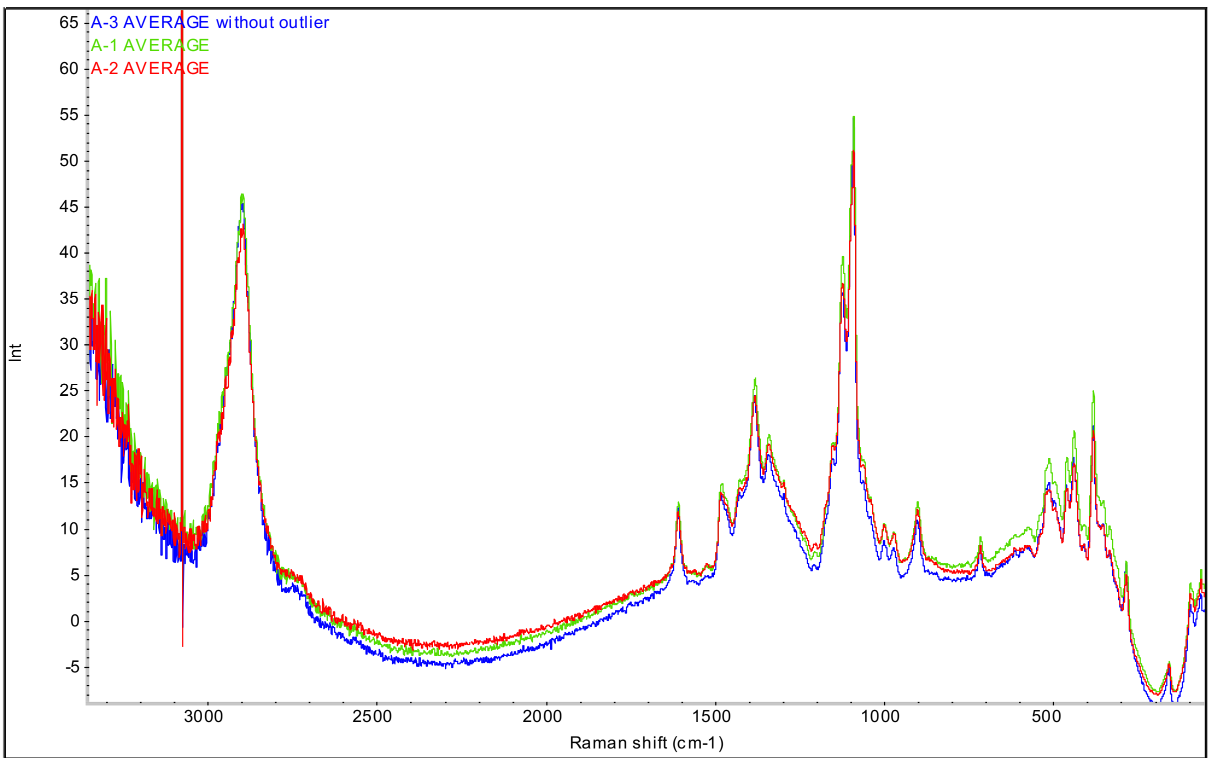


A-3 Average with & without outlier

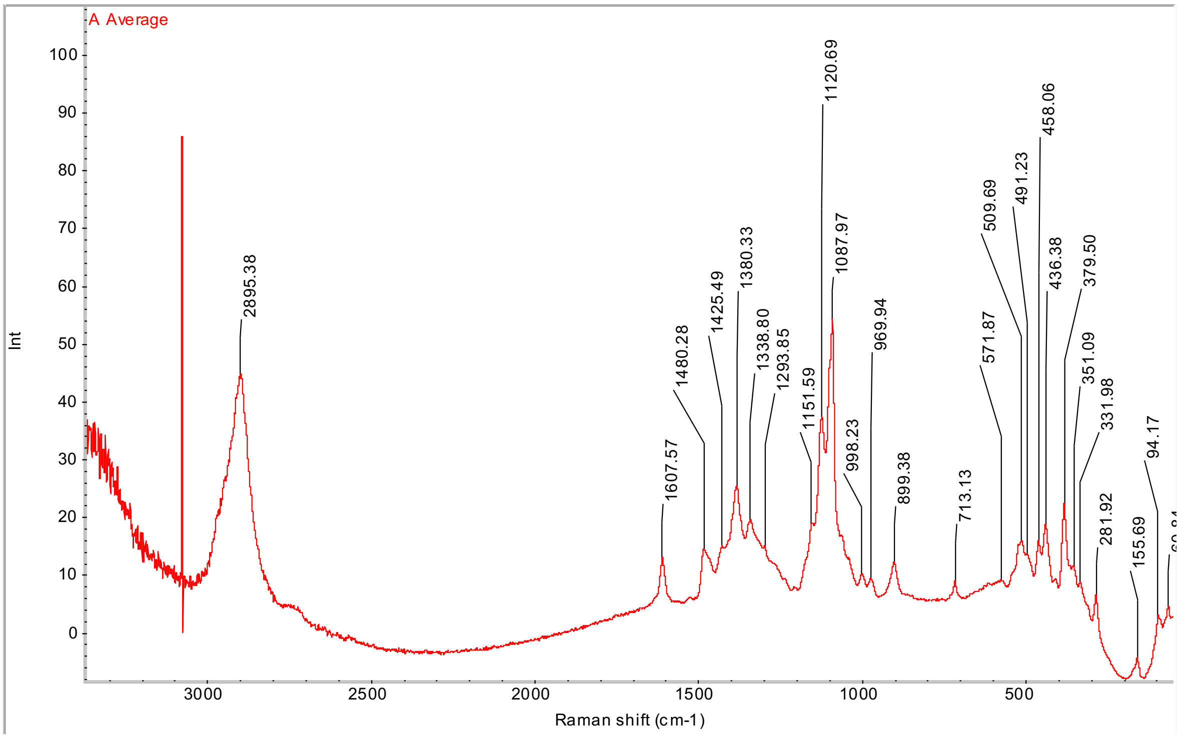


Raman BOX A AVERAGES:

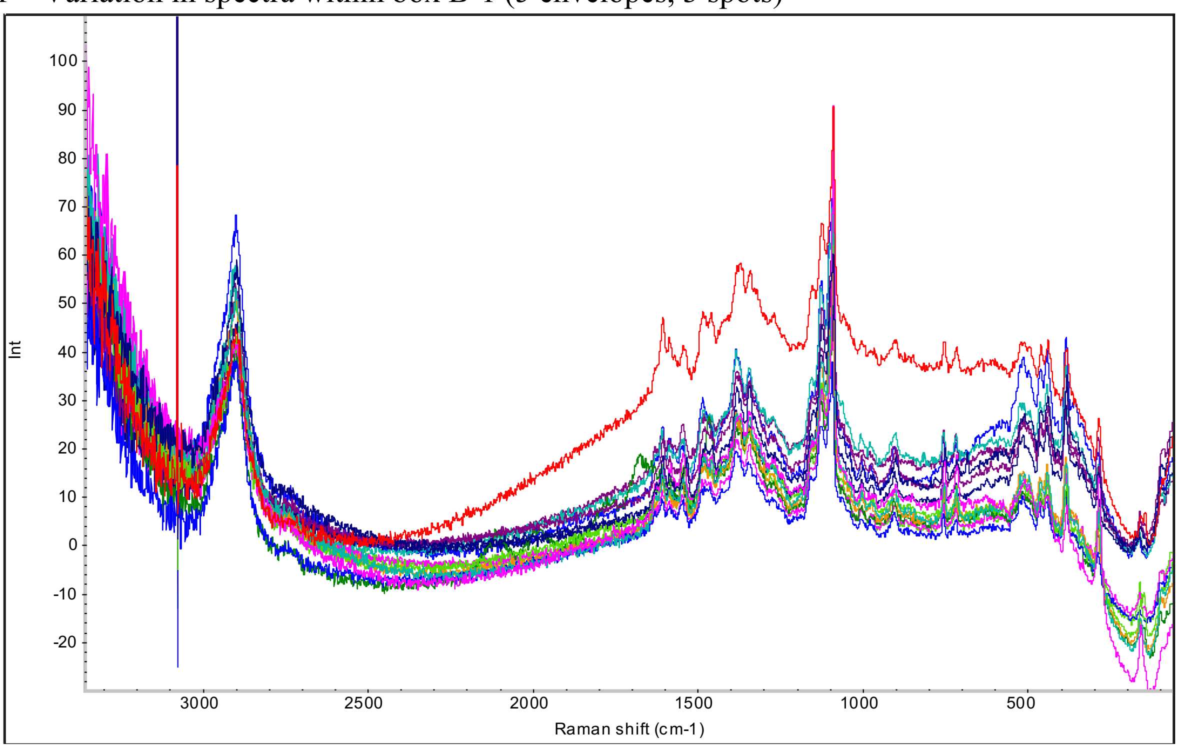




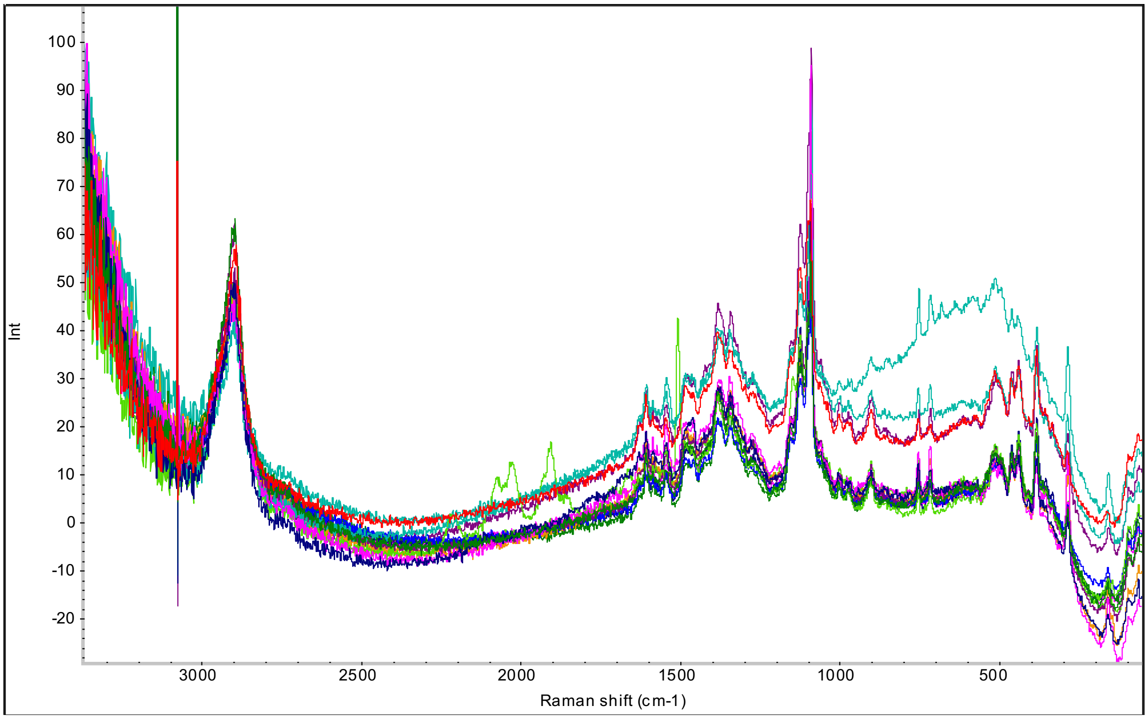
AVERAGE SPECTRA FOR BRAND A:



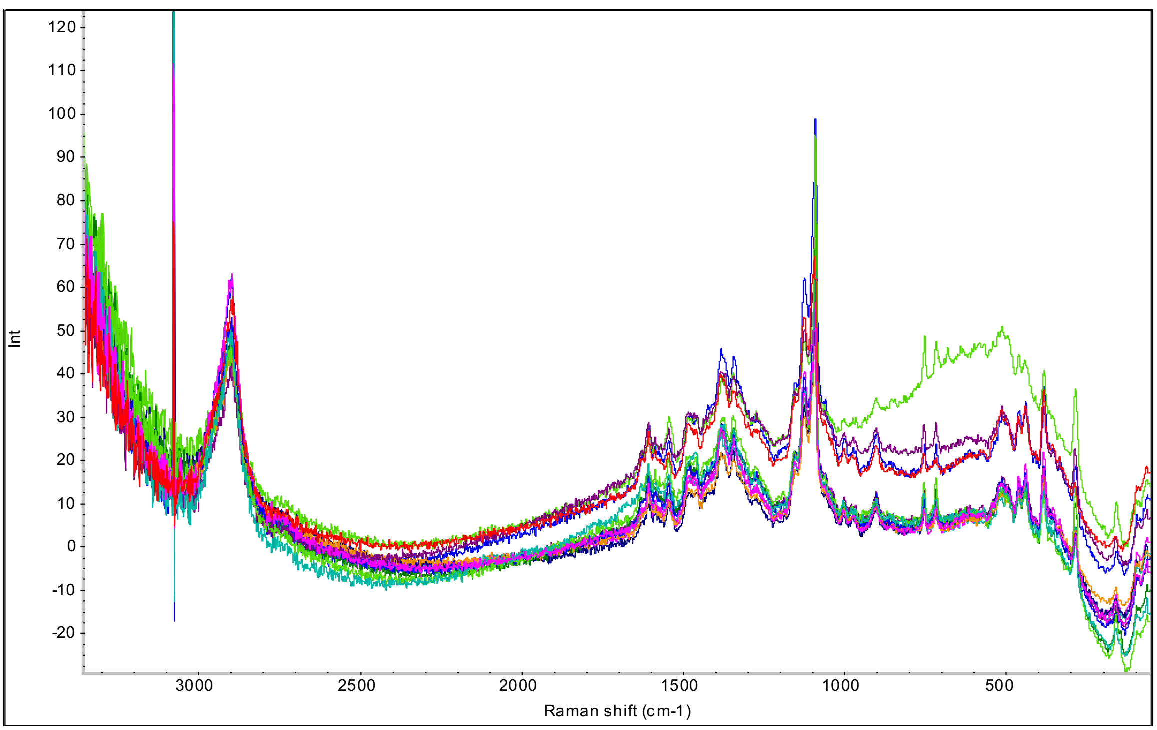
B-1 – Variation in spectra within box B-1 (5 envelopes, 3 spots)



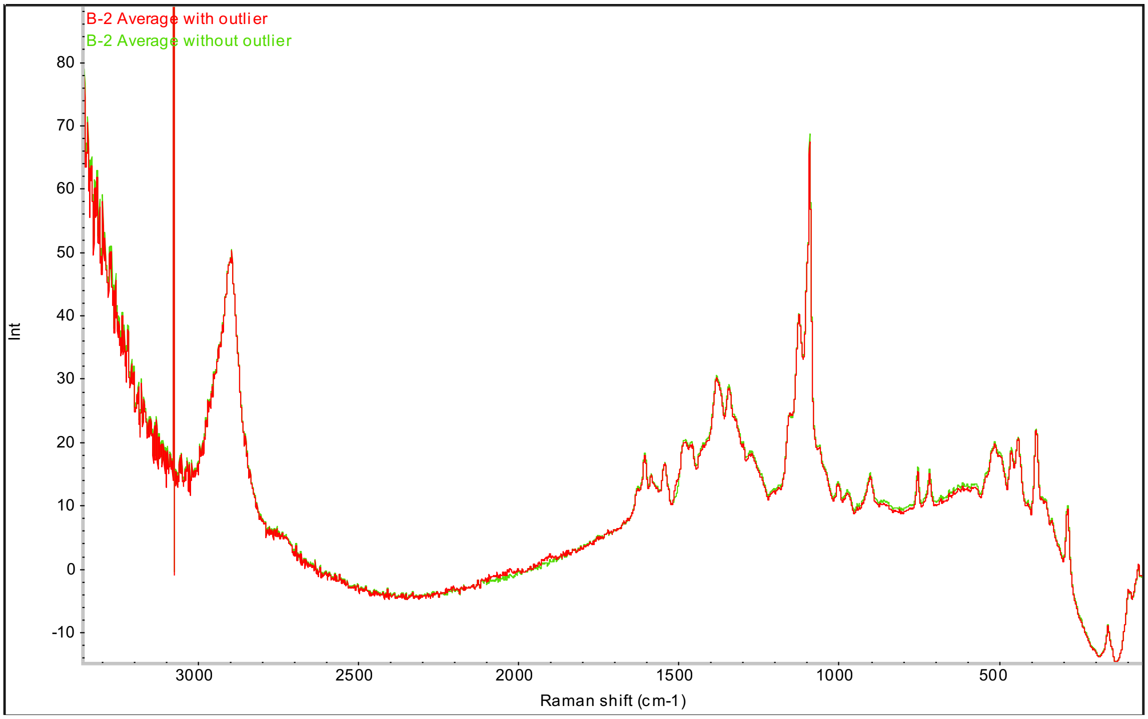
B-2 – Variation in spectra within box B-2 (5 envelopes, 3 spots). One outlier spectrum, B-2-4-1, has added peaks at 1506, 1904, 2031, 2072, and 2210 cm-1.



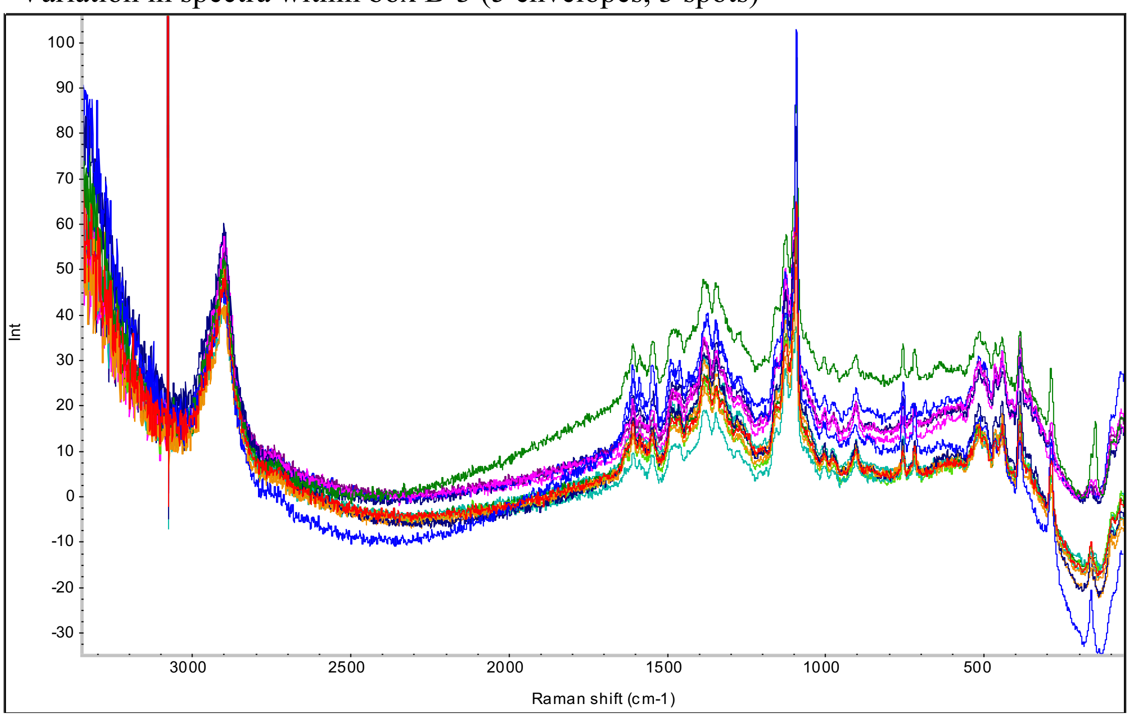
B-2 – Variation in spectra within box B-2 (5 envelopes, 3 spots). One outlier was removed (B-2-4-1).



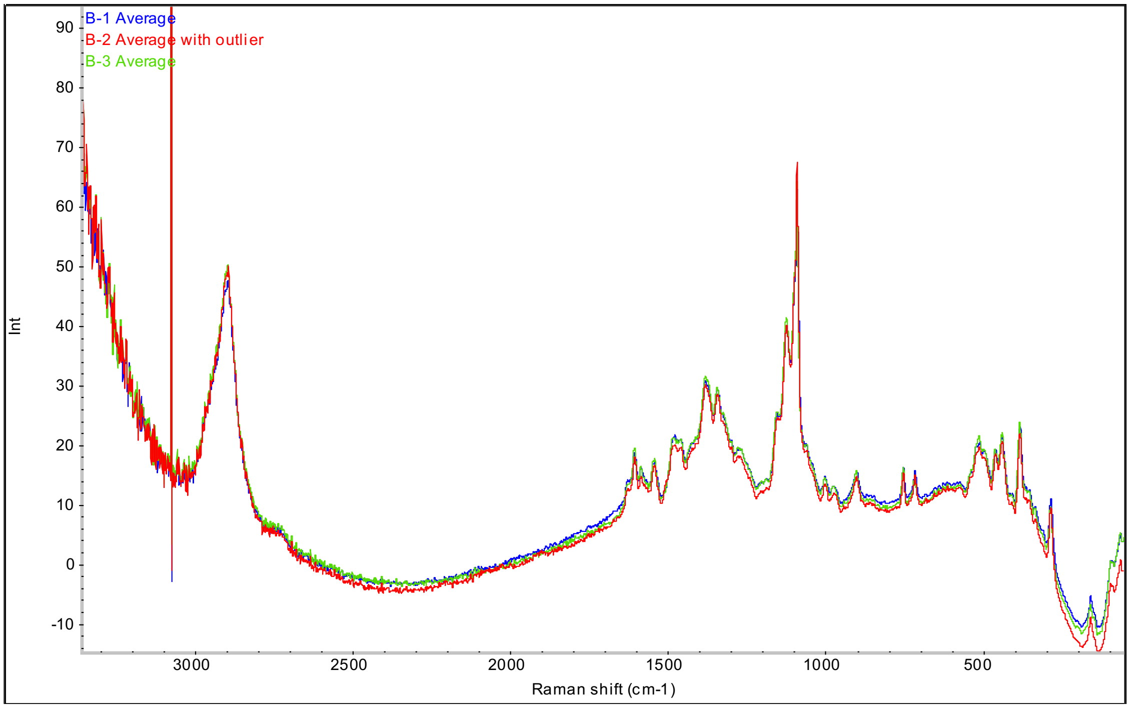
B-2 Average with & without outlier



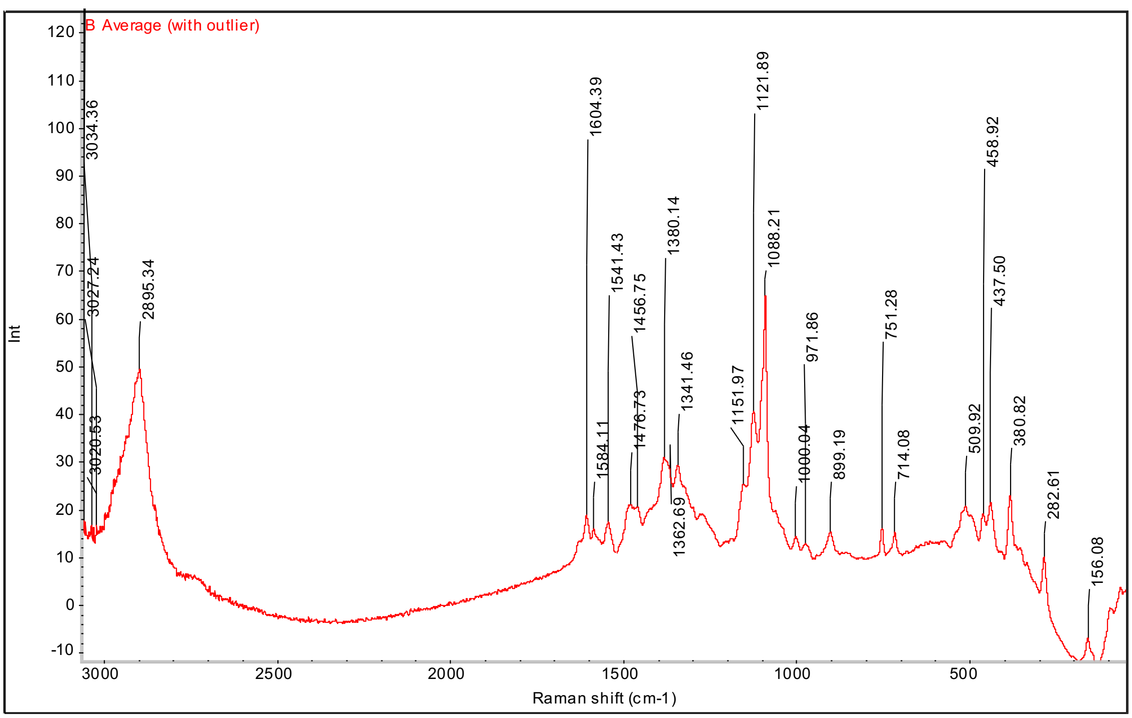
B-3 – Variation in spectra within box B-3 (5 envelopes, 3 spots)

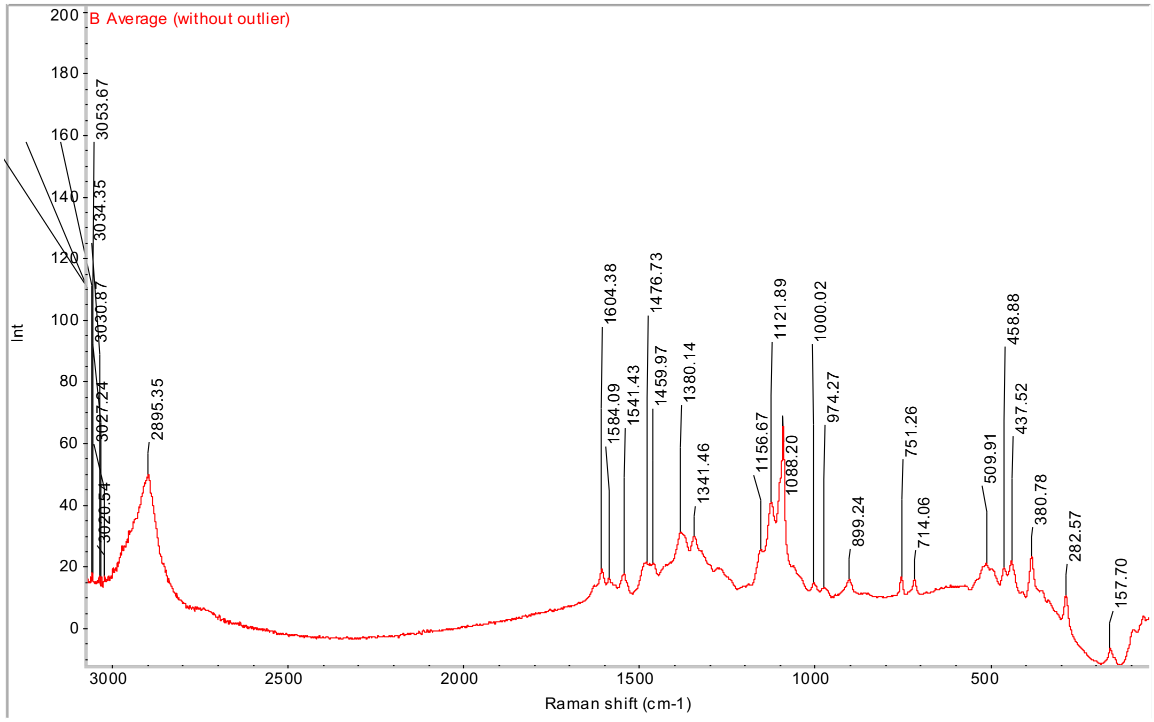


Raman BOX B AVERAGES:

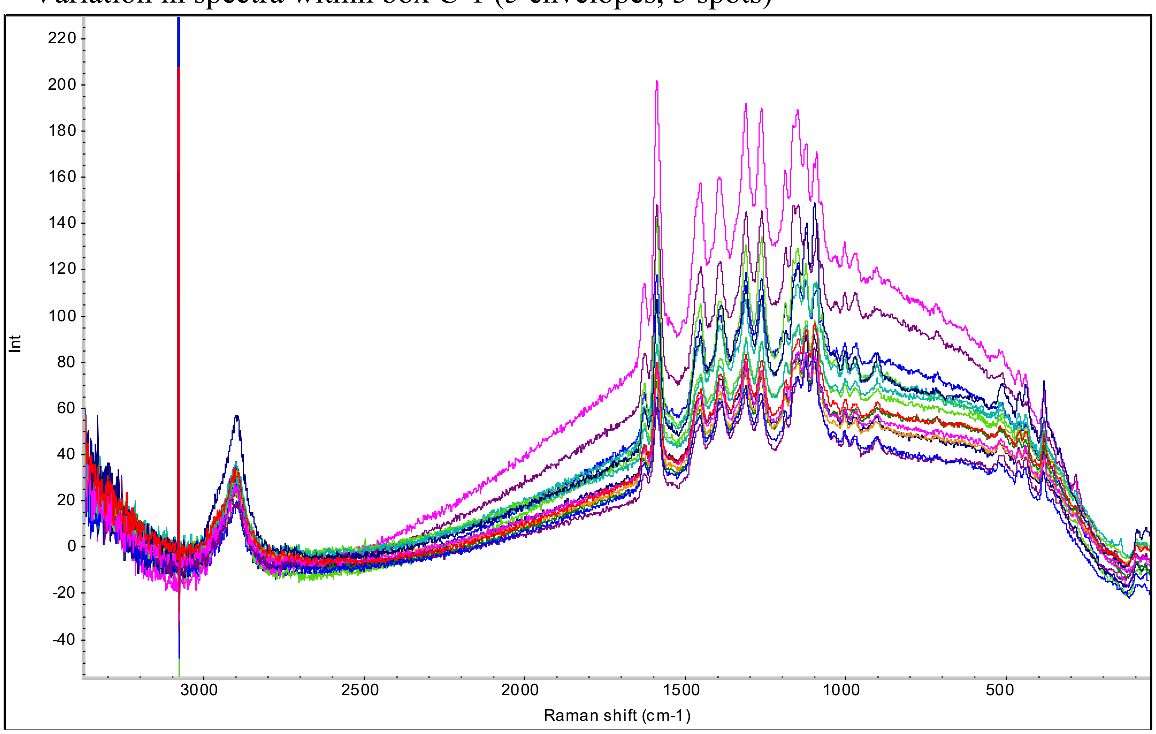


AVERAGE SPECTRA FOR BRAND B:

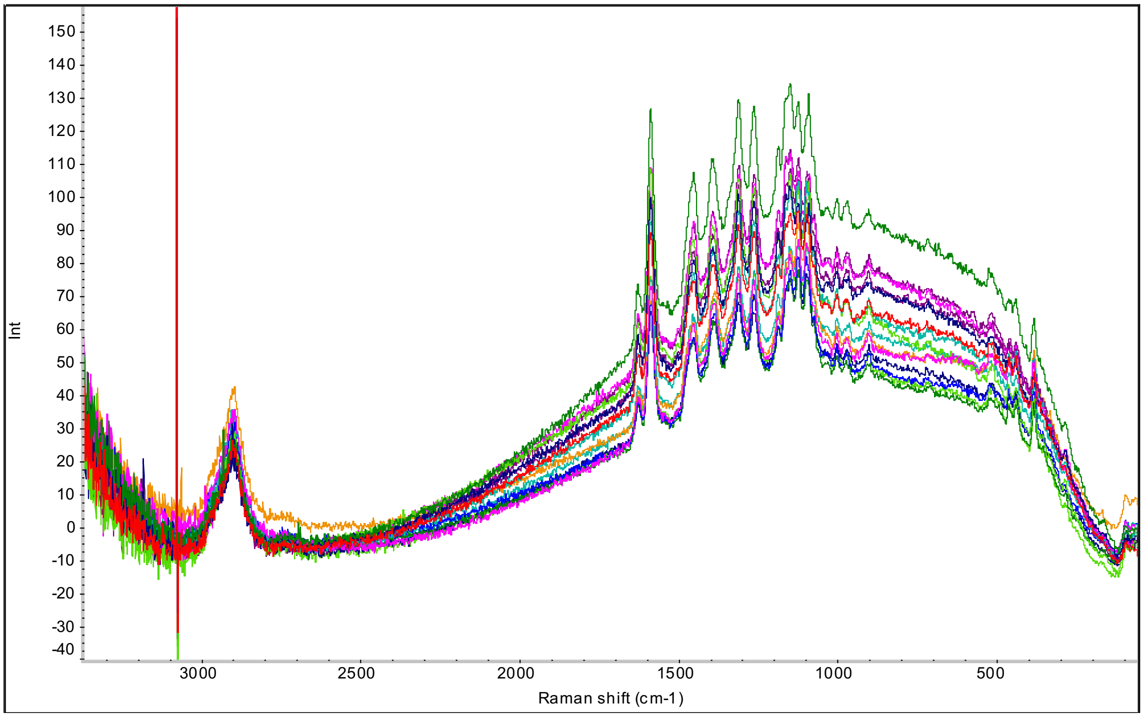




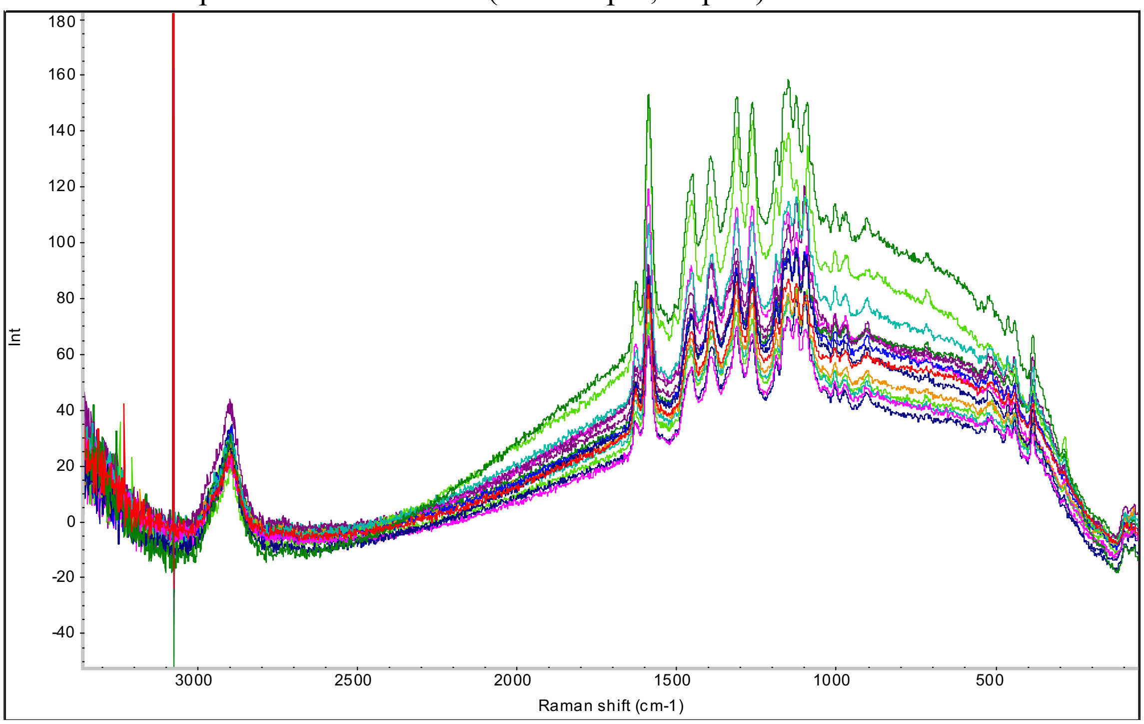
C-1 – Variation in spectra within box C-1 (5 envelopes, 3 spots)



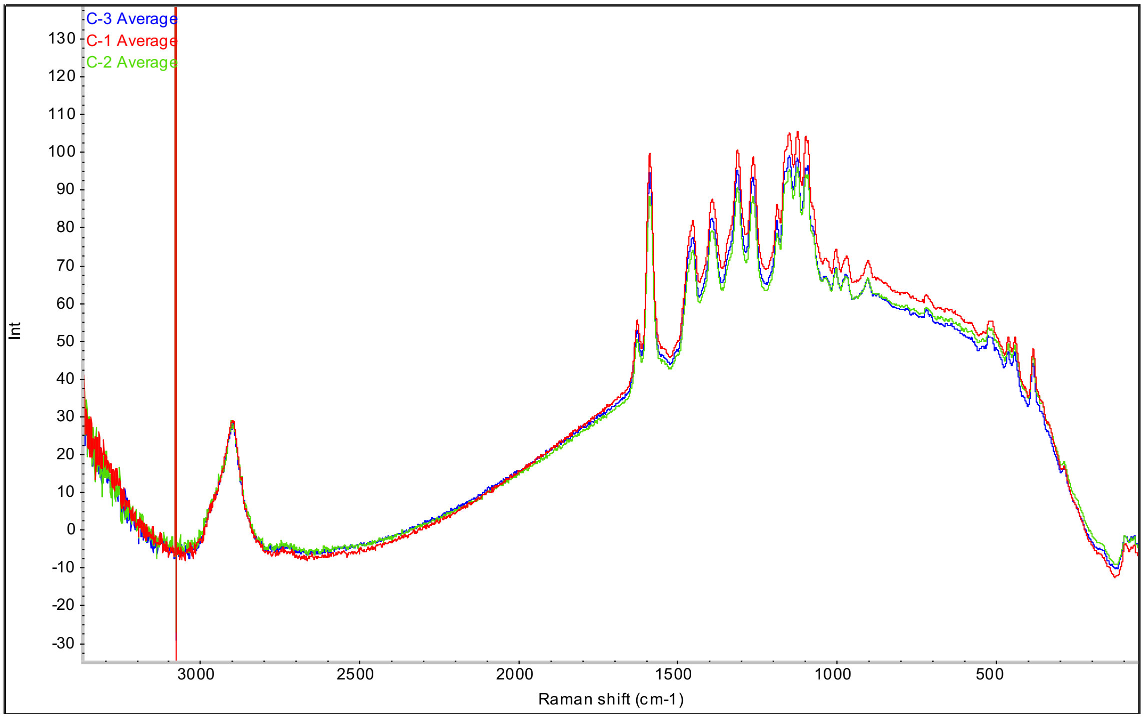
C-2 – Variation in spectra within box C-2 (5 envelopes, 3 spots)



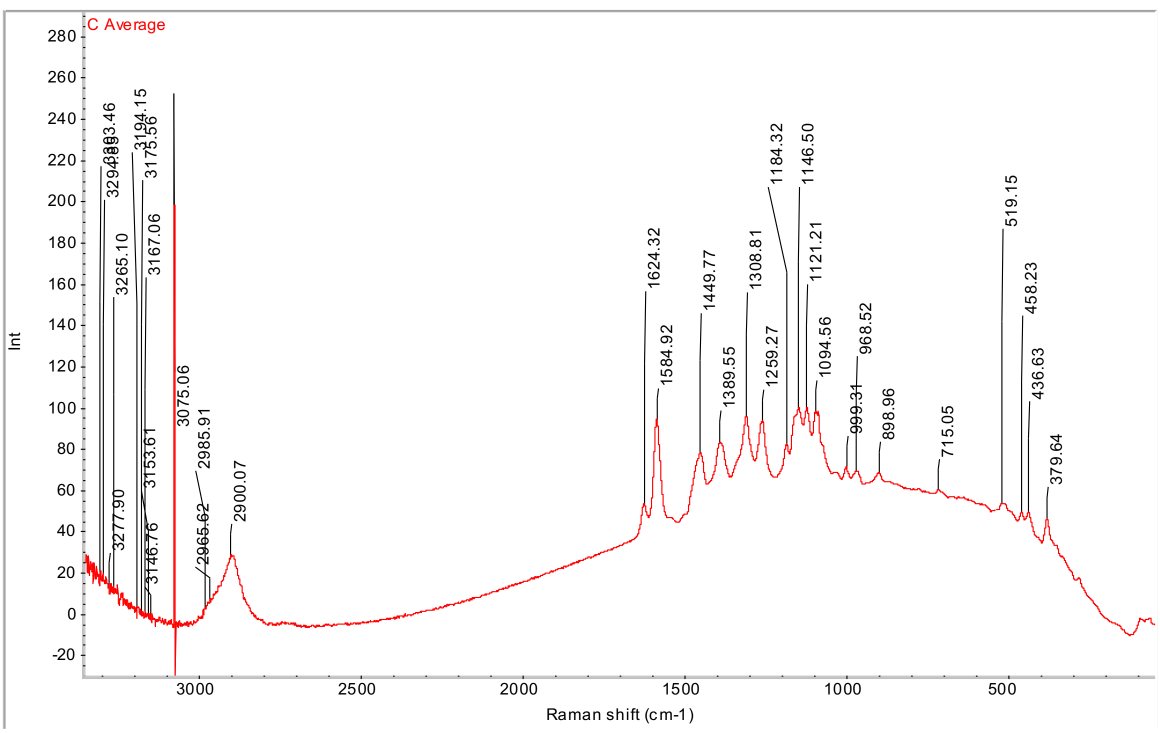
C-3 – Variation in spectra within box C-3 (5 envelopes, 3 spots)



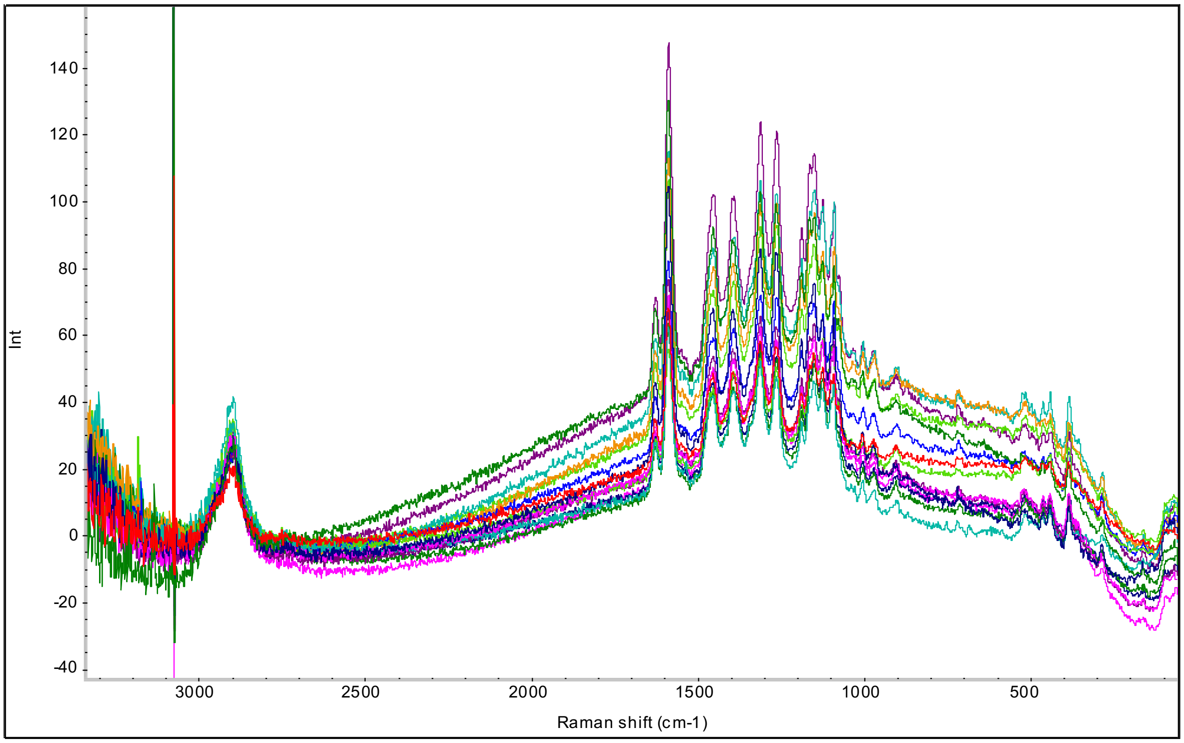
Raman BOX C AVERAGES:



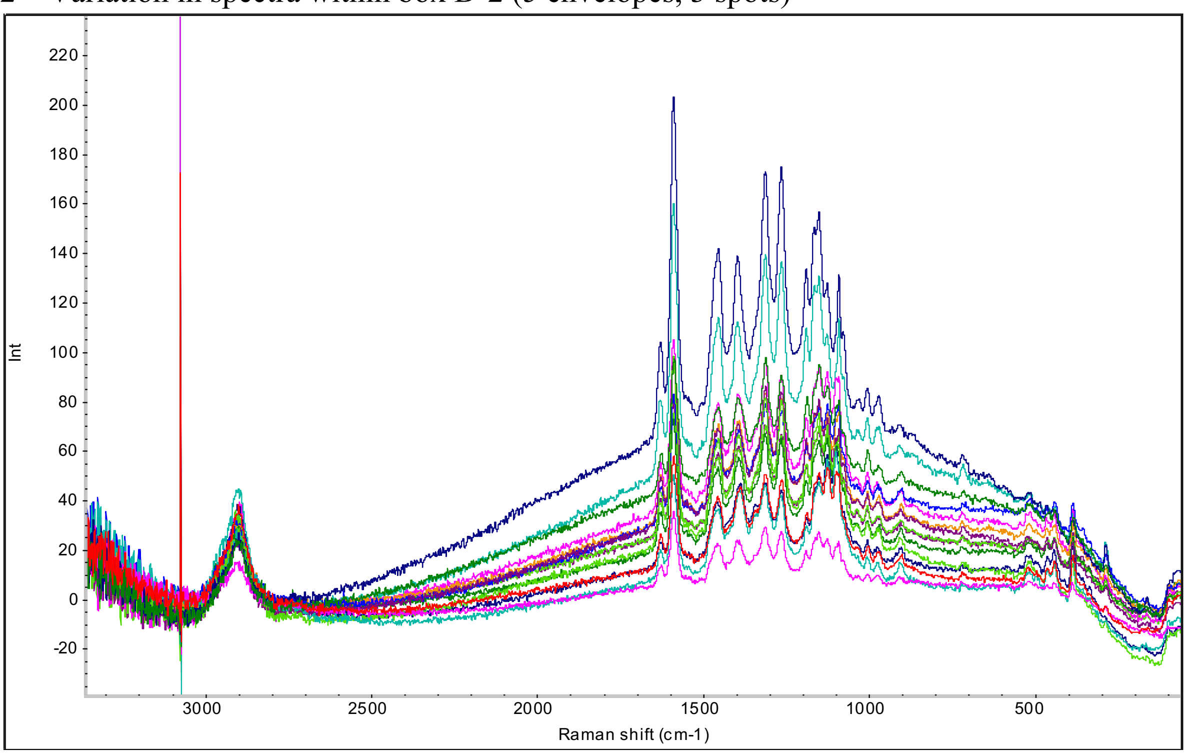
AVERAGE SPECTRA FOR BRAND C:



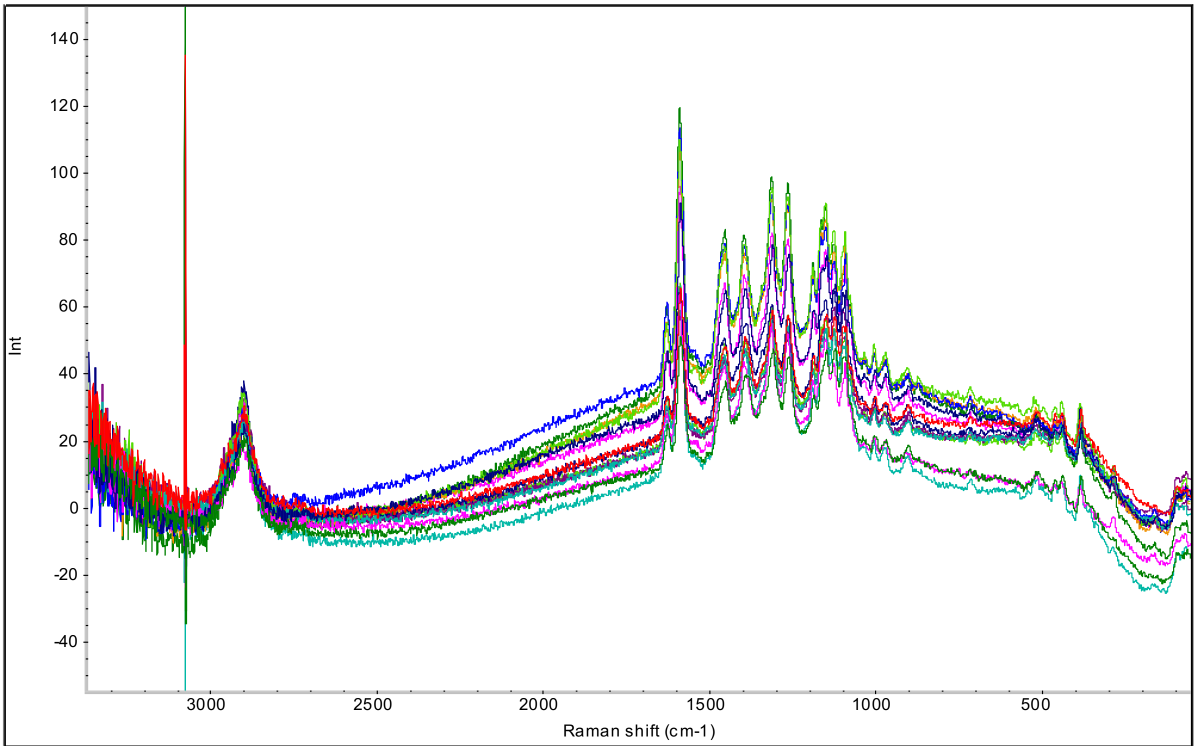
D-1 – Variation in spectra within box D-1 (5 envelopes, 3 spots)



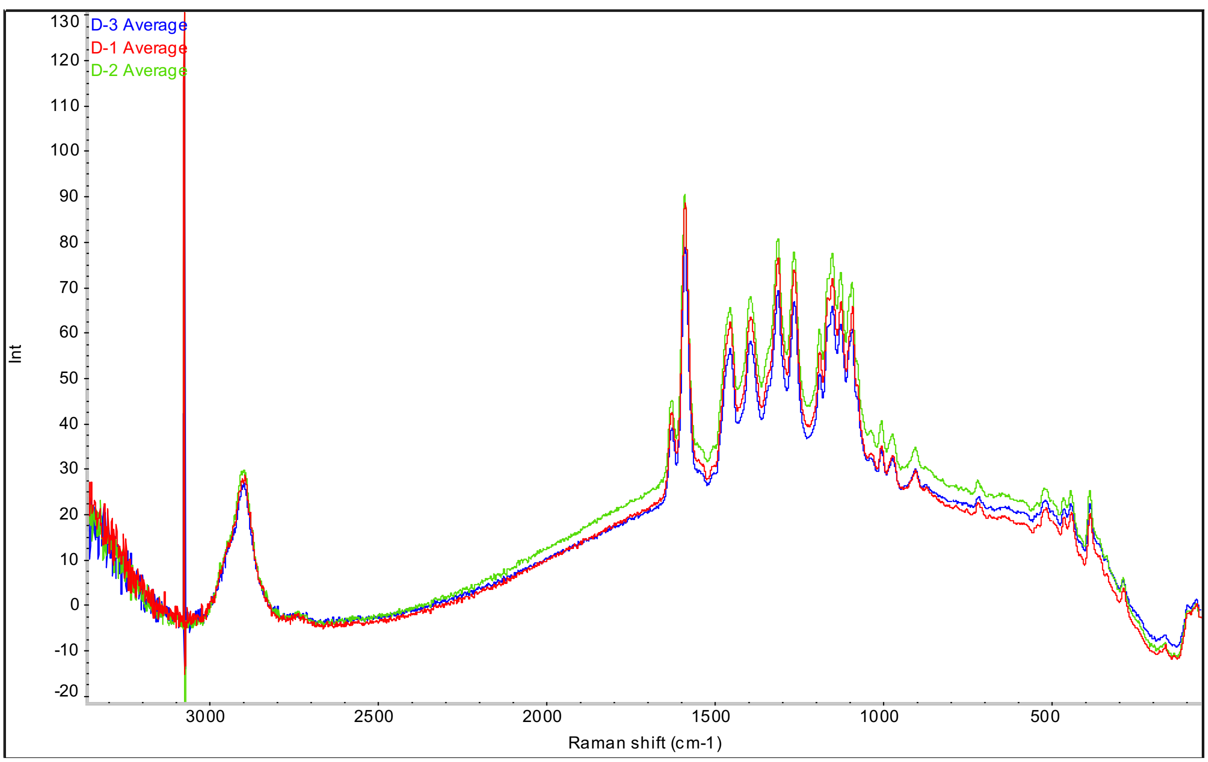
D-2 – Variation in spectra within box D-2 (5 envelopes, 3 spots)



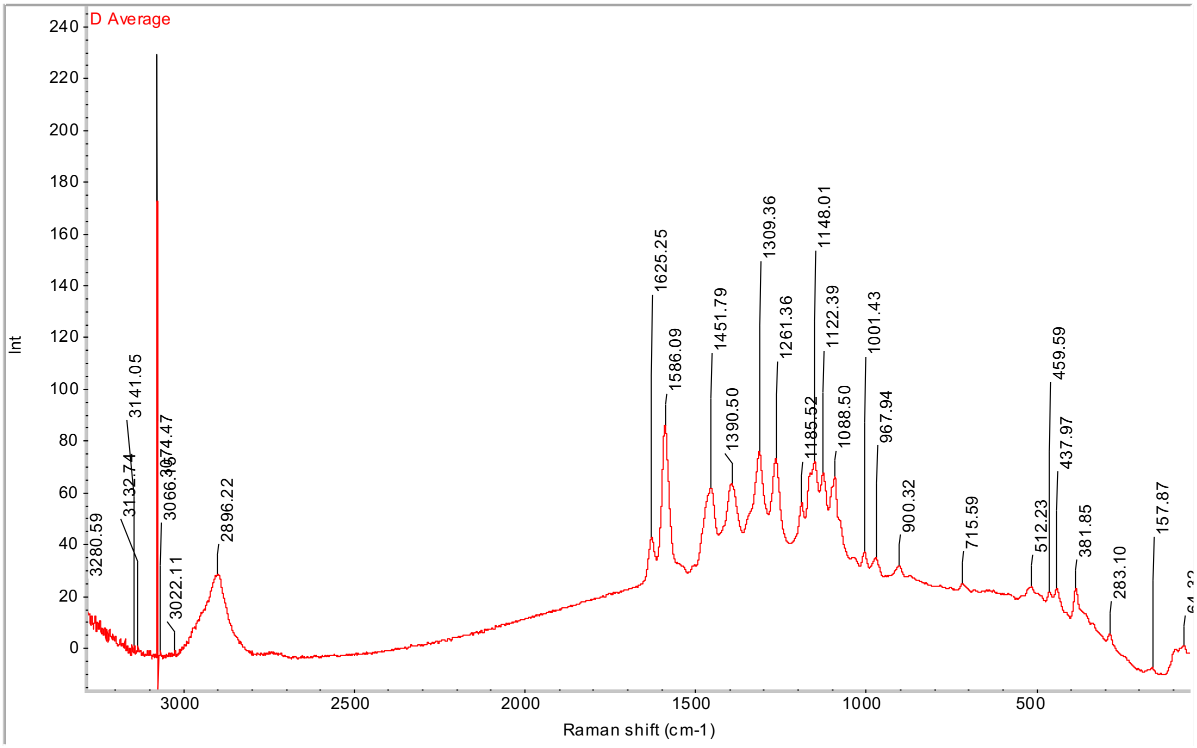
D-3 – Variation in spectra within box D-3 (5 envelopes, 3 spots)



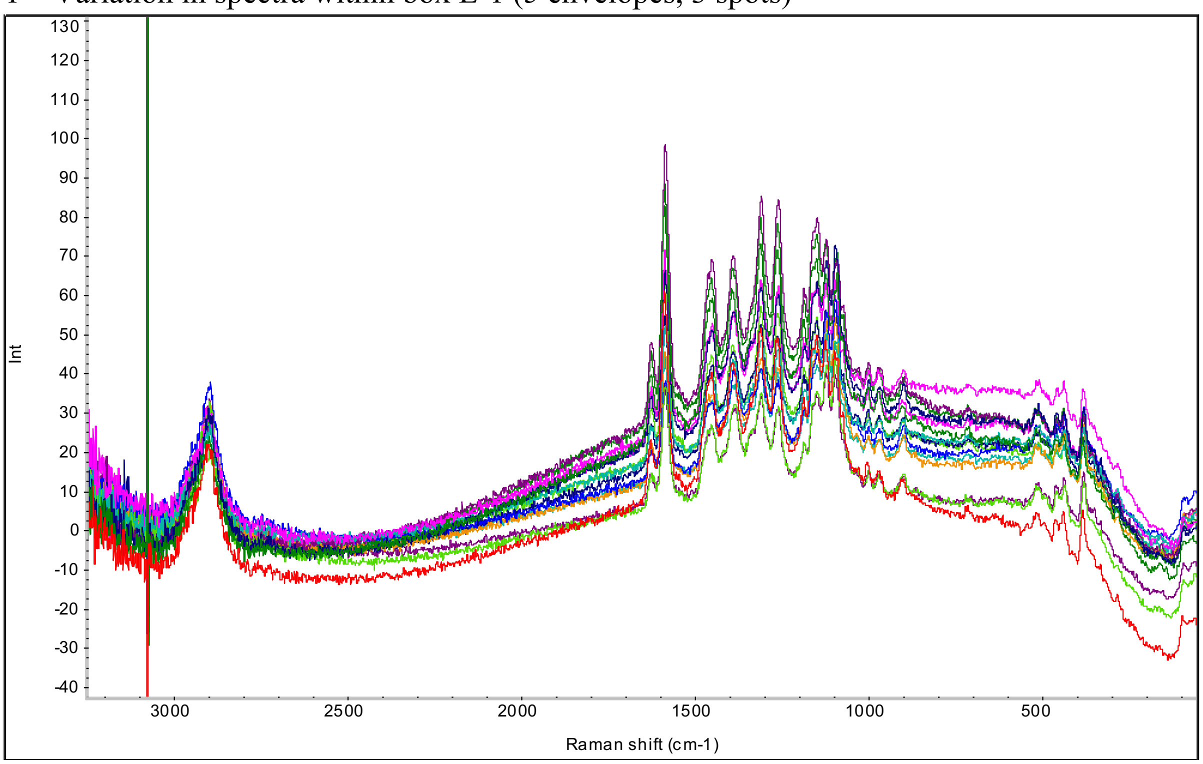
Raman BOX D AVERAGES:



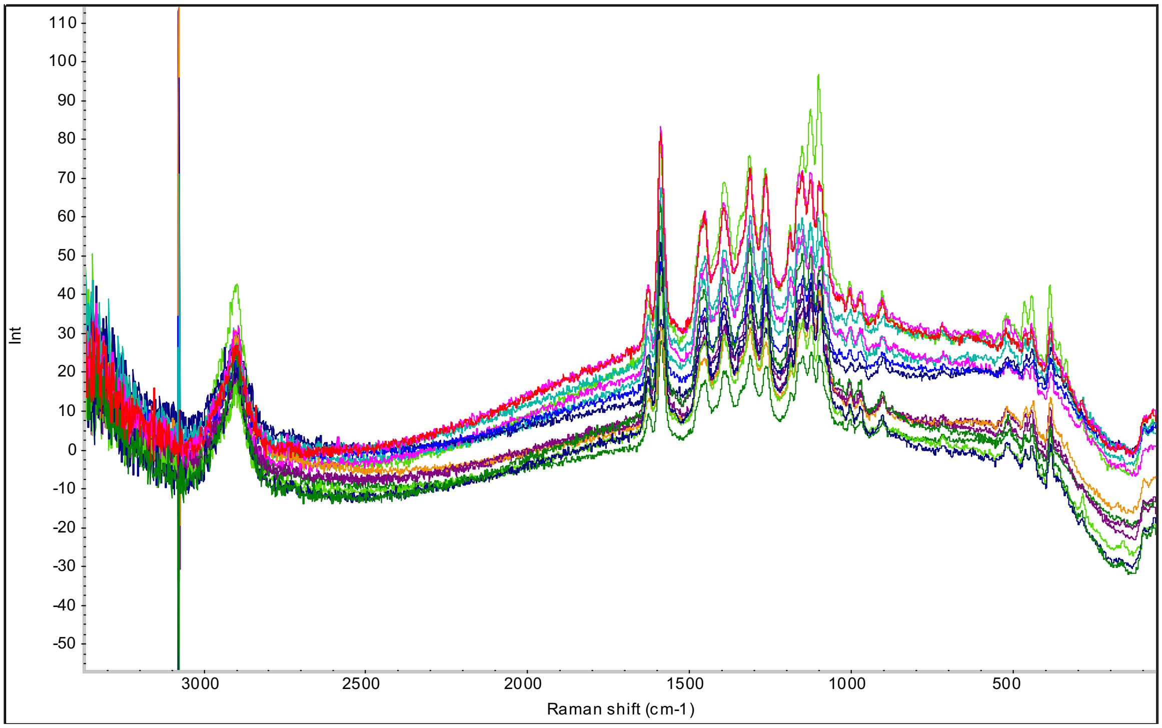
AVERAGE SPECTRA FOR BRAND D:



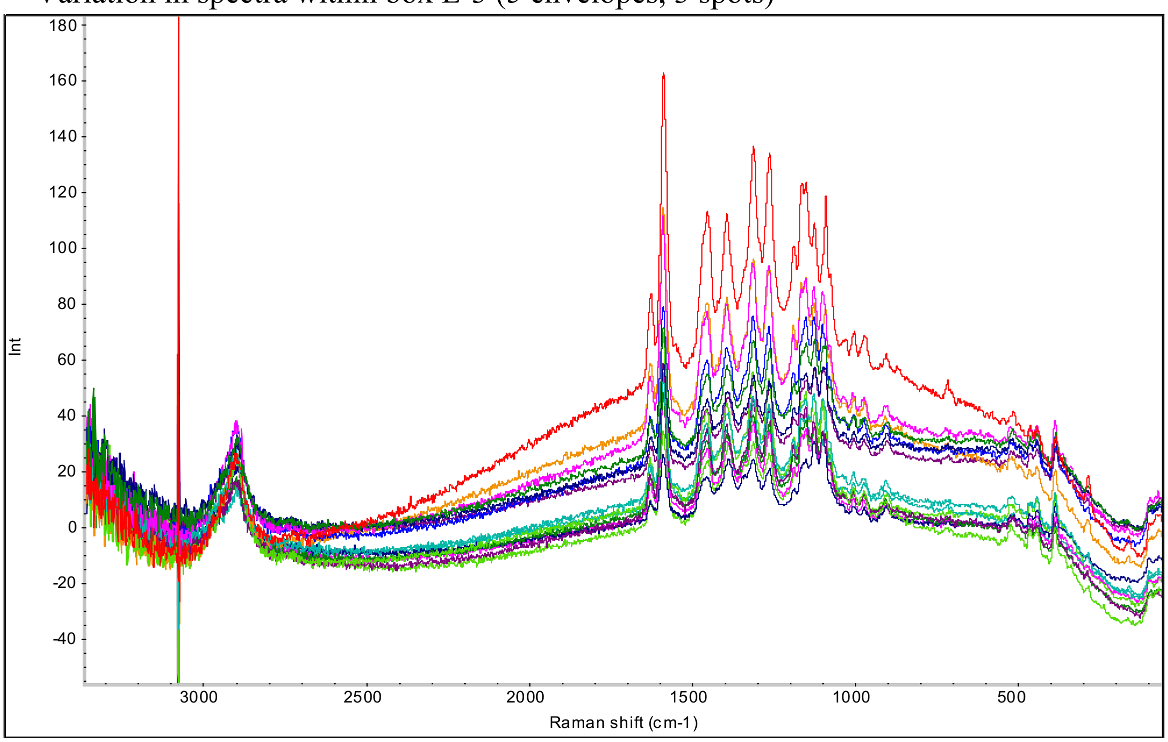
E-1 – Variation in spectra within box E-1 (5 envelopes, 3 spots)



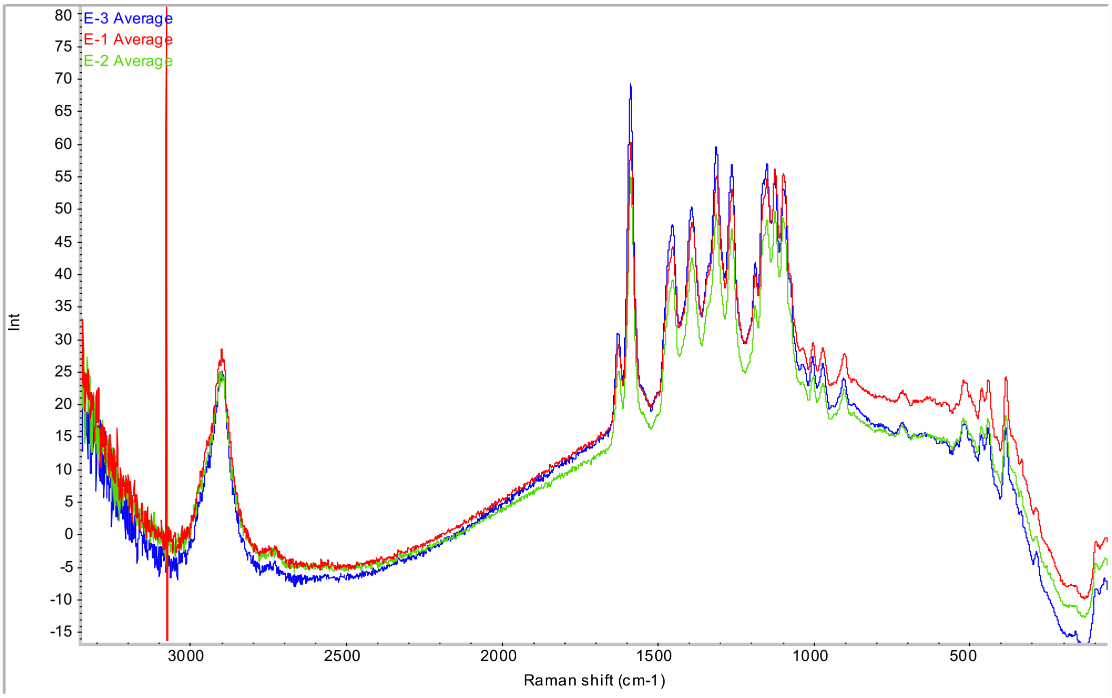
E-2 – Variation in spectra within box E-2 (5 envelopes, 3 spots)



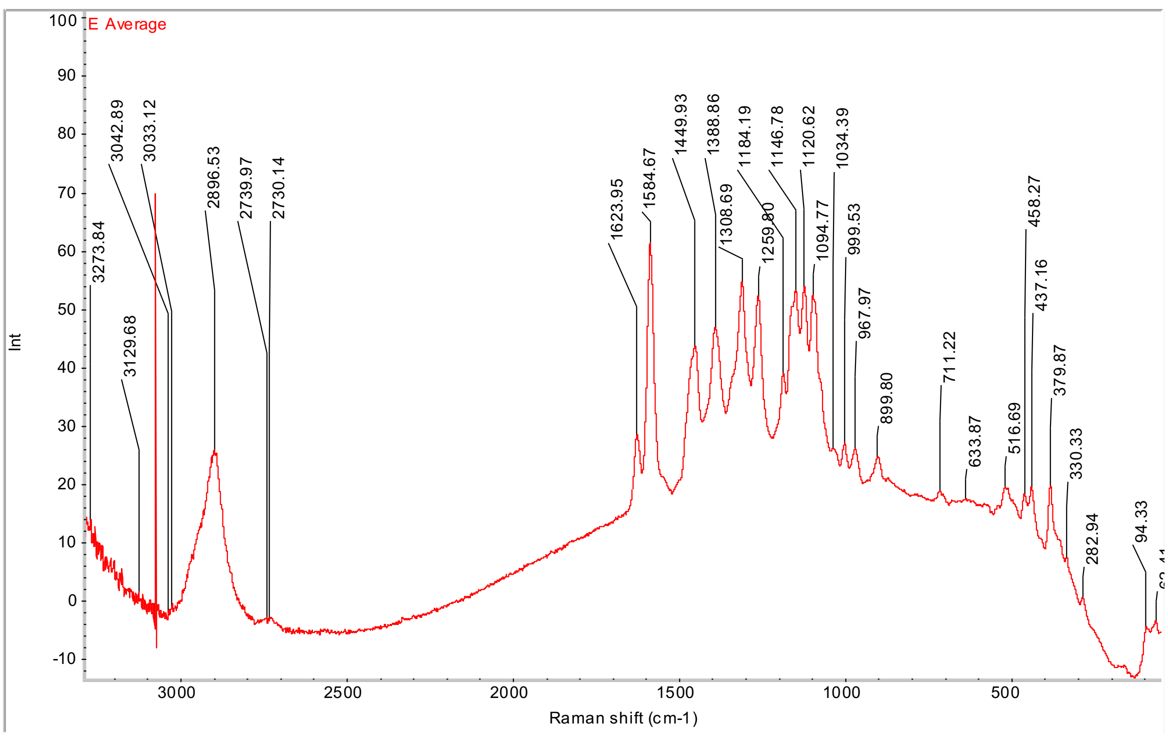
E-3 – Variation in spectra within box E-3 (5 envelopes, 3 spots)



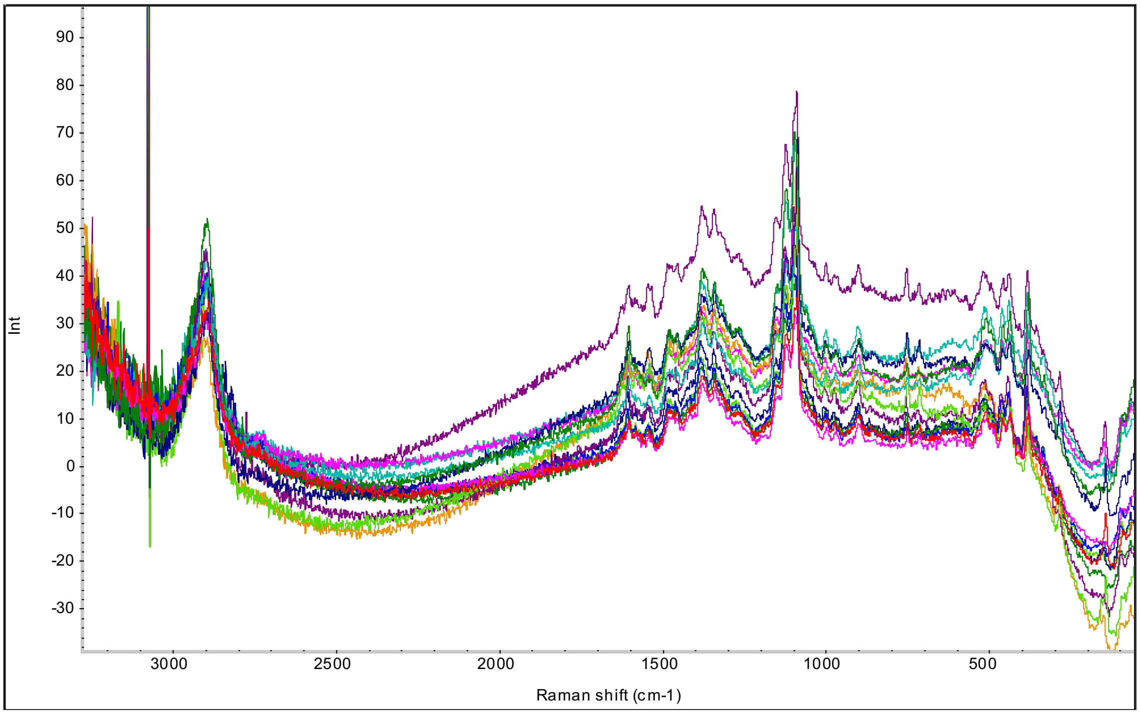
Raman BOX E AVERAGES:



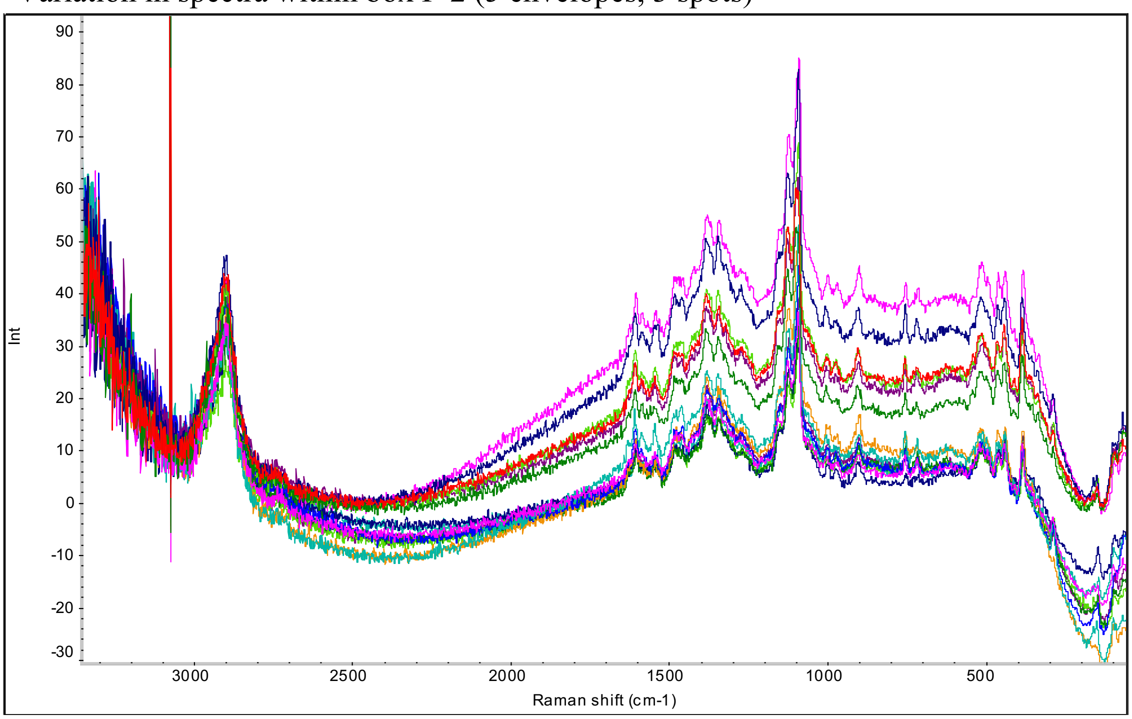
AVERAGE SPECTRA FOR BRAND E:



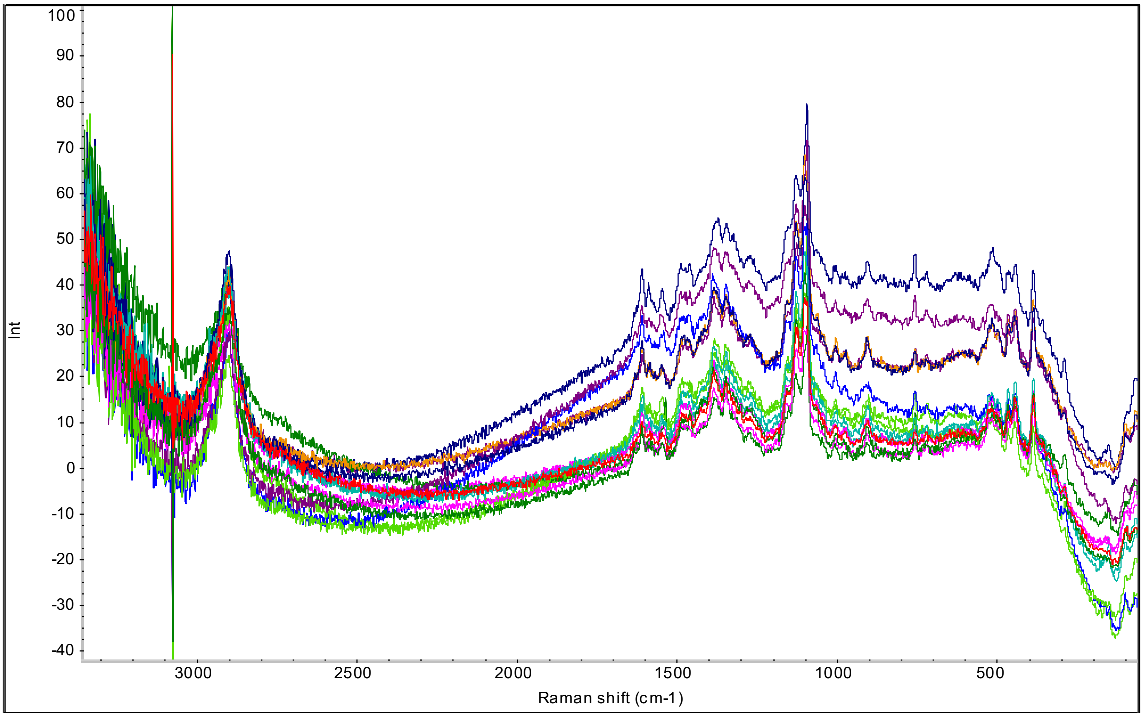
F-1 – Variation in spectra within box F-1 (5 envelopes, 3 spots)



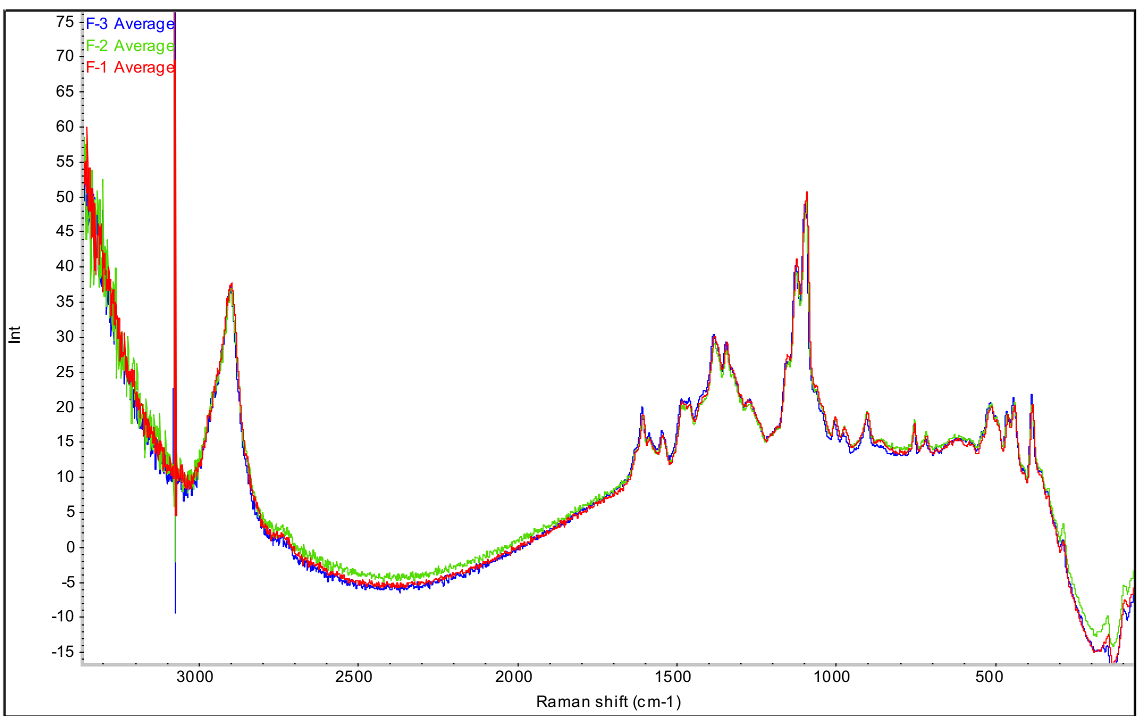
F-2 – Variation in spectra within box F-2 (5 envelopes, 3 spots)



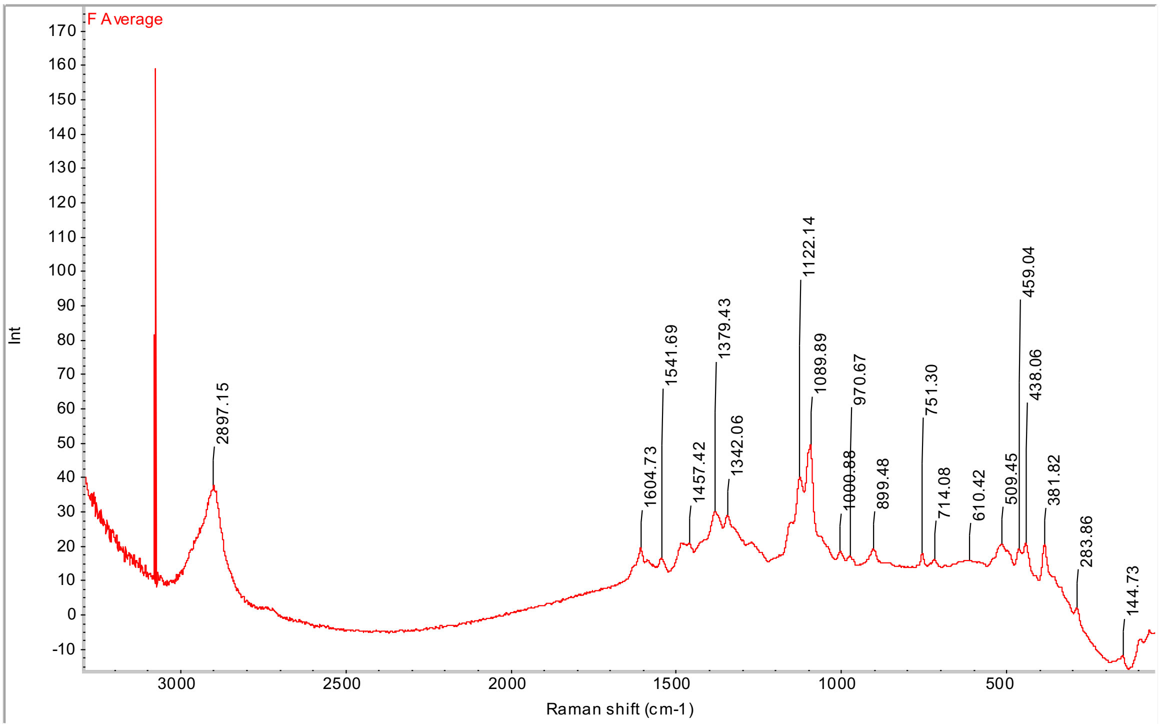
F-3 – Variation in spectra within box F-3 (5 envelopes, 3 spots)



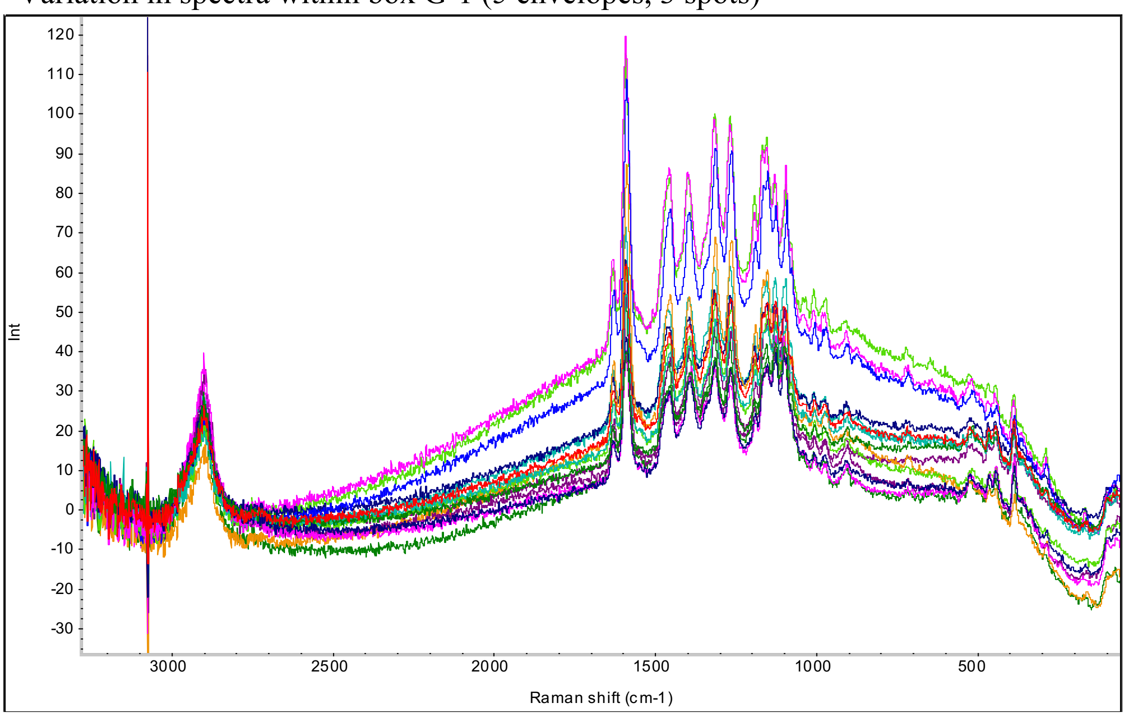
Raman BOX F AVERAGES:



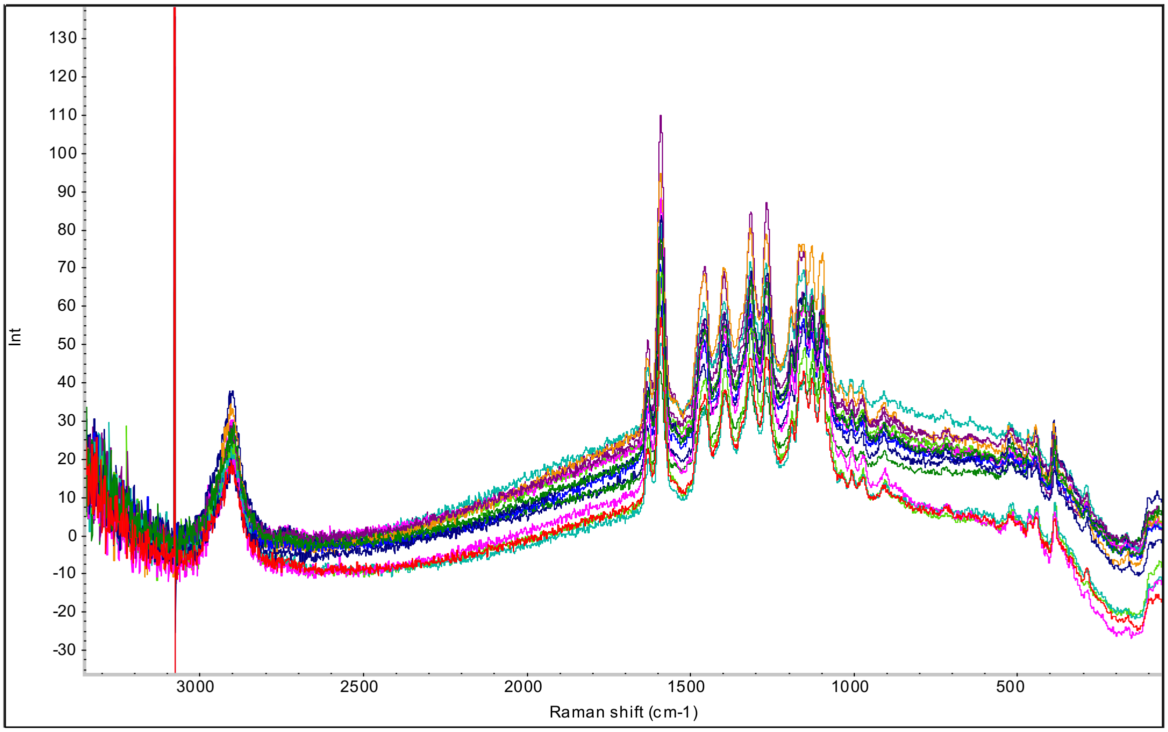
AVERAGE SPECTRA FOR BRAND F:



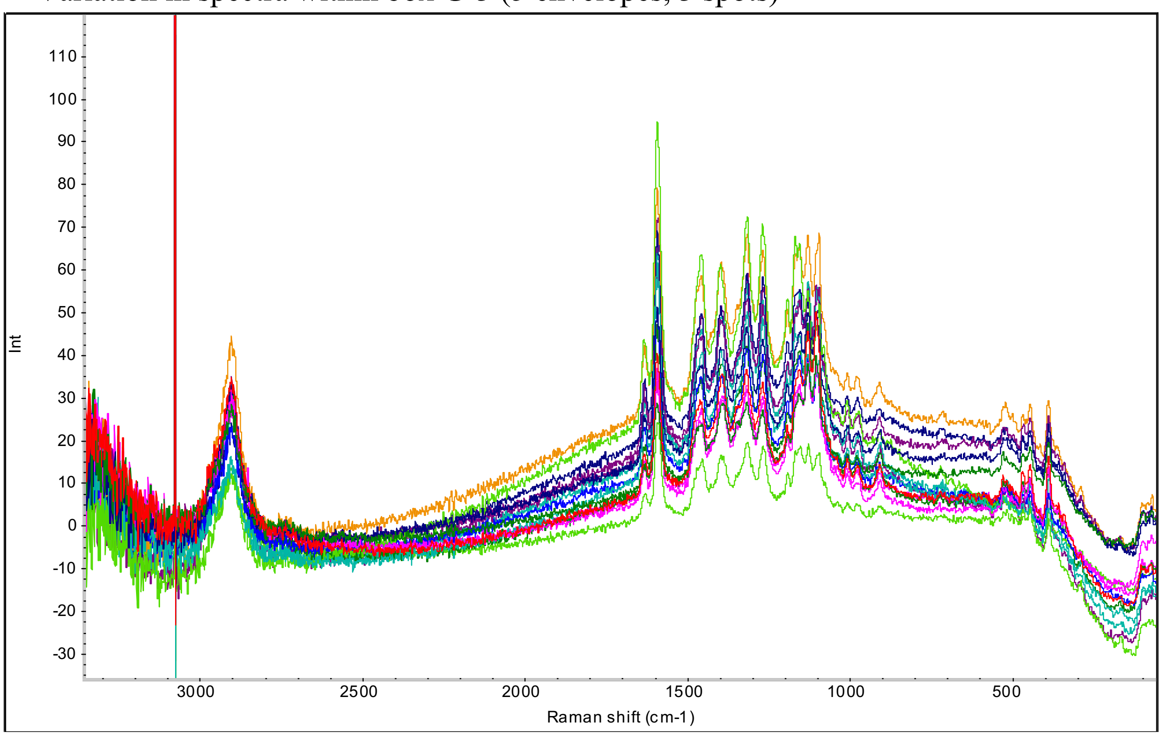
G-1 – Variation in spectra within box G-1 (5 envelopes, 3 spots)



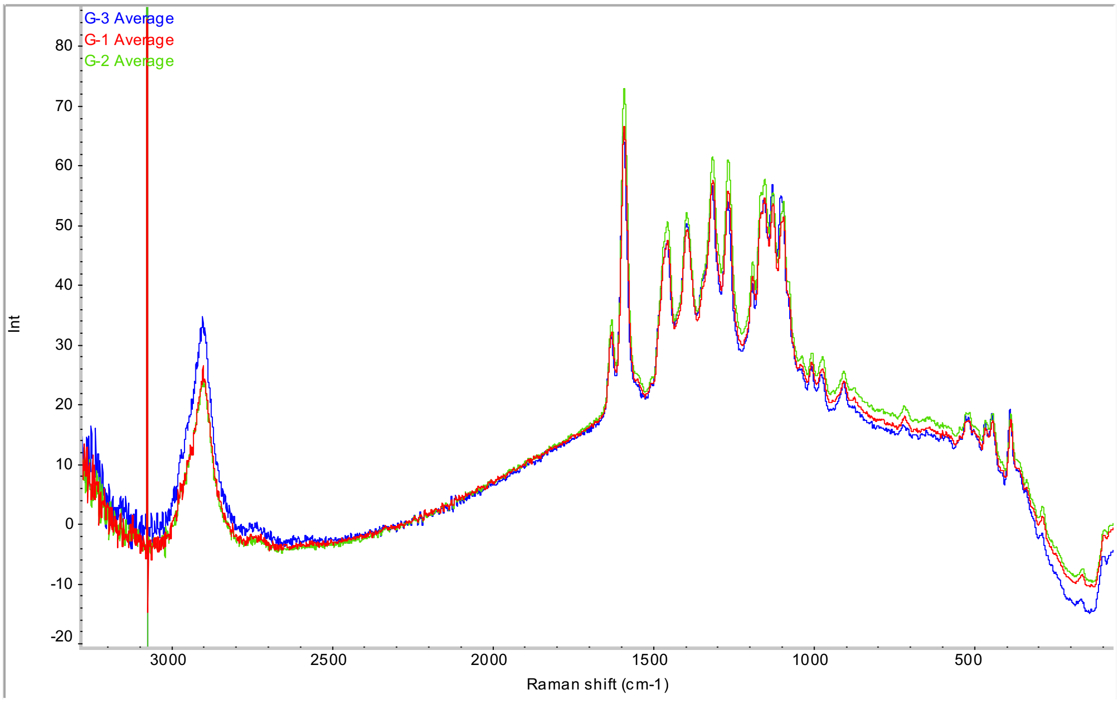
G-2 – Variation in spectra within box G-2 (5 envelopes, 3 spots)



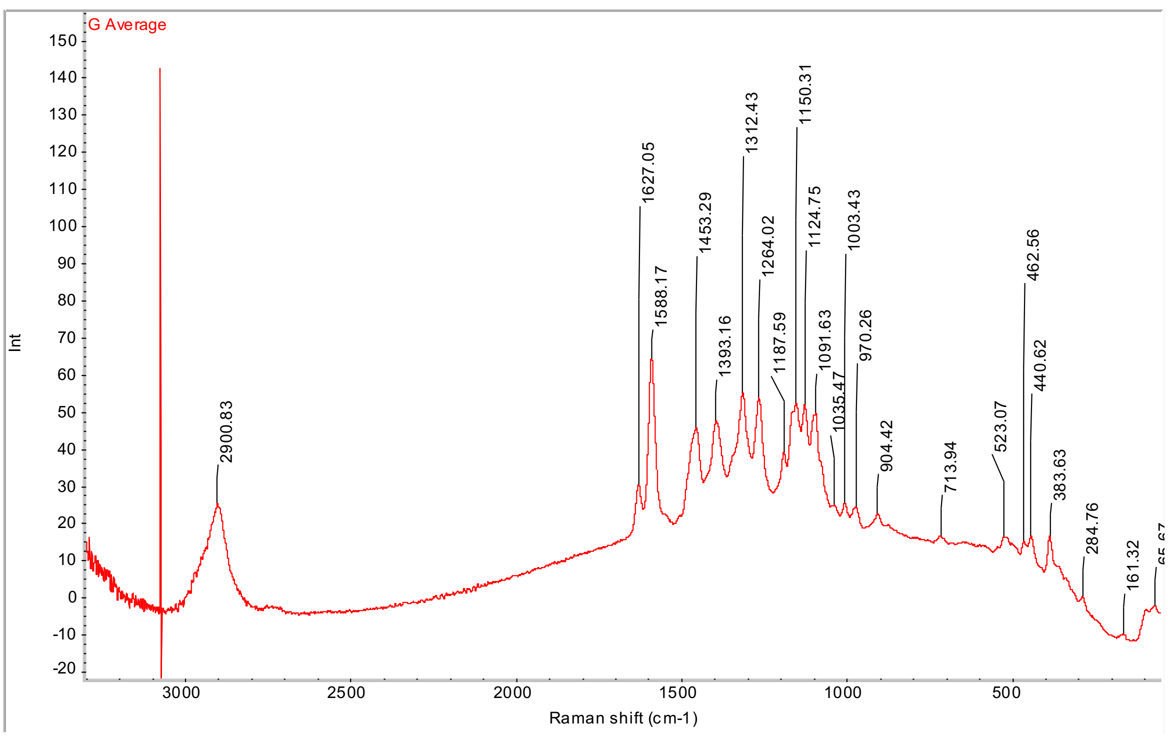
G-3 – Variation in spectra within box G-3 (5 envelopes, 3 spots)



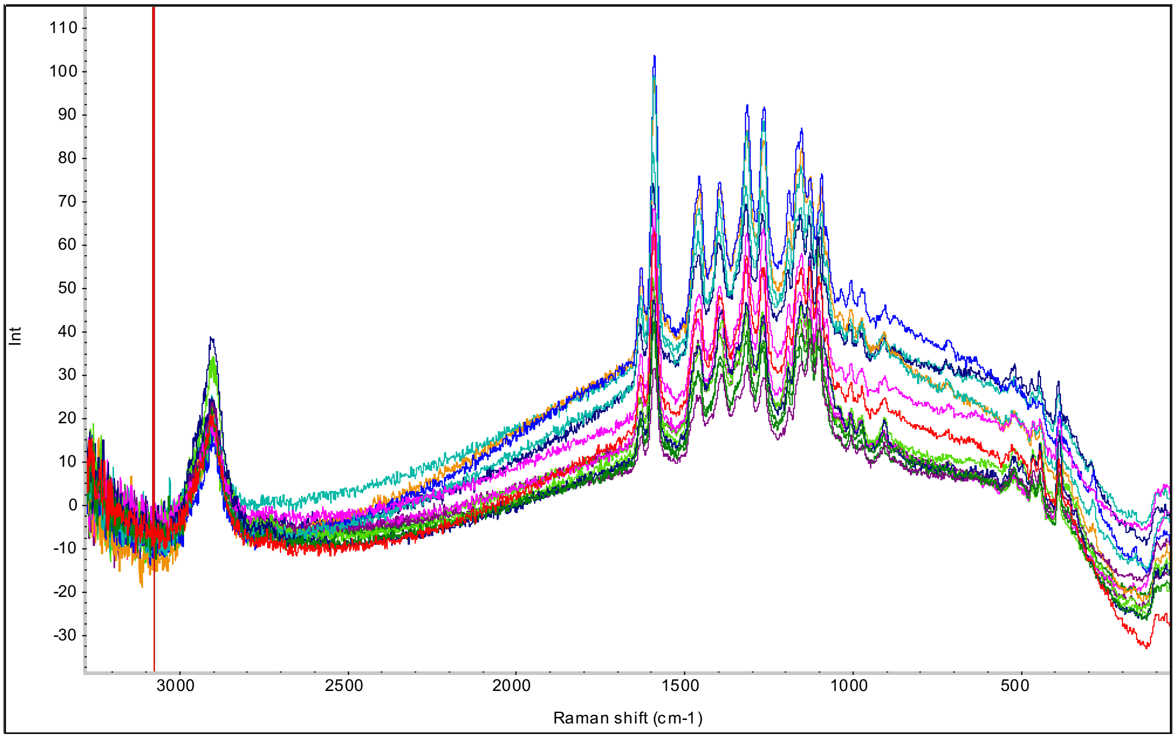
Raman BOX G AVERAGES:



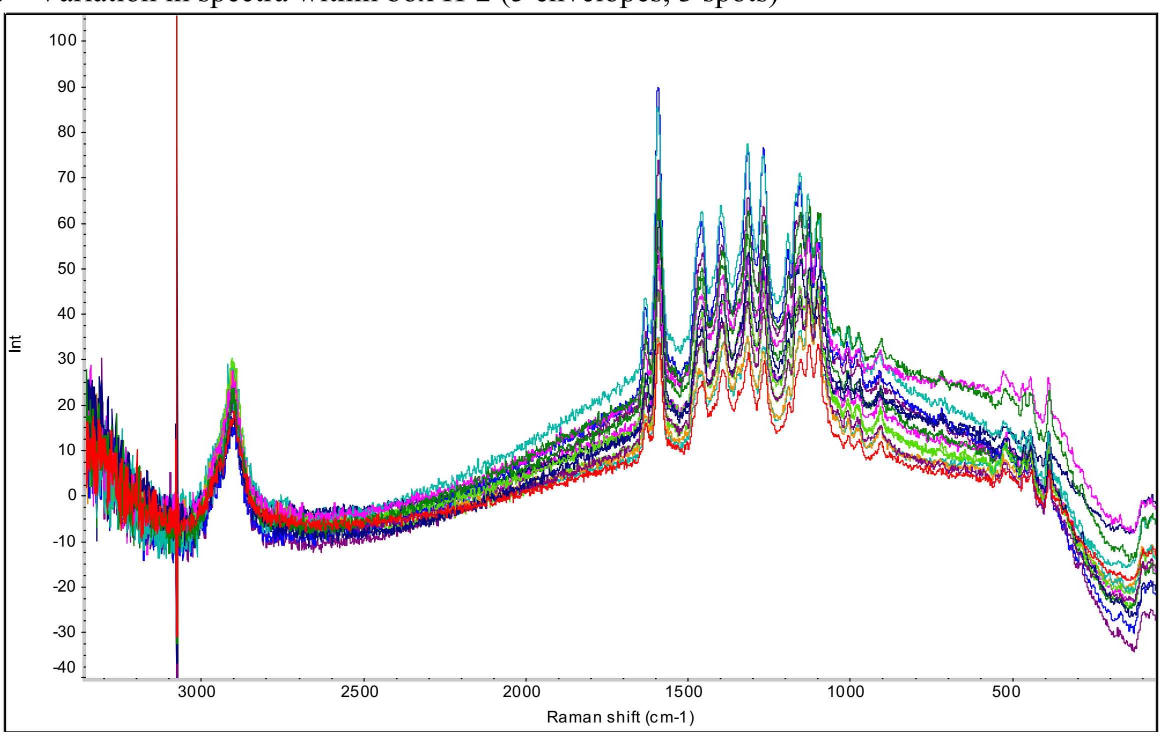
AVERAGE SPECTRA FOR BRAND G:



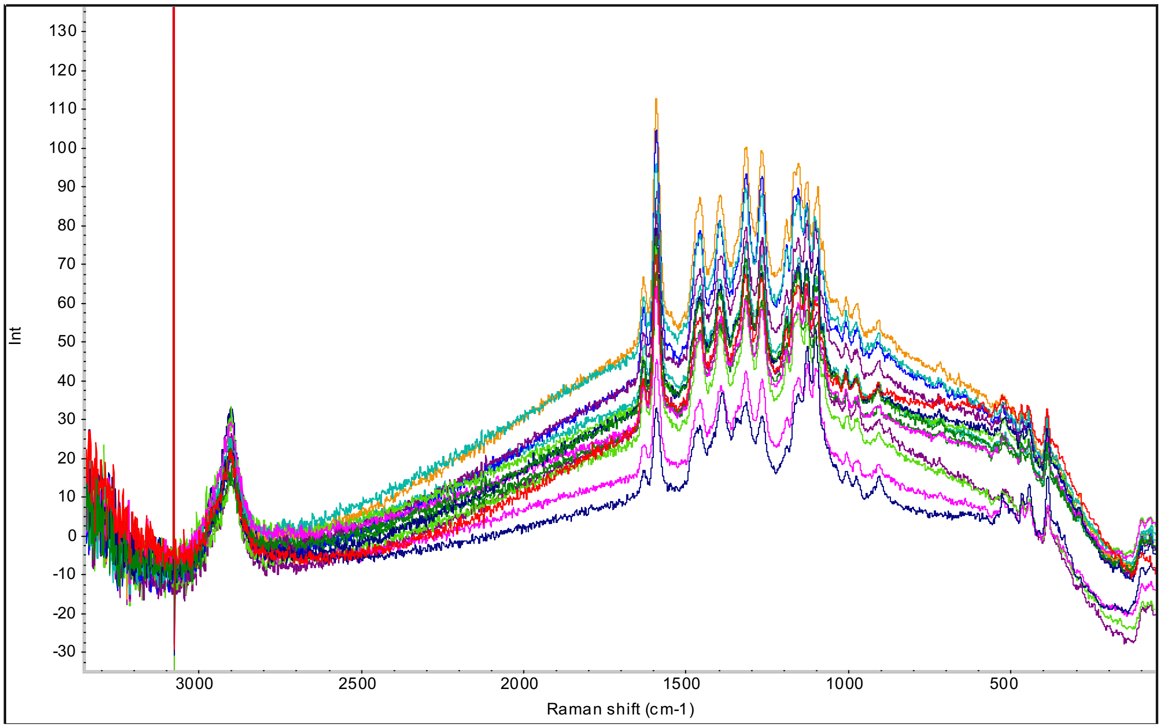
H-1 – Variation in spectra within box H-1 (5 envelopes, 3 spots)



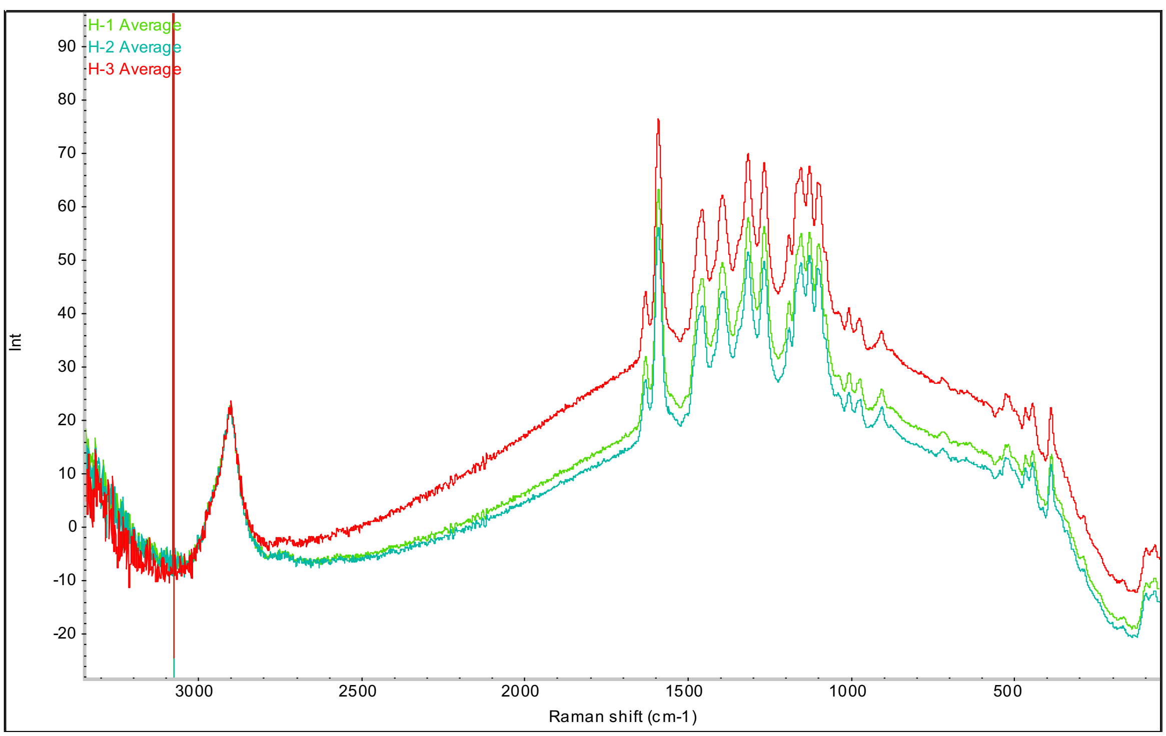
H-2 – Variation in spectra within box H-2 (5 envelopes, 3 spots)



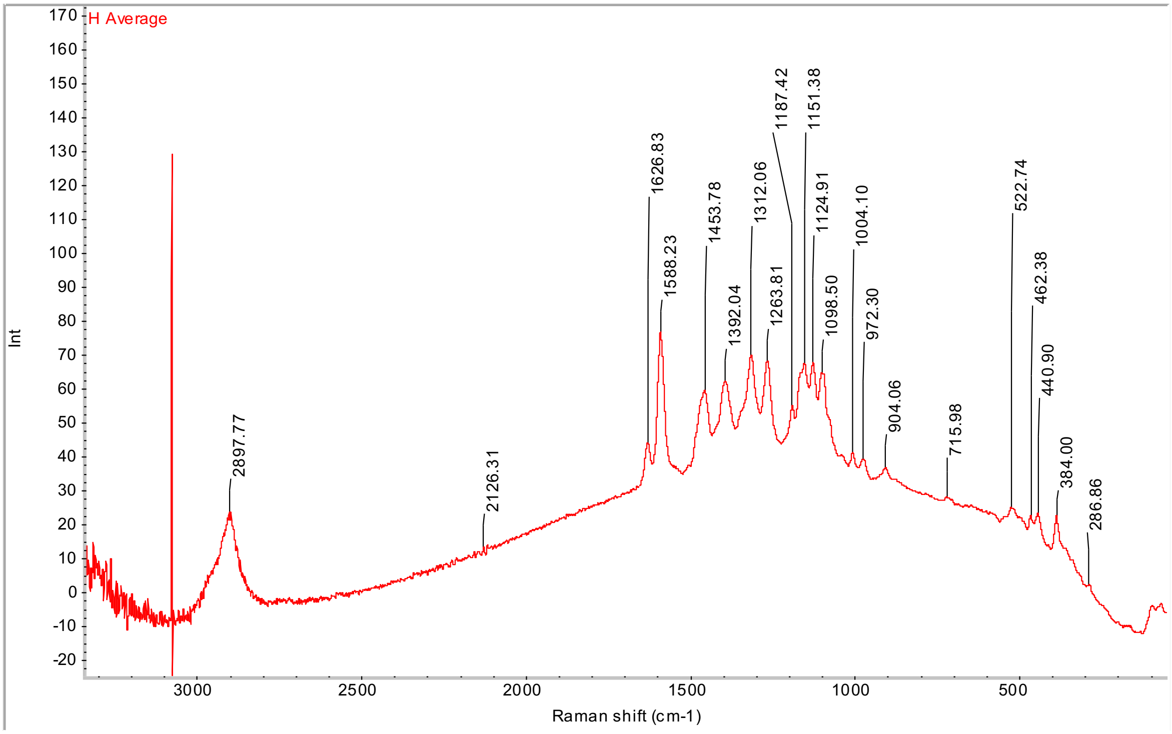
H-3 – Variation in spectra within box H-3 (5 envelopes, 3 spots)



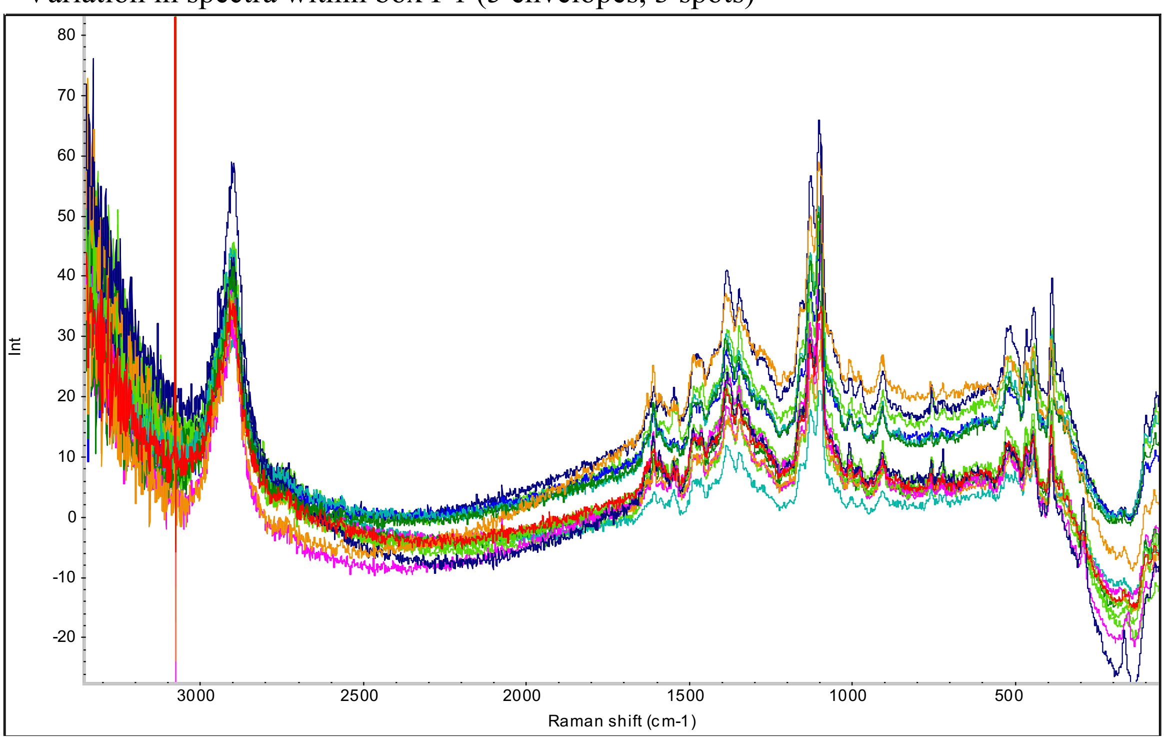
Raman BOX H AVERAGES:



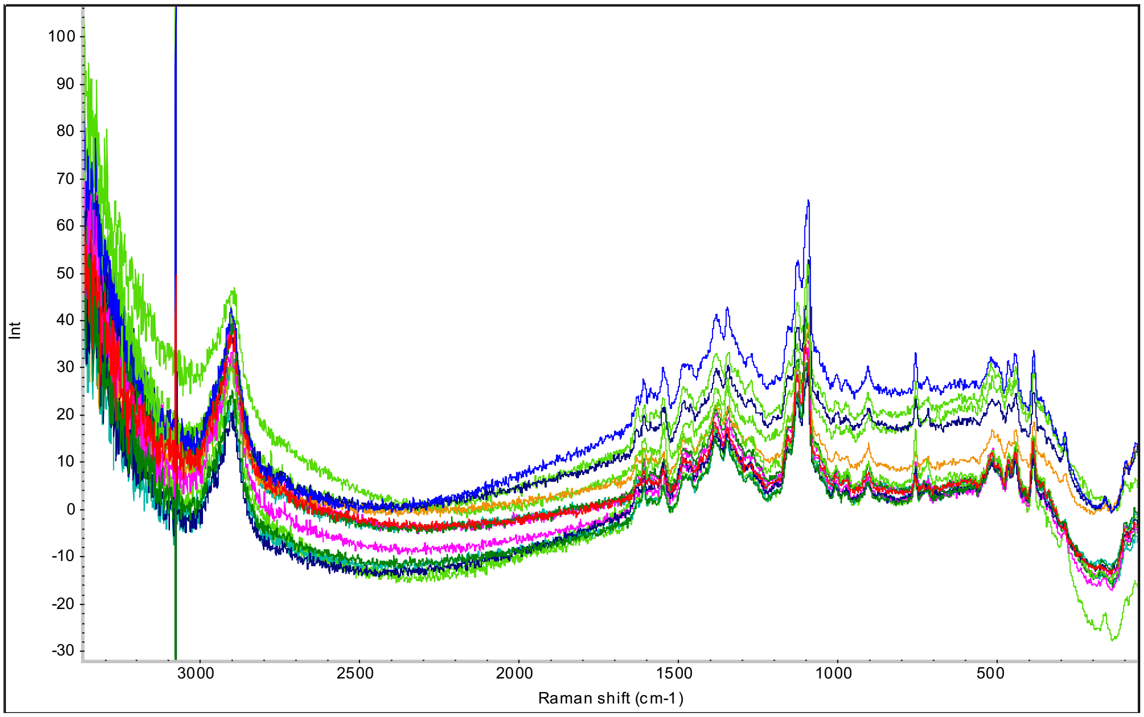
AVERAGE SPECTRA FOR BRAND H:



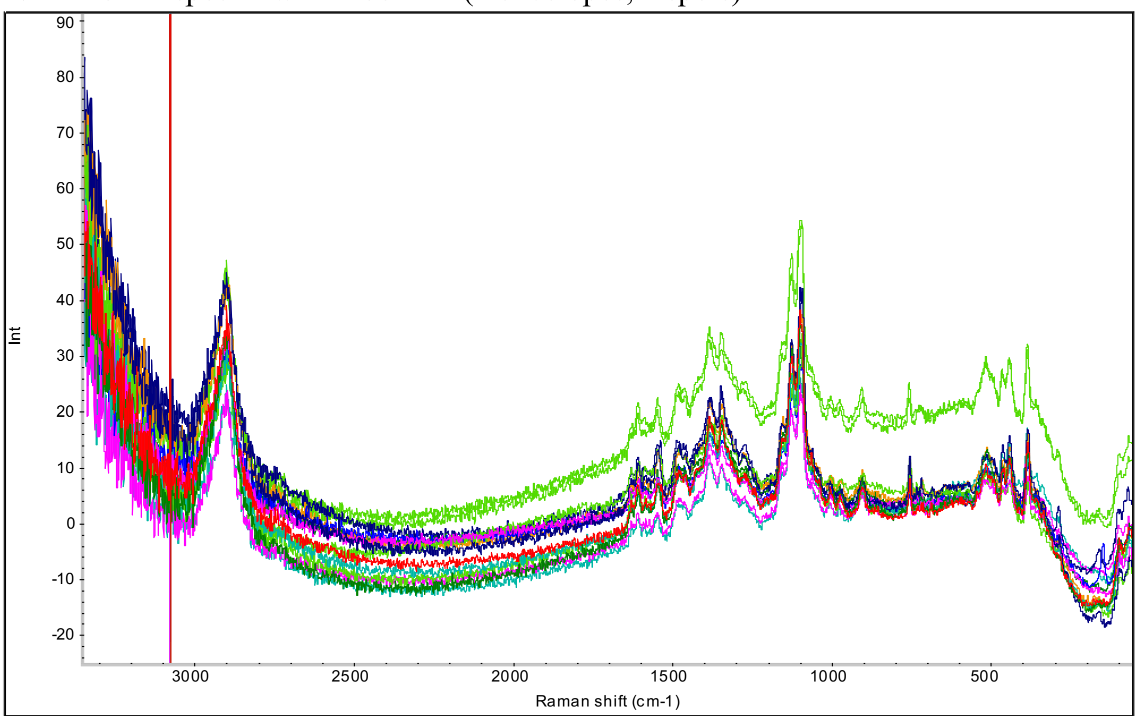
I-1 – Variation in spectra within box I-1 (5 envelopes, 3 spots)



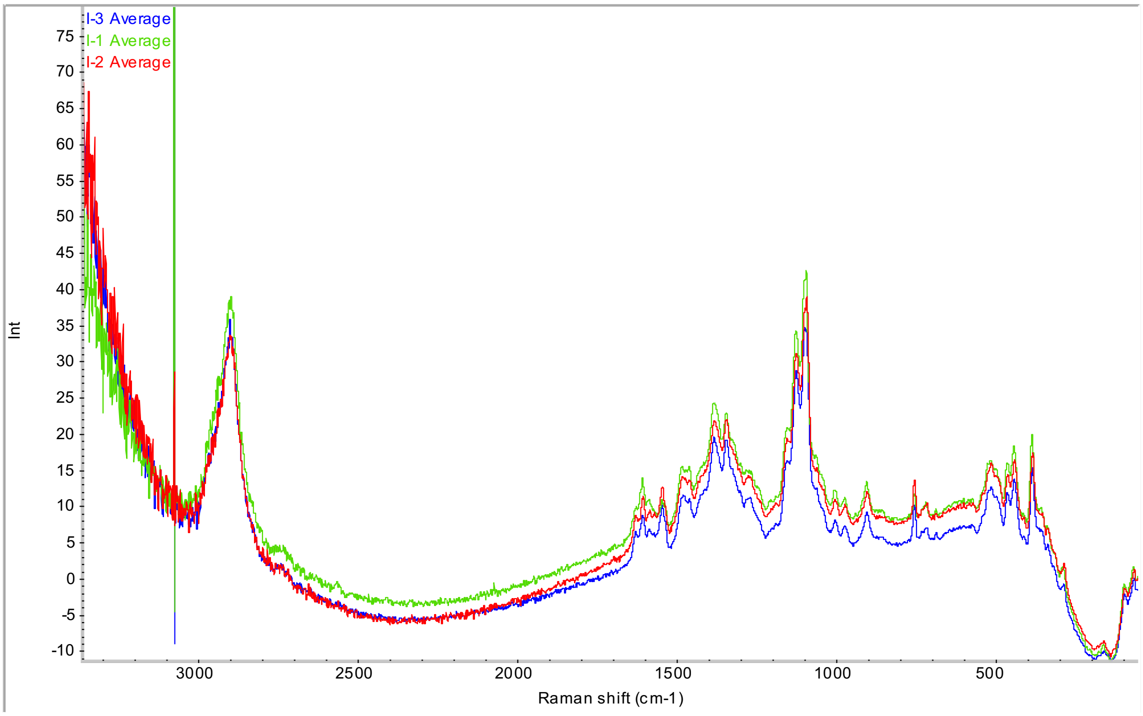
I-2 – Variation in spectra within box I-2 (5 envelopes, 3 spots)



I-3 – Variation in spectra within box I-3 (5 envelopes, 3 spots)

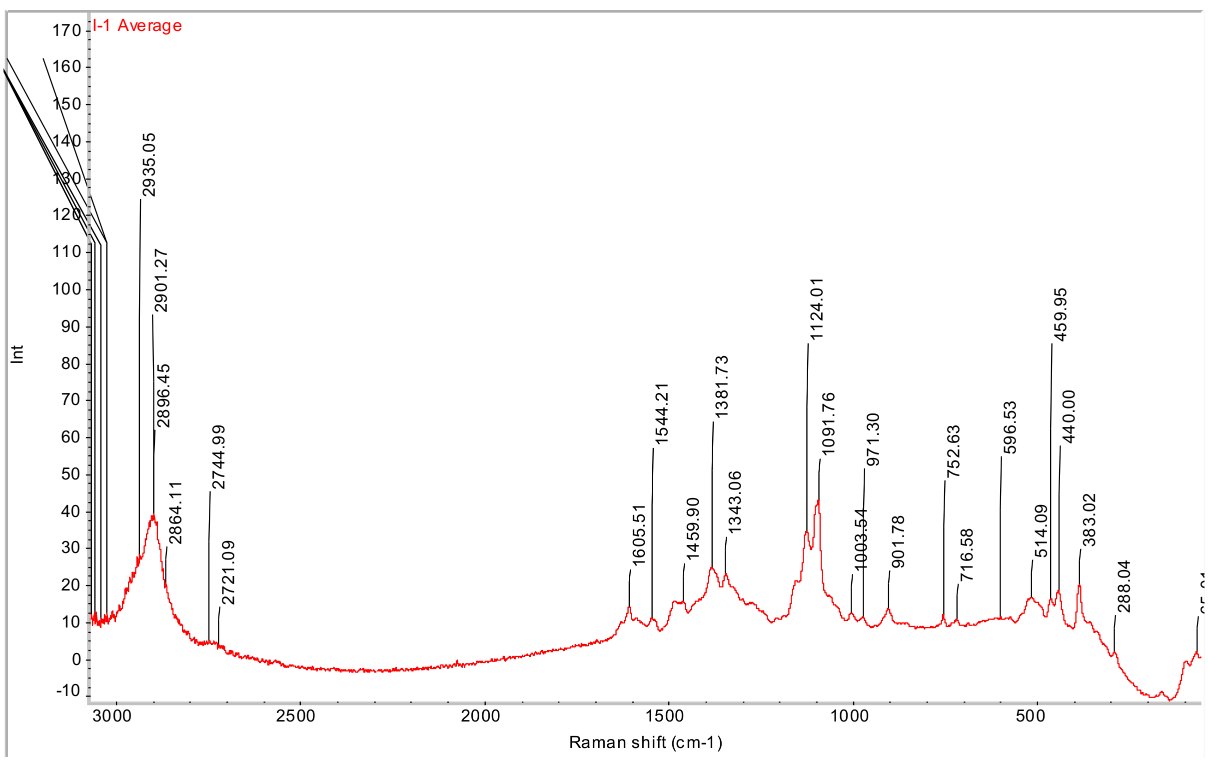


Raman BOX I AVERAGES:

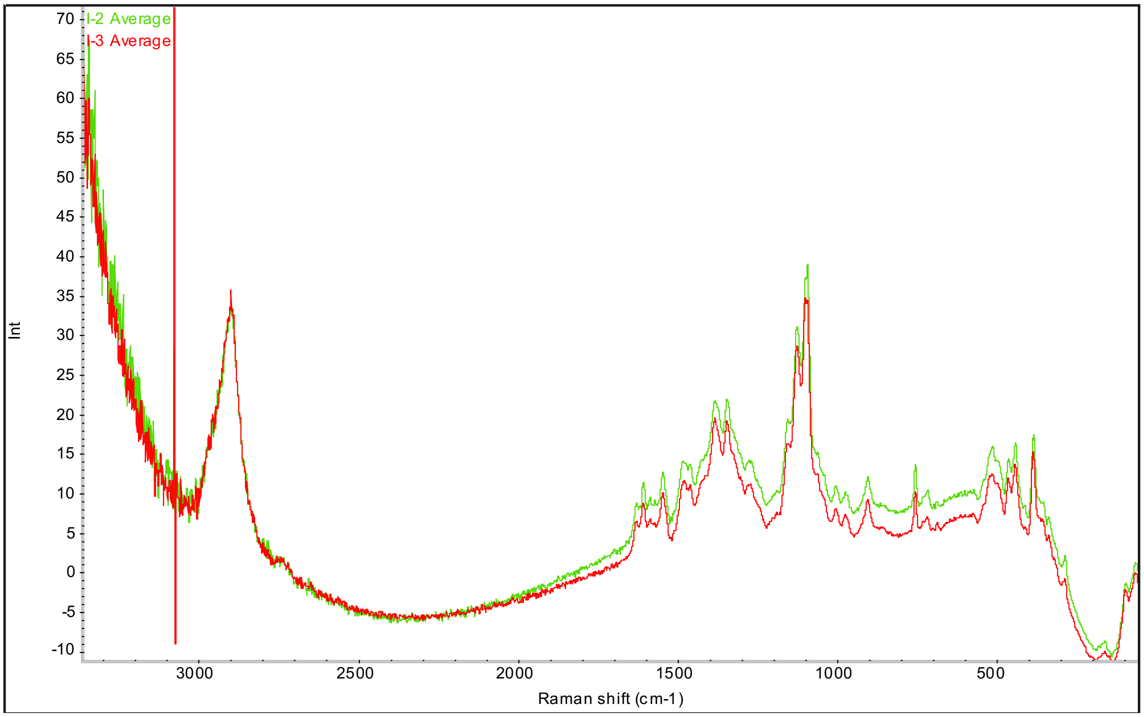


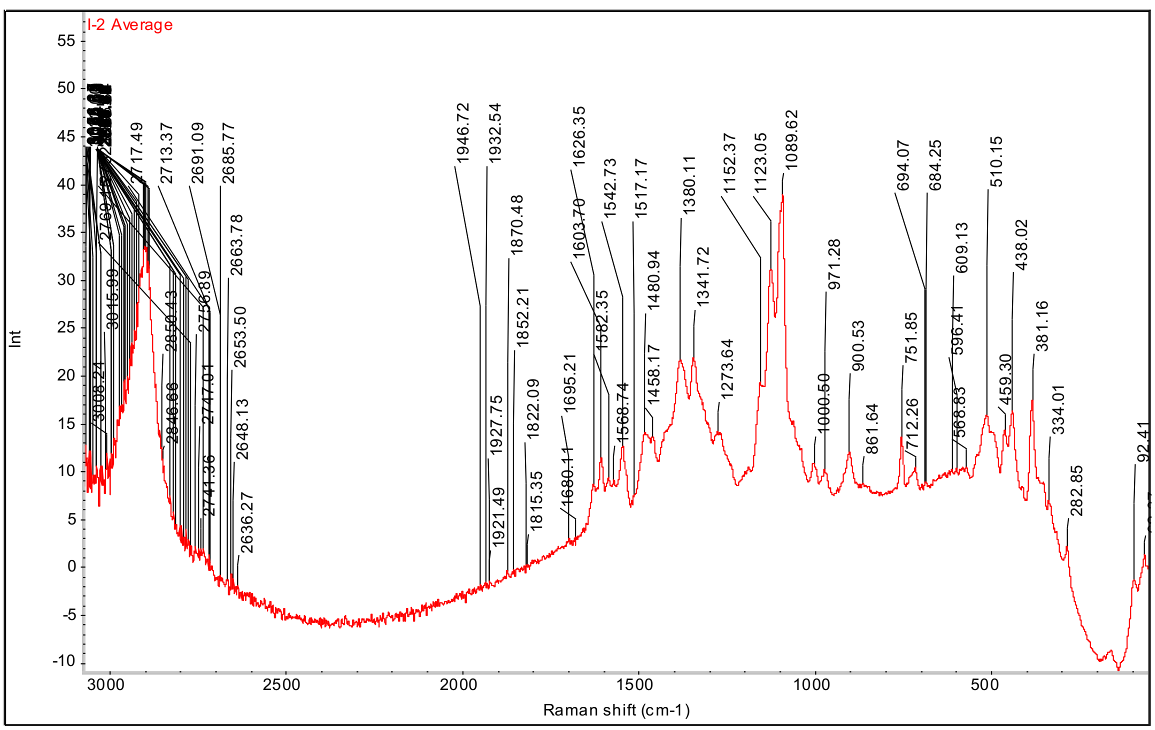
BRAND AVERAGES (separating I into 2):

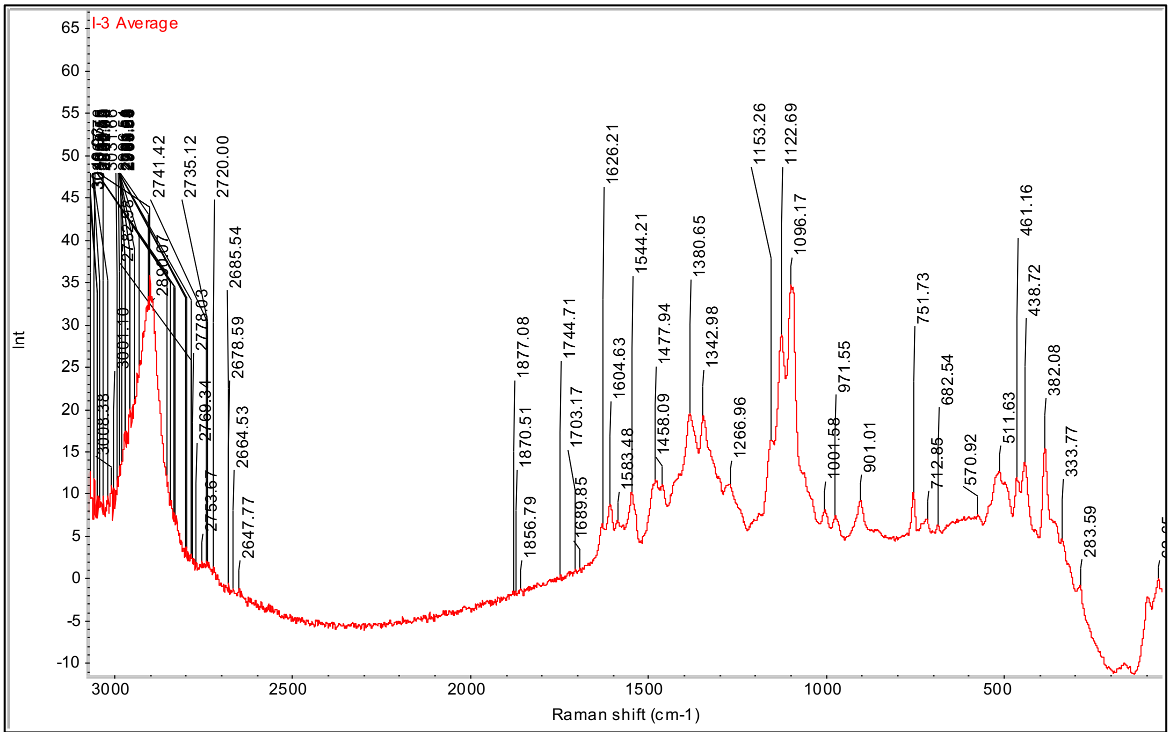
- I-1:



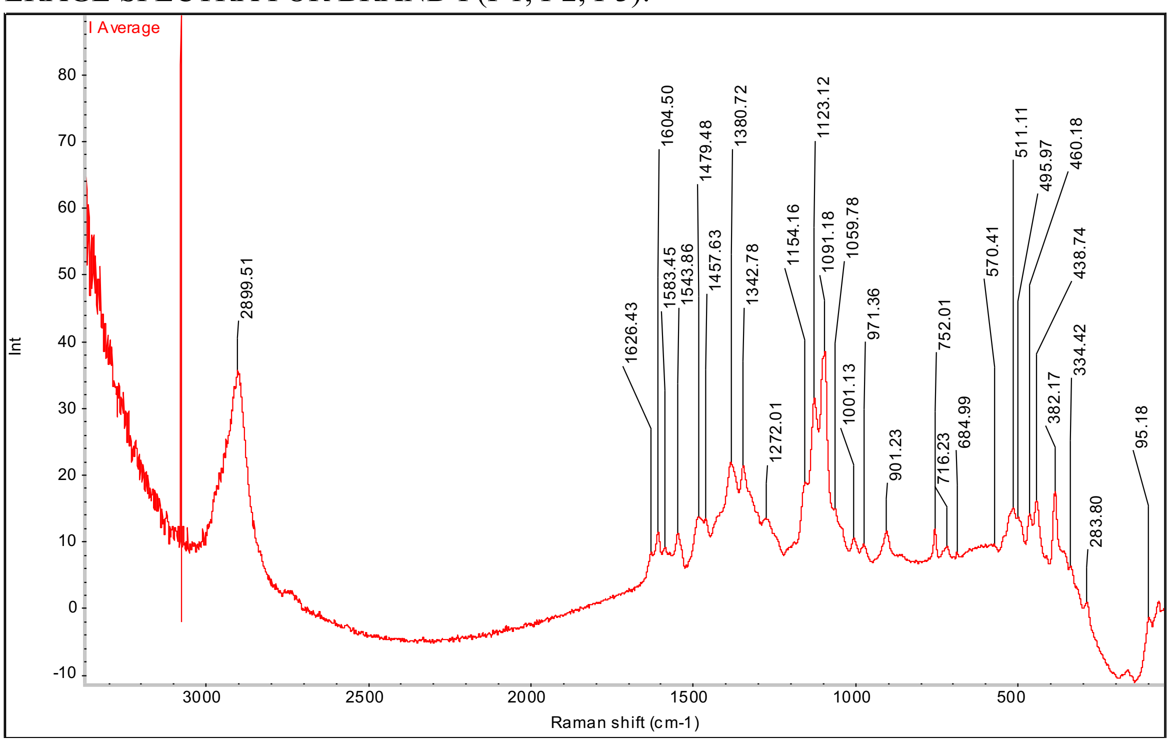
- I-2 & I-3:


I-2 Average
I-3 Average
Int
Raman shift (cm-1)

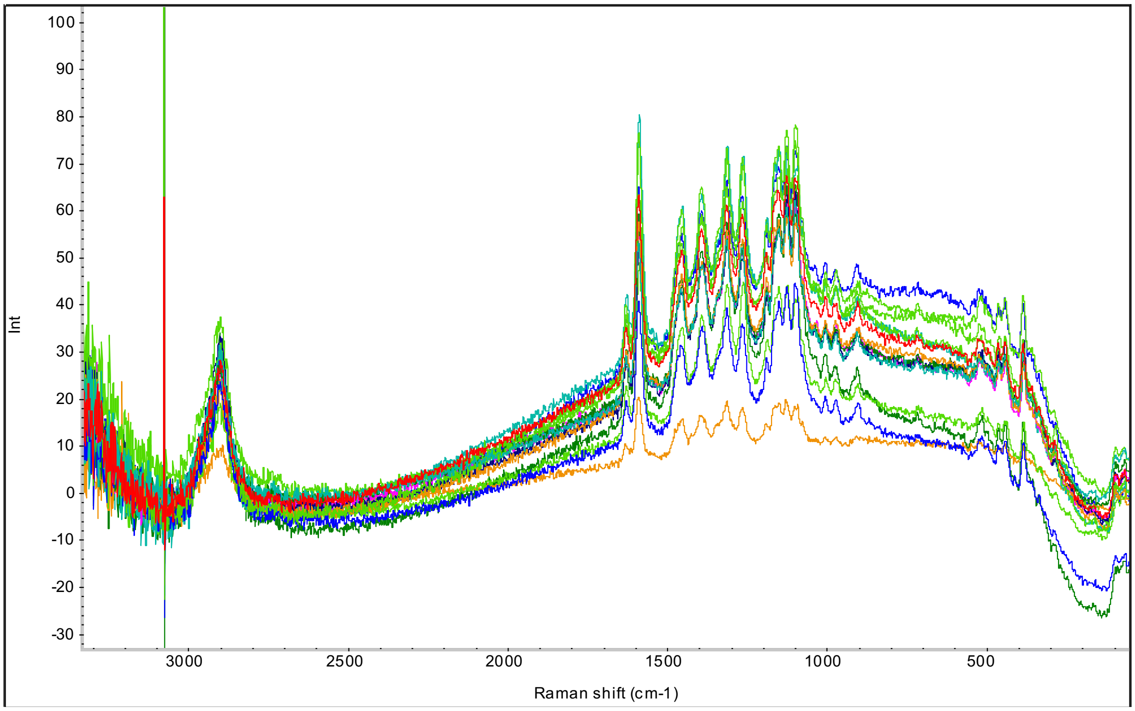

I-2 Average
Int
Raman shift (cm-1)
1946.72
1932.54
1870.48
1852.21
1927.75
1921.49
1822.09
1815.35
1695.21
1680.11
1626.35
1603.70
1582.35
1568.74
1542.73
1517.17
1480.94
1458.17
1380.11
1341.72
1273.64
1152.37
1123.05
1089.62
1000.50
971.28
900.53
861.64
751.85
712.26
694.07
684.25
609.13
596.41
568.83
510.15
459.30
438.02
381.16
334.01
282.85
92.41
2717.49
2713.37
2691.09
2685.77
2663.78
2653.50
2648.13
2636.27
2756.89
2747.01
2741.36
2850.43
2846.66
2760.40
3015.99
3008.21



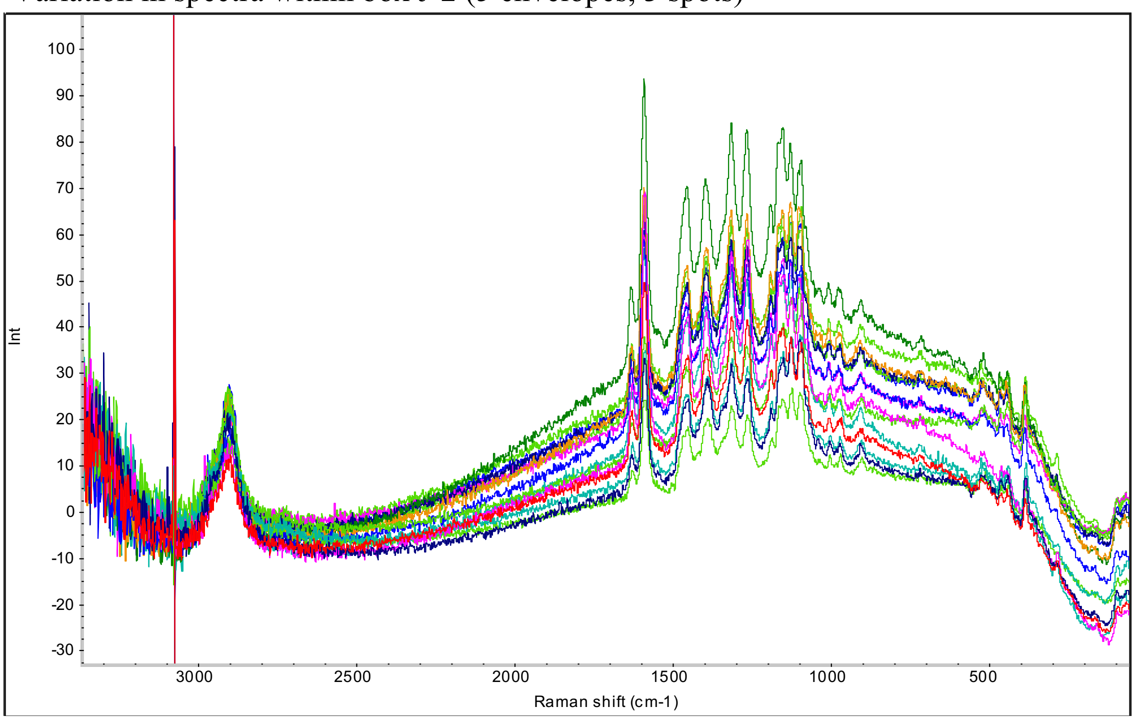
AVERAGE SPECTRA FOR BRAND I (I-1, I-2, I-3):



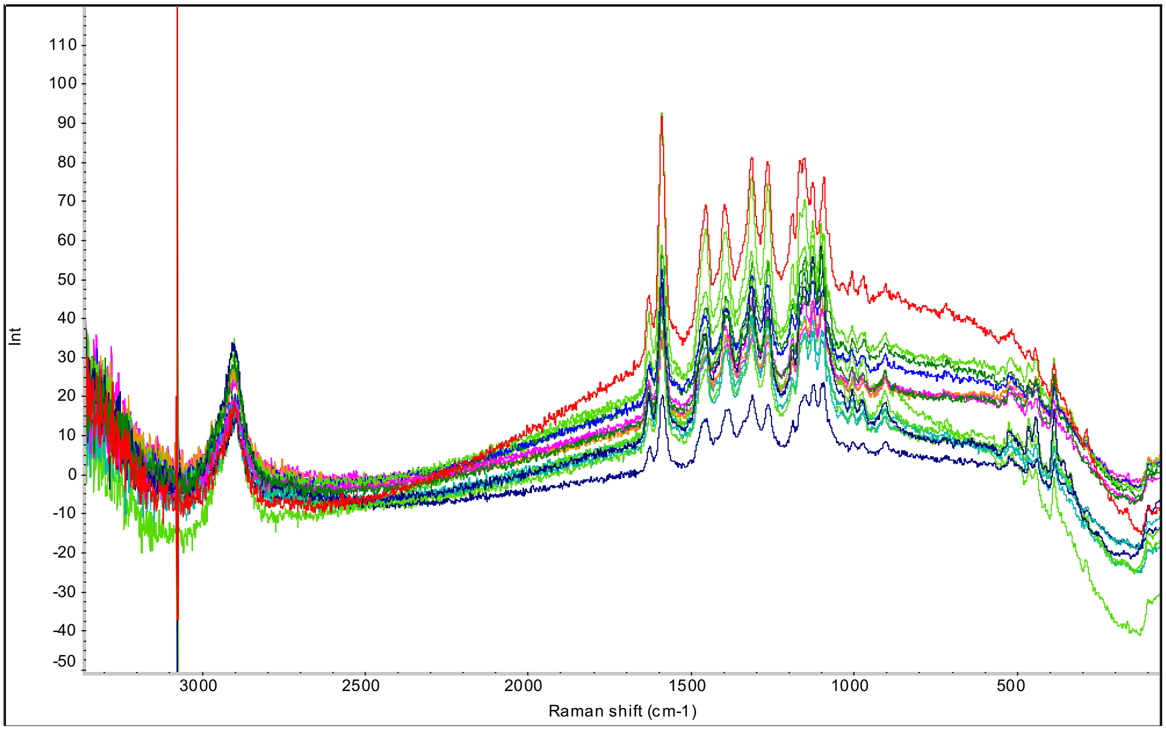
J-1 – Variation in spectra within box J-1 (5 envelopes, 3 spots)



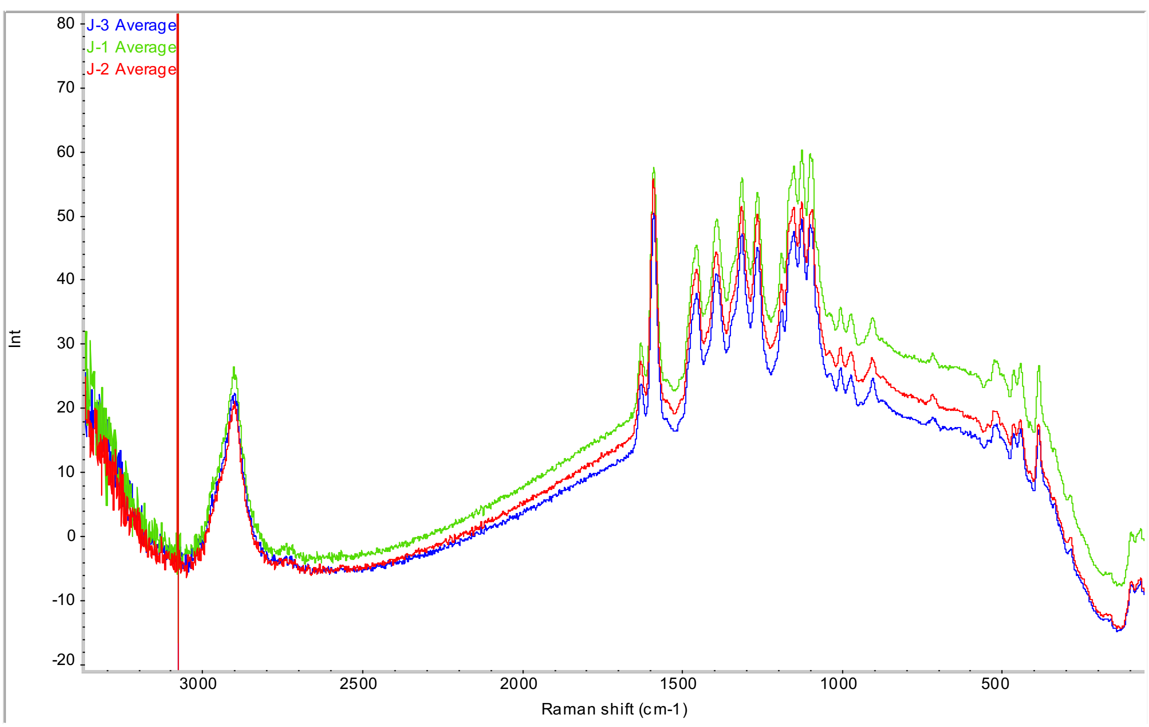
J-2 – Variation in spectra within box J-2 (5 envelopes, 3 spots)



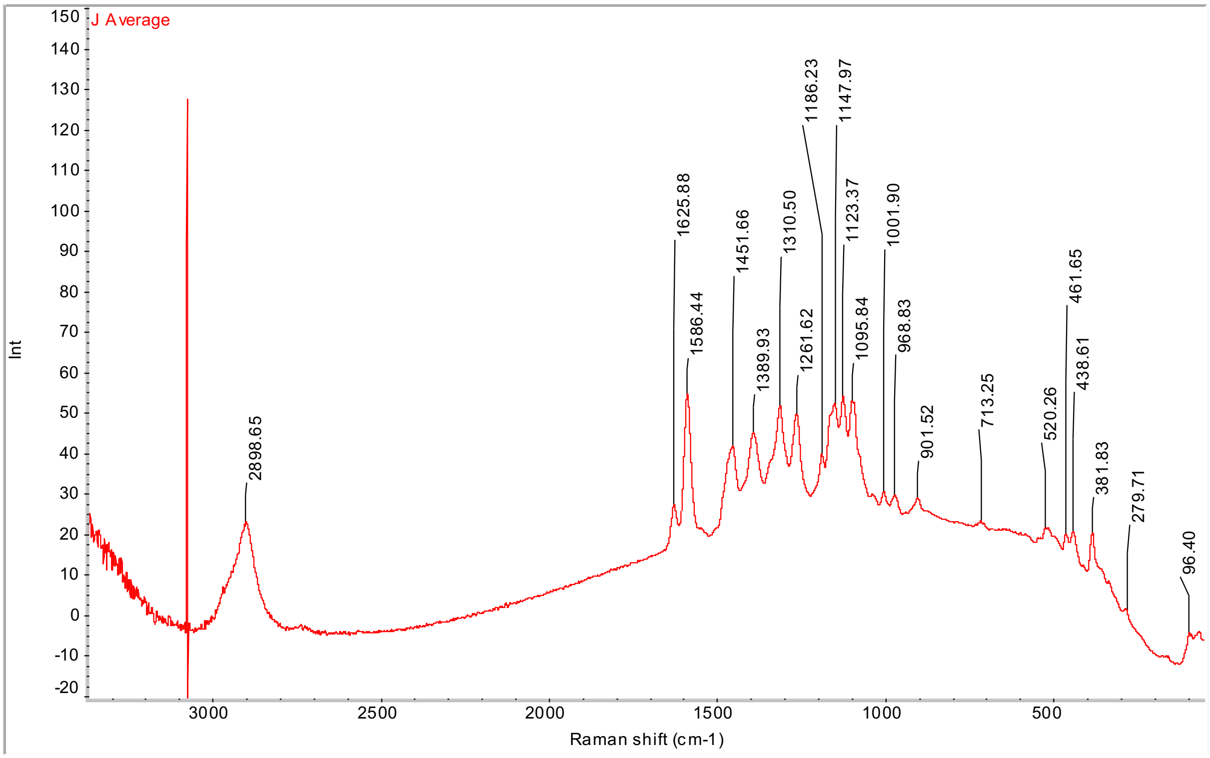
J-3 – Variation in spectra within box J-3 (5 envelopes, 3 spots)

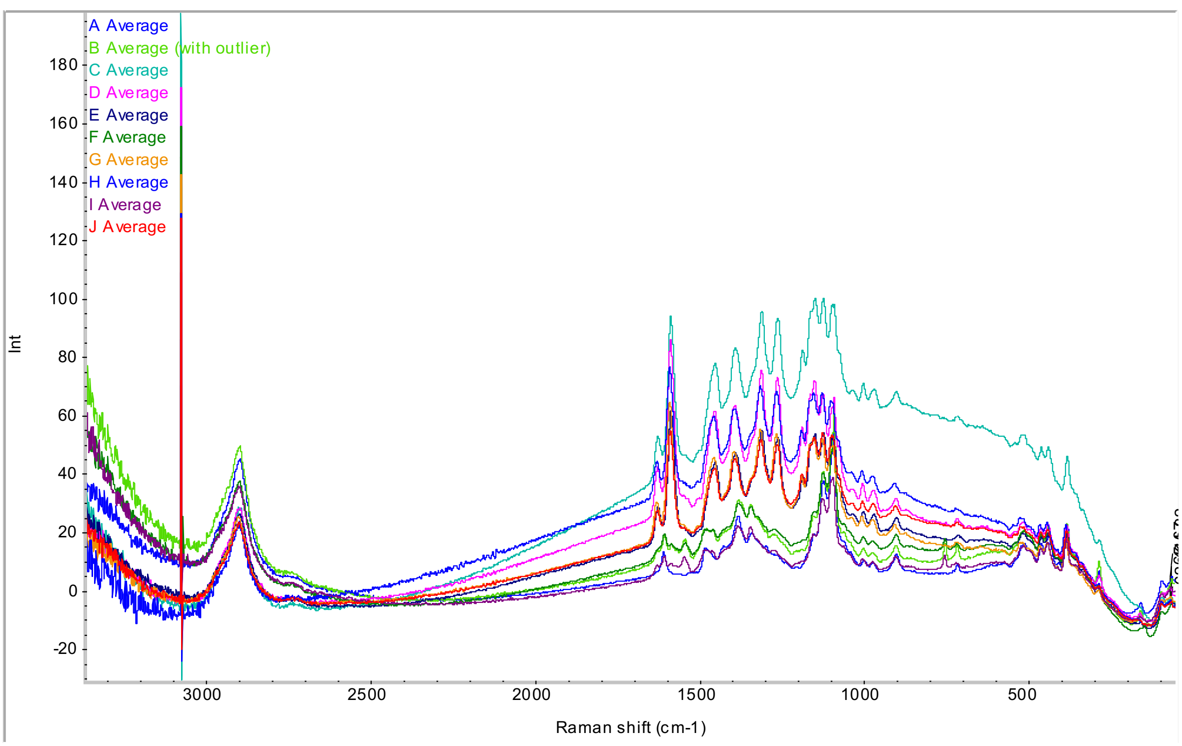


Raman BOX J AVERAGES:



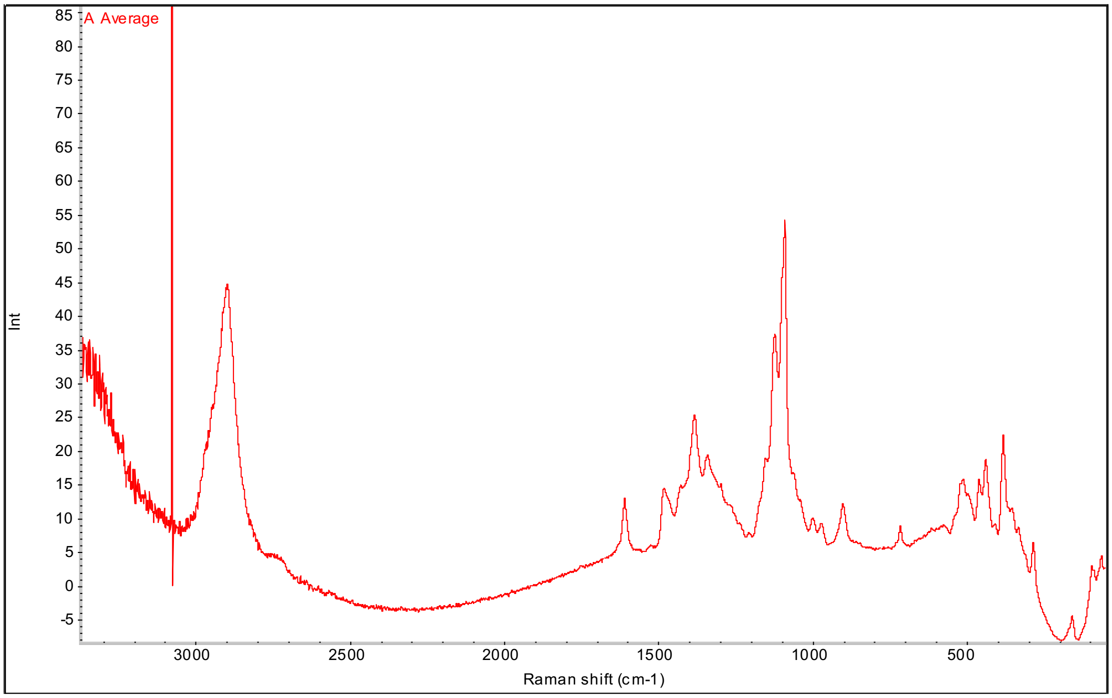
AVERAGE SPECTRA FOR BRAND J:



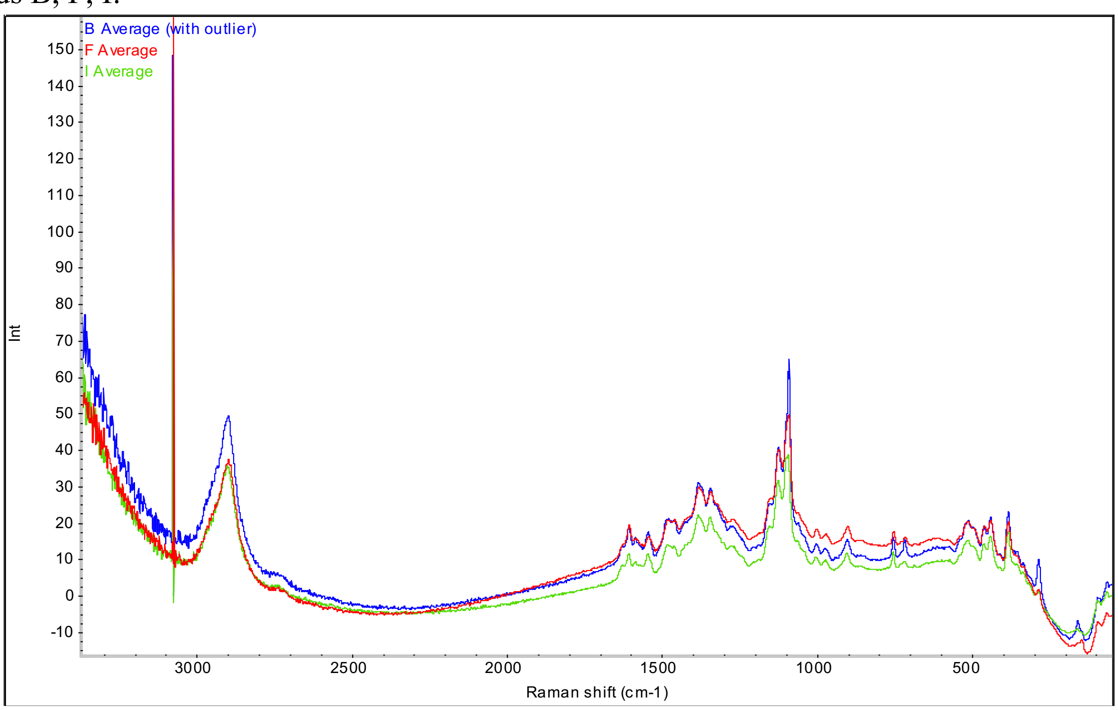


SPECTRA AVERAGES BY GROUPS:

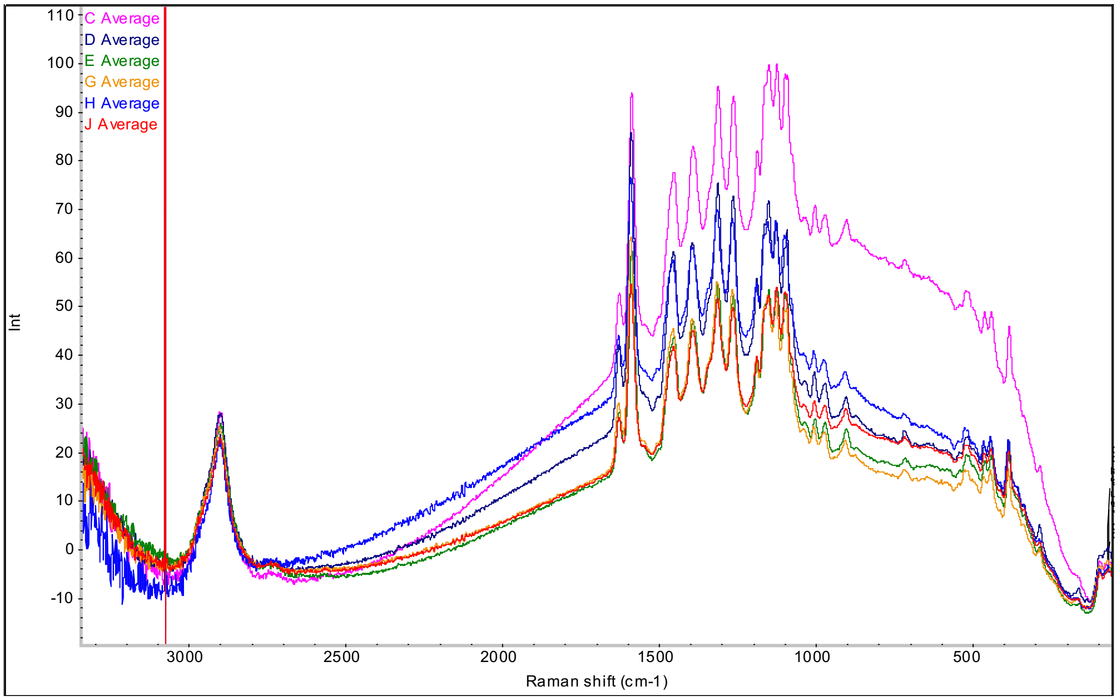
Brand A:



Brands B, F, I:



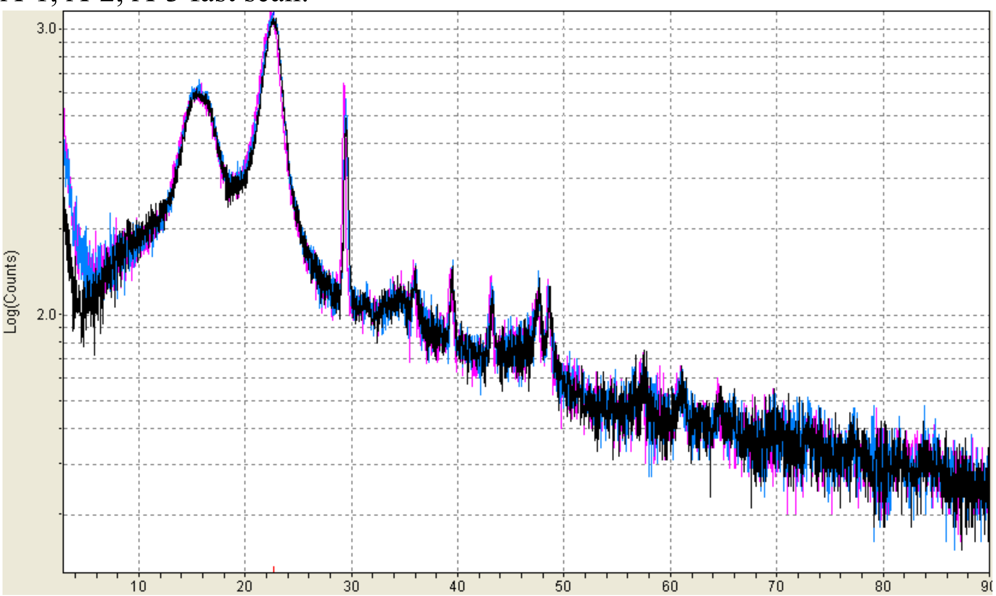
Brands C, D, E, G, H, J:



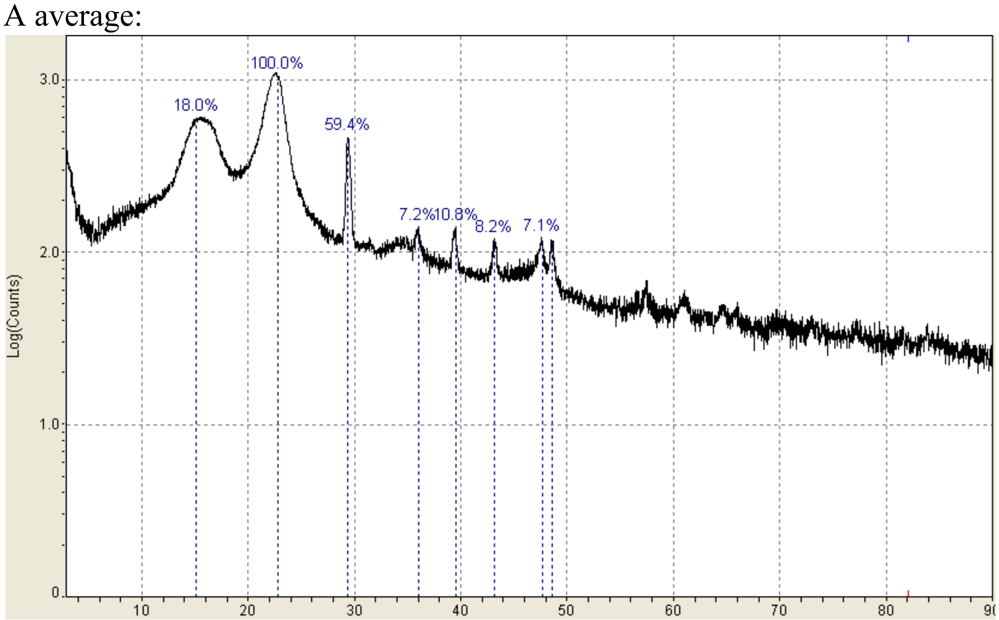
APPENDIX XIII

XRD spectra results

A-1, A-2, A-3 fast scan:



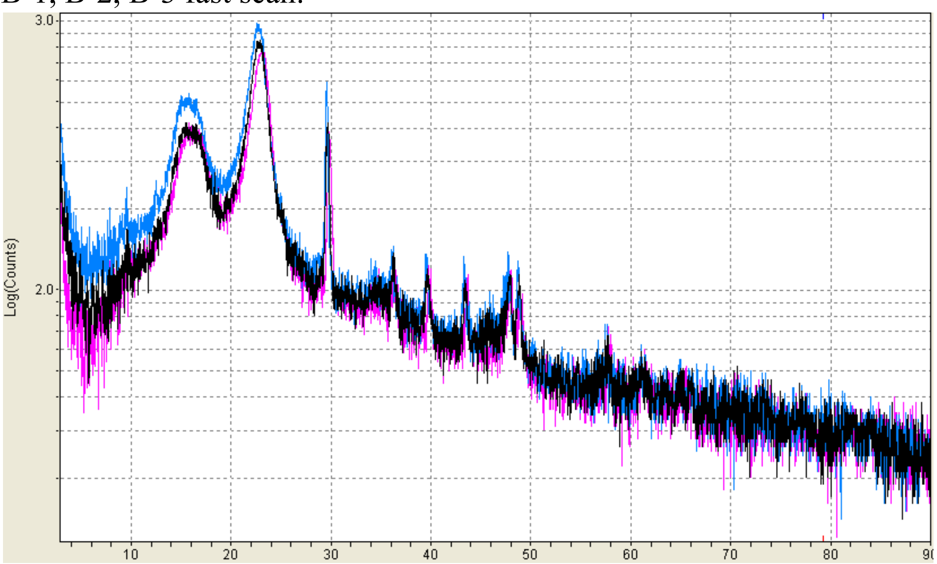
A average:



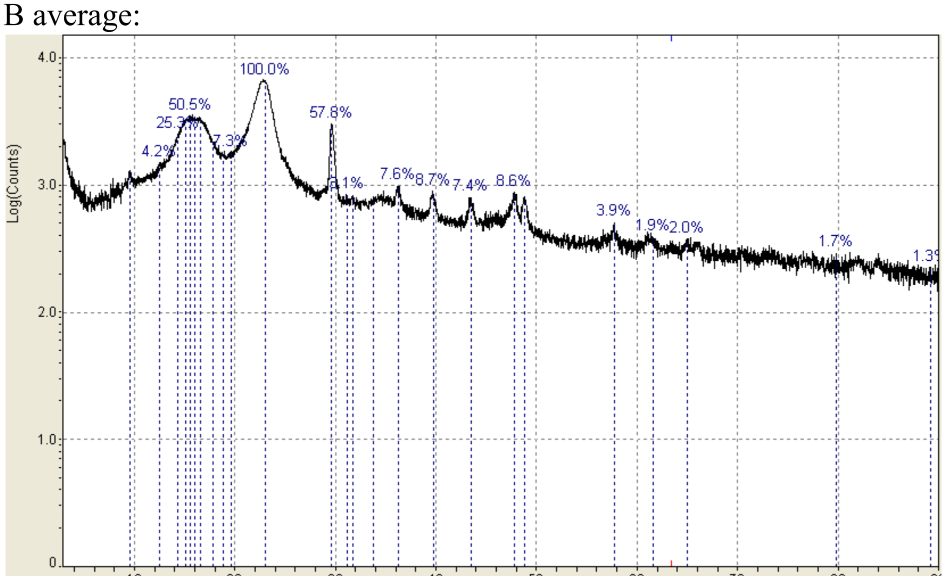
Peak Search Report (8 Peaks, Max P/N = 9.0)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.120	5.8550	492	105	18.0	5282	13.0	2.1
22.759	**3.9040**	**469**	**583**	**100.0**	**40578**	**100.0**	**9.0**
29.420	3.0335	115	346	59.4	7529	18.6	8.1
36.041	2.4900	97	42	7.2	923	2.3	1.8
39.559	2.2763	77	63	10.8	1400	3.5	2.7
43.181	2.0933	71	48	8.2	1109	2.7	2.2
47.641	1.9073	79	41	7.1	988	2.4	1.9
48.543	1.8739	75	42	7.3	827	2.0	2.0

B-1, B-2, B-3 fast scan:



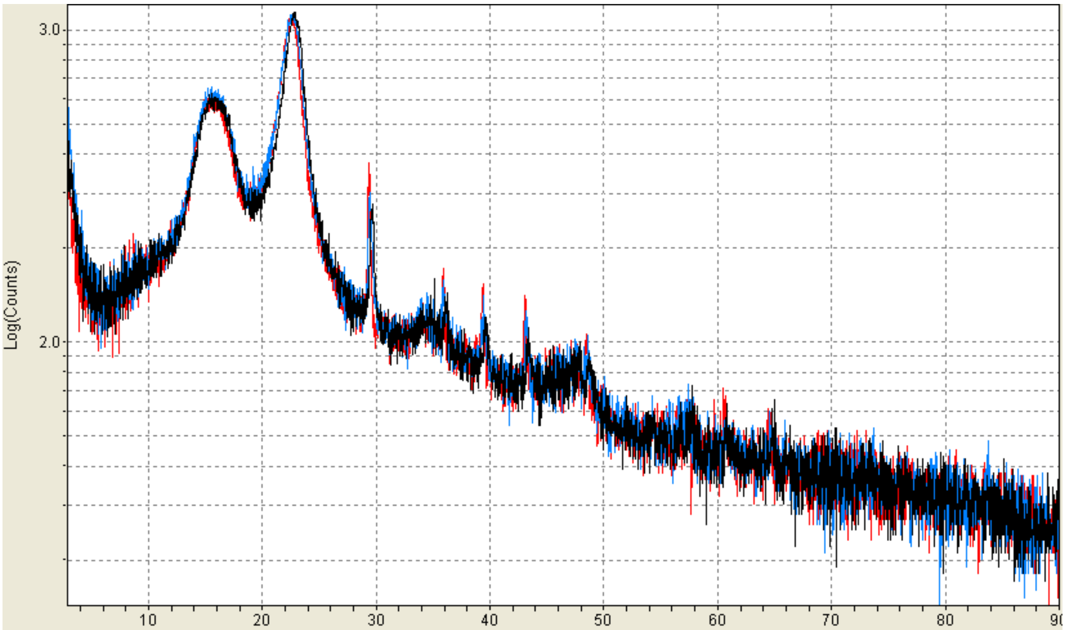
B average:



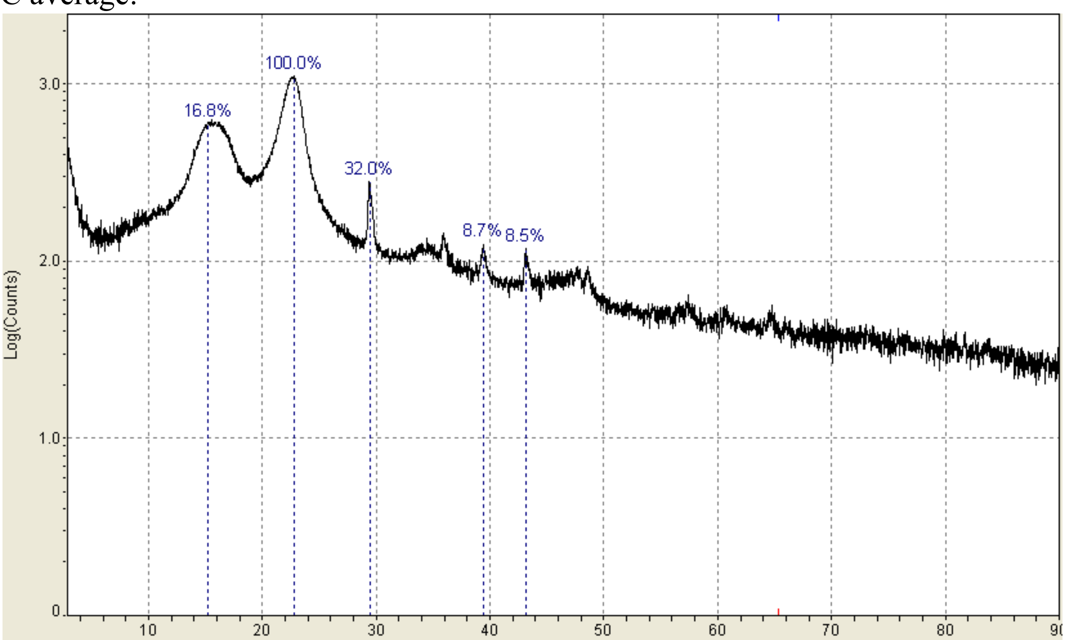
Peak Search Report (26 Peaks, Max P/N = 23.4)
PEAK: 39(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
9.597	9.2082	966	314	8.3	4540	1.8	4.4
12.545	7.0503	1316	161	4.2	1590	0.6	2.1
14.272	6.2008	1520	845	22.3	16195	6.4	8.7
14.341	6.1713	1520	961	25.3	23284	9.2	9.6
15.141	5.8469	1520	1744	46.0	61383	24.3	15.3
15.560	5.6904	1520	1916	50.5	151724	60.0	16.3
15.979	5.5420	1520	1824	48.1	165622	65.5	15.8
16.561	5.3487	1520	1852	48.8	84256	33.3	15.9
17.817	4.9744	1520	691	18.2	19855	7.9	7.3
18.842	4.7058	1520	212	5.6	3818	1.5	2.5
19.645	4.5152	1520	278	7.3	4445	1.8	3.3
23.060	**3.8538**	**2799**	**3793**	**100.0**	**252684**	**100.0**	**23.4**
29.641	3.0114	809	2191	57.8	52654	20.8	20.0
31.155	2.8684	724	116	3.1	2042	0.8	2.0
31.762	2.8150	706	121	3.2	2178	0.9	2.1
33.806	2.6493	695	103	2.7	3232	1.3	1.8
36.314	2.4719	684	290	7.6	5463	2.2	4.6
39.719	2.2675	563	330	8.7	7587	3.0	5.5
43.460	2.0806	512	280	7.4	6205	2.5	5.0
47.820	1.9006	543	325	8.6	8864	3.5	5.5
48.858	1.8626	519	282	7.4	5719	2.3	5.0
57.775	1.5945	354	150	3.9	2102	0.8	3.3
61.585	1.5047	321	71	1.9	2587	1.0	1.8
64.992	1.4338	300	76	2.0	1312	0.5	2.0
79.878	1.1999	223	66	1.7	349	0.1	1.9
89.254	1.0965	174	49	1.3	1241	0.5	1.7

C-1, C-2, C-3 fast scan:



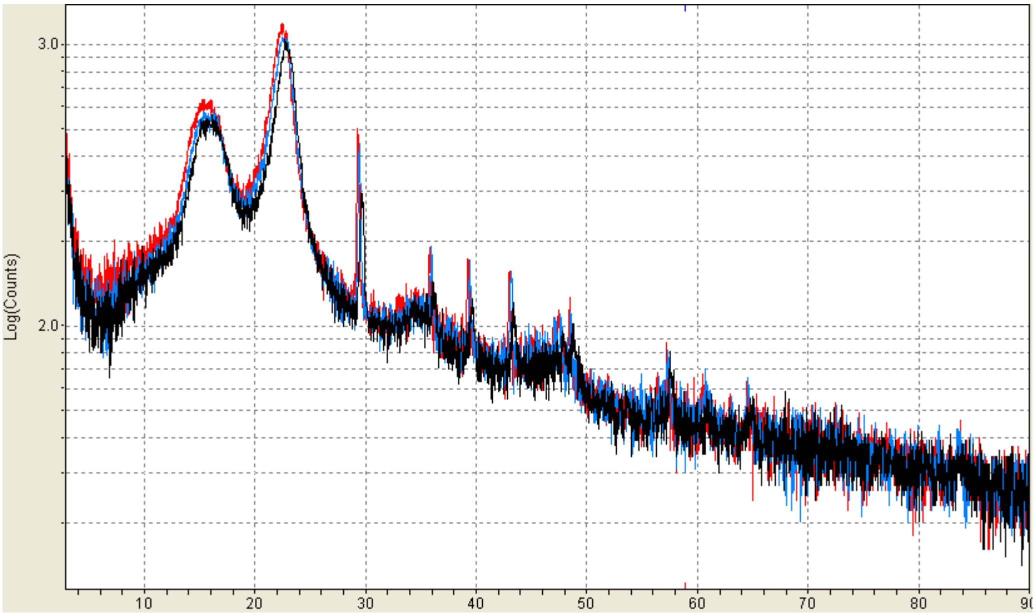
C average:



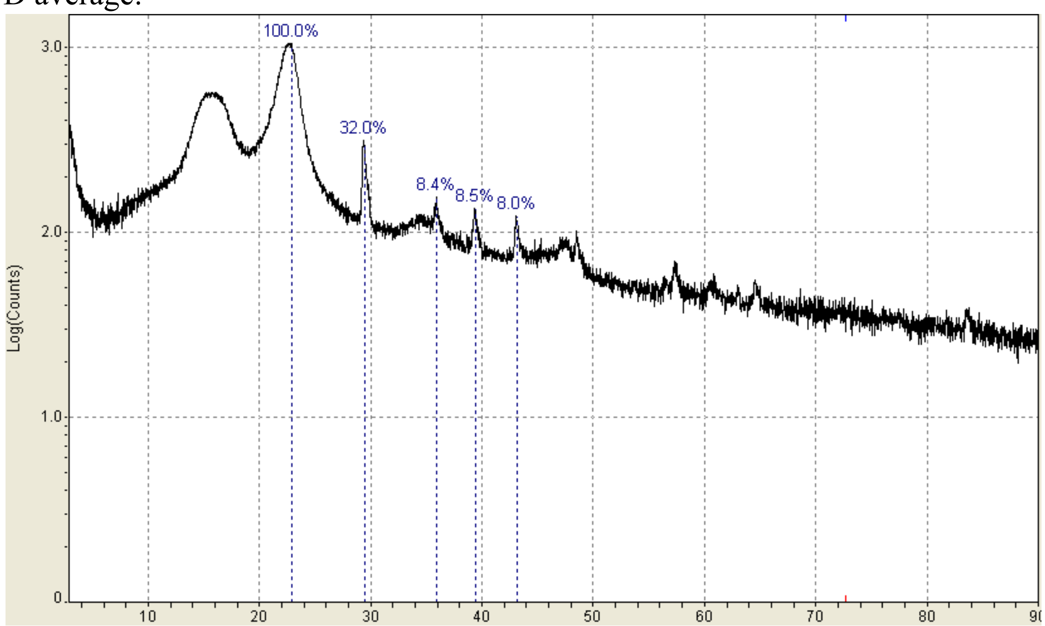
Peak Search Report (5 Peaks, Max P/N = 7.5)
PEAK: 67(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.242	5.8084	509	83	16.8	4628	16.3	1.7
22.840	**3.8904**	**602**	**496**	**100.0**	**28404**	**100.0**	**7.5**
29.443	3.0313	121	159	32.0	3237	11.4	4.7
39.480	2.2807	81	43	8.7	1001	3.5	1.9
43.198	2.0926	74	42	8.5	693	2.4	2.0

D-1, D-2, D-3 fast scan:



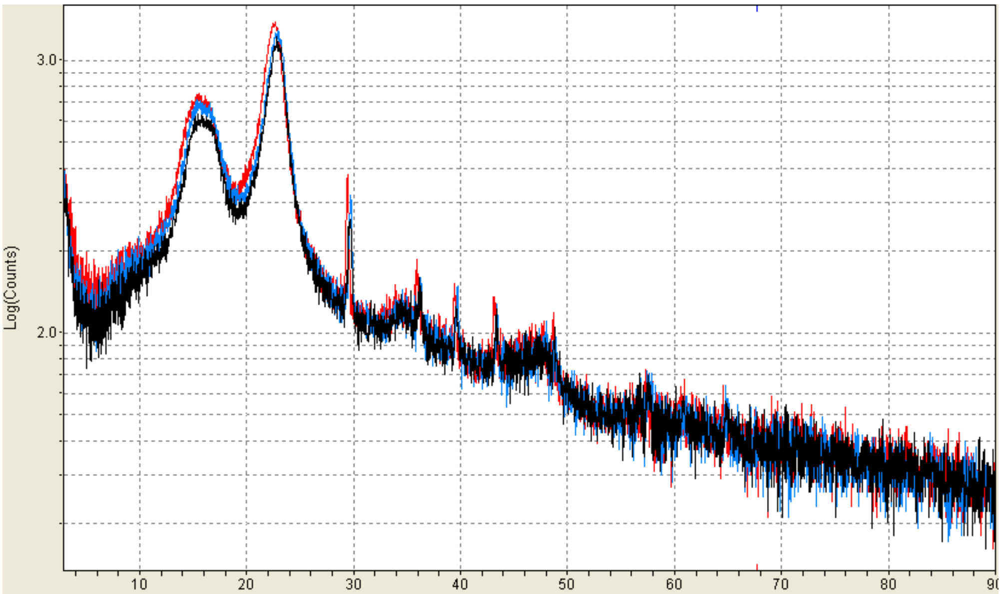
D average:



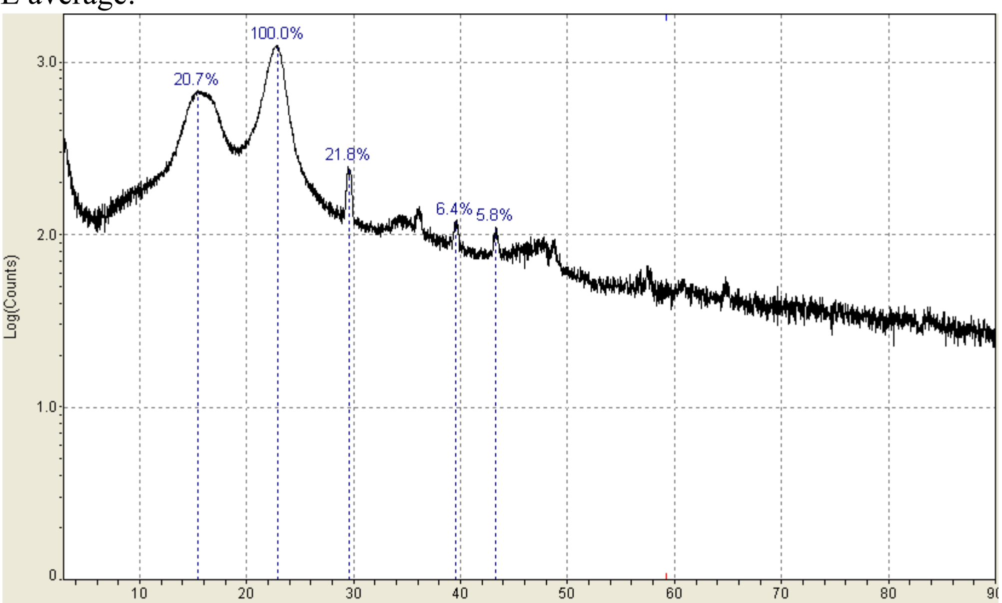
Peak Search Report (5 Peaks, Max P/N = 9.6)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
22.920	**3.8770**	**422**	**618**	**100.0**	**41543**	**100.0**	**9.6**
29.440	3.0315	113	198	32.0	4272	10.3	5.6
35.981	2.4940	102	52	8.4	878	2.1	2.1
39.399	2.2851	81	53	8.5	1028	2.5	2.3
43.120	2.0962	73	50	8.0	999	2.4	2.2

E-1, E-2, E-3 fast scan:



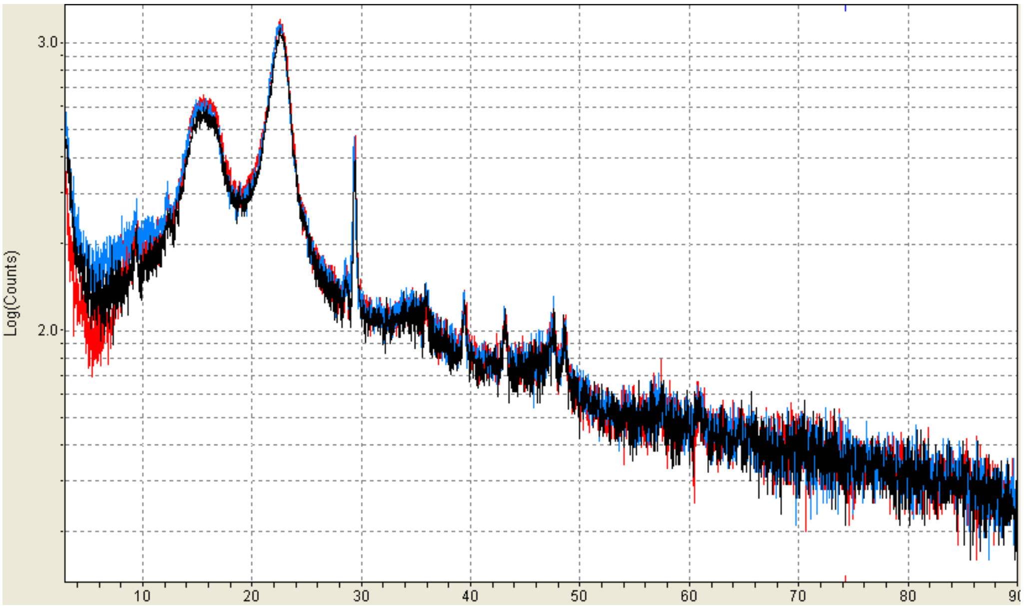
E average:



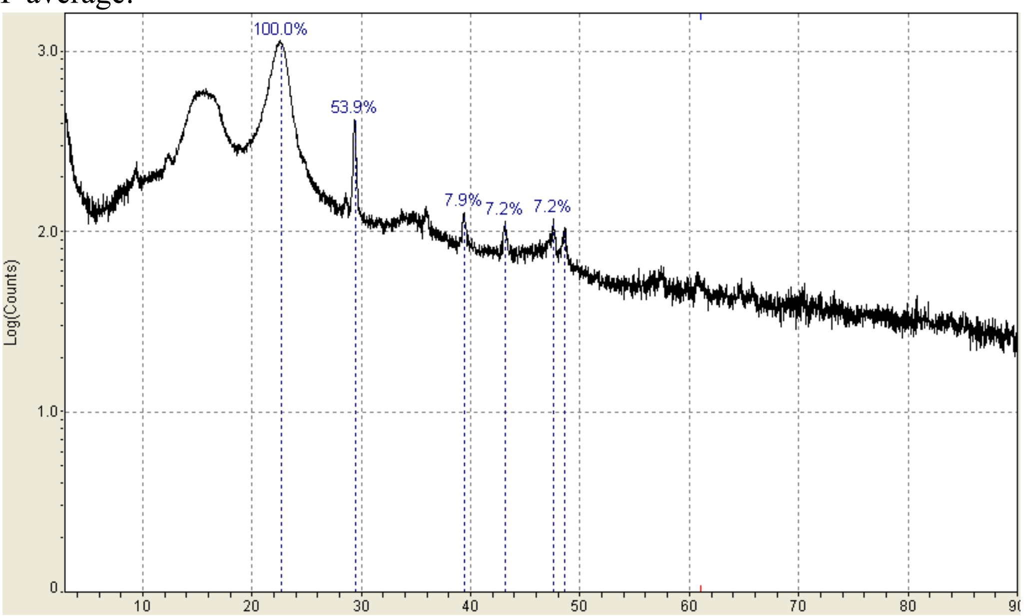
Peak Search Report (5 Peaks, Max P/N = 7.9)
PEAK: 67(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.442	5.7336	559	116	20.7	6587	20.3	2.2
22.919	**3.8771**	**676**	**558**	**100.0**	**32514**	**100.0**	**7.9**
29.579	3.0176	123	121	21.8	2971	9.1	3.9
39.560	2.2762	83	36	6.4	927	2.9	1.6
43.298	2.0880	76	33	5.8	613	1.9	1.6

F-1, F-2, F-3 fast scan:



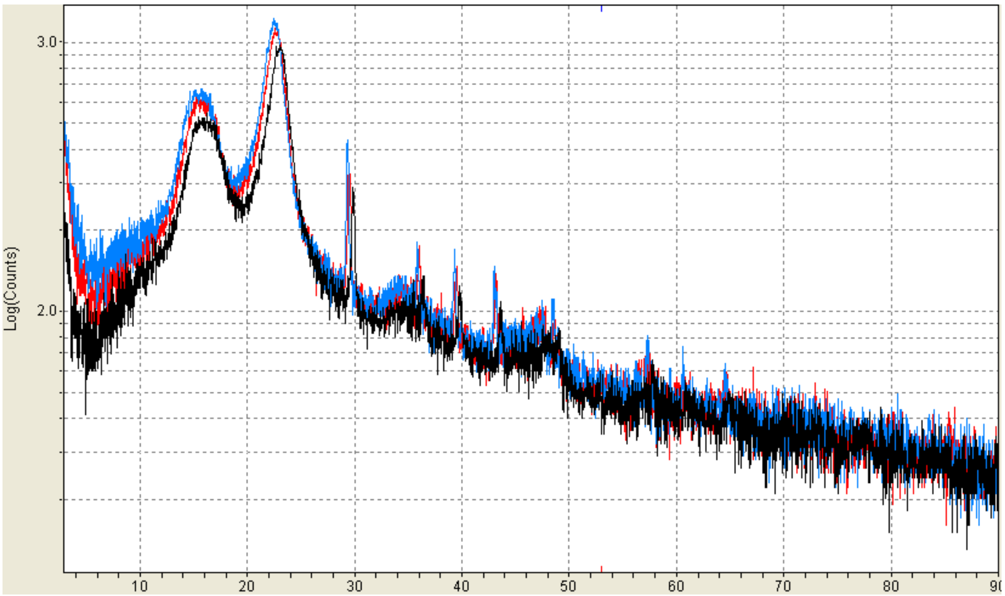
F average:



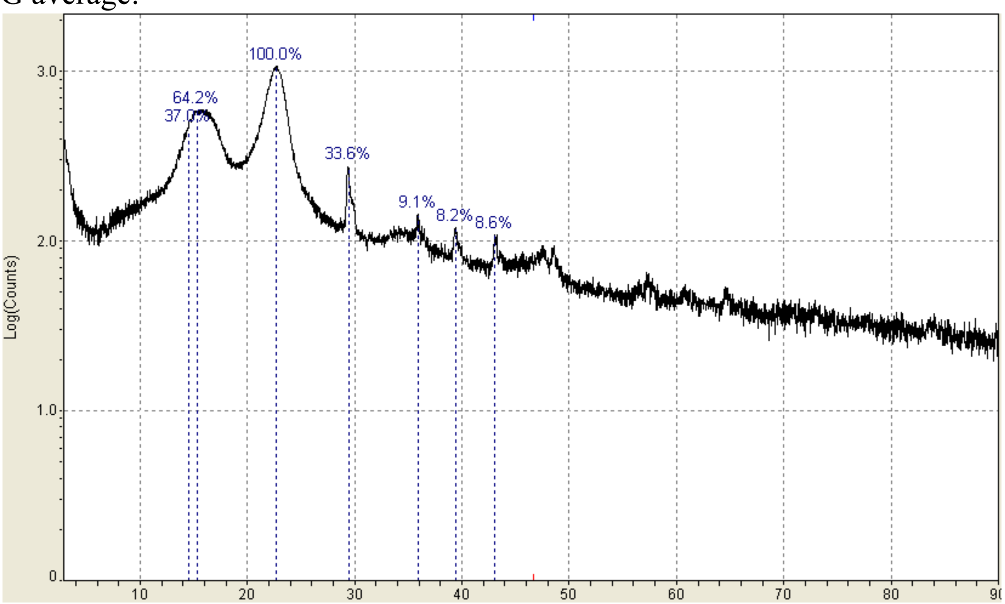
Peak Search Report (6 Peaks, Max P/N = 8.0)
PEAK: 43(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
22.640	**3.9243**	**595**	**537**	**100.0**	**30896**	**100.0**	**8.0**
29.421	3.0334	126	289	53.9	4532	14.7	7.1
39.441	2.2828	84	42	7.9	739	2.4	1.9
43.219	2.0916	73	39	7.2	752	2.4	1.8
47.599	1.9089	78	39	7.2	563	1.8	1.8
48.620	1.8711	70	34	6.4	629	2.0	1.7

G-1, G-2. G-3 fast scan:



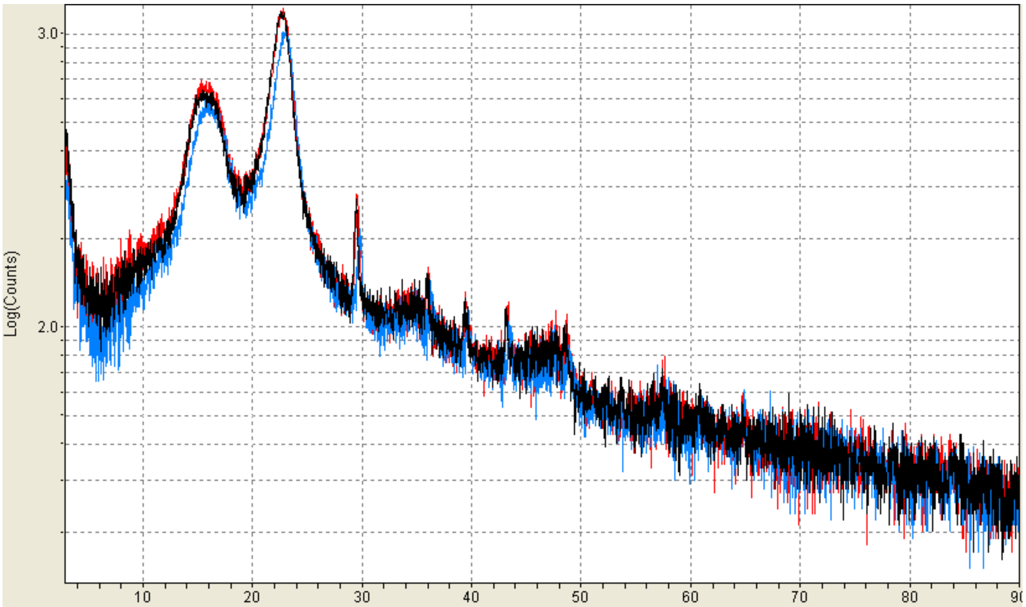
G average:



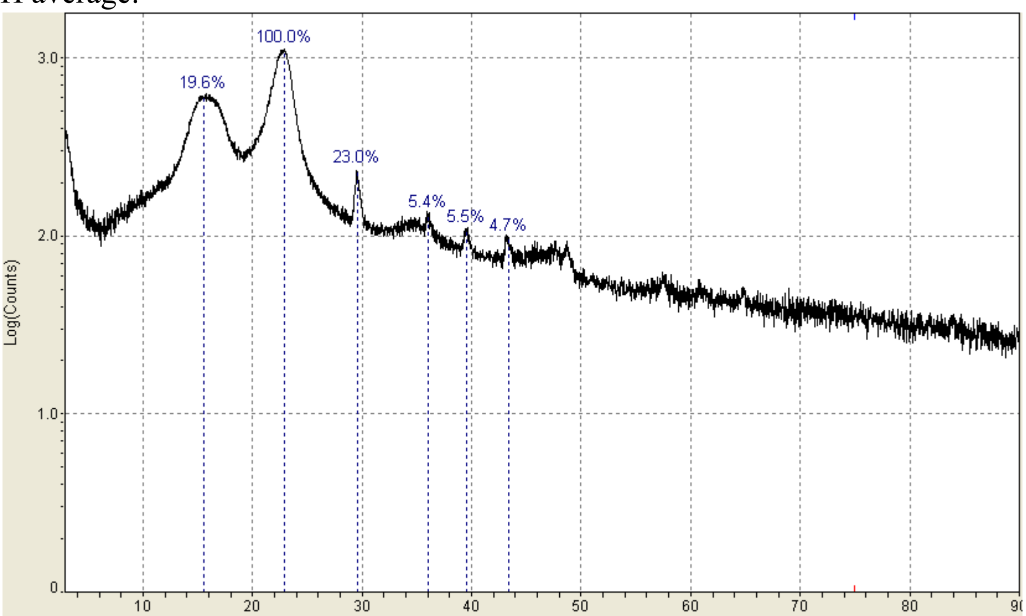
Peak Search Report (7 Peaks, Max P/N = 7.1)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
14.490	6.1078	286	171	37.0	4436	16.2	4.0
15.280	5.7940	286	297	64.2	24147	88.4	6.1
22.740	**3.9073**	**598**	**463**	**100.0**	**27309**	**100.0**	**7.1**
29.441	3.0314	119	155	33.6	3399	12.4	4.7
35.978	2.4942	100	42	9.1	868	3.2	1.8
39.460	2.2817	81	38	8.2	863	3.2	1.7
43.103	2.0970	69	40	8.6	897	3.3	1.9

H-1, H-2, H-3 fast scan:



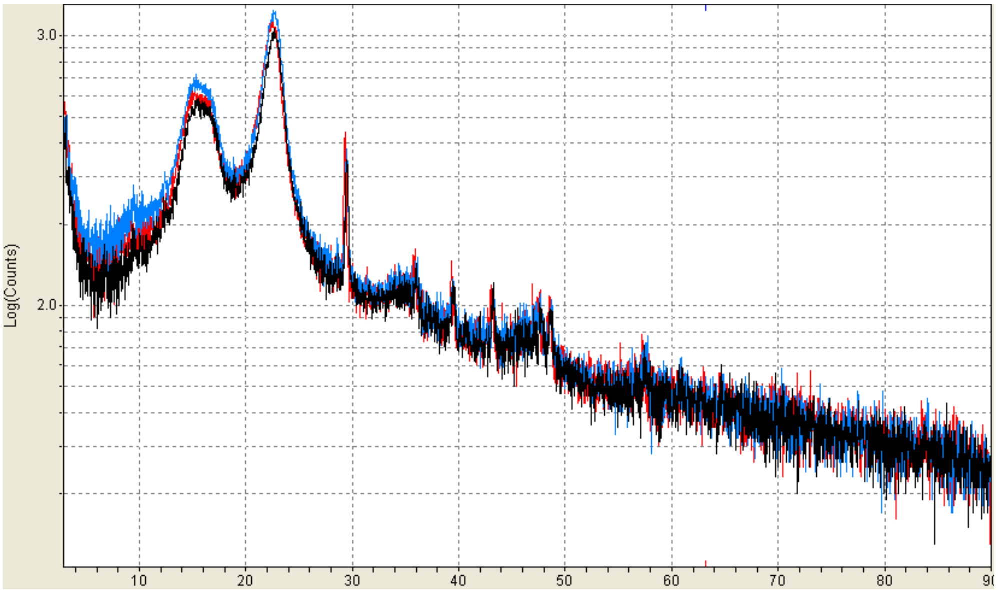
H average:



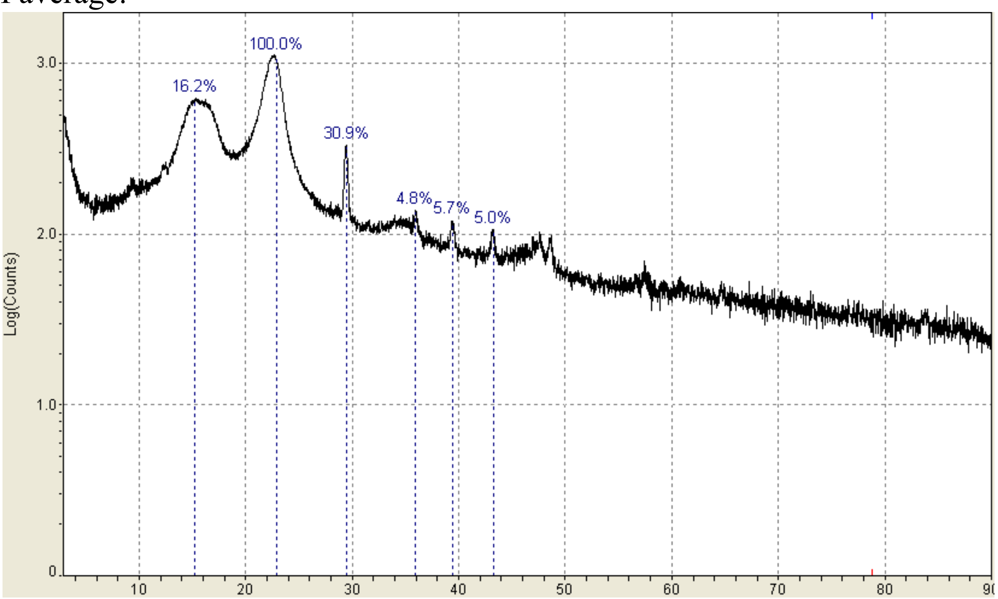
Peak Search Report (6 Peaks, Max P/N = 7.5)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.539	5.6979	514	98	19.6	5765	19.5	2.0
22.920	**3.8770**	**612**	**499**	**100.0**	**29555**	**100.0**	**7.5**
29.579	3.0175	119	115	23.0	2691	9.1	3.7
36.063	2.4885	105	27	5.4	540	1.8	1.2
39.542	2.2772	82	28	5.5	713	2.4	1.3
43.339	2.0861	74	24	4.7	598	2.0	1.2

I-1, I-2, I-3 fast scan:



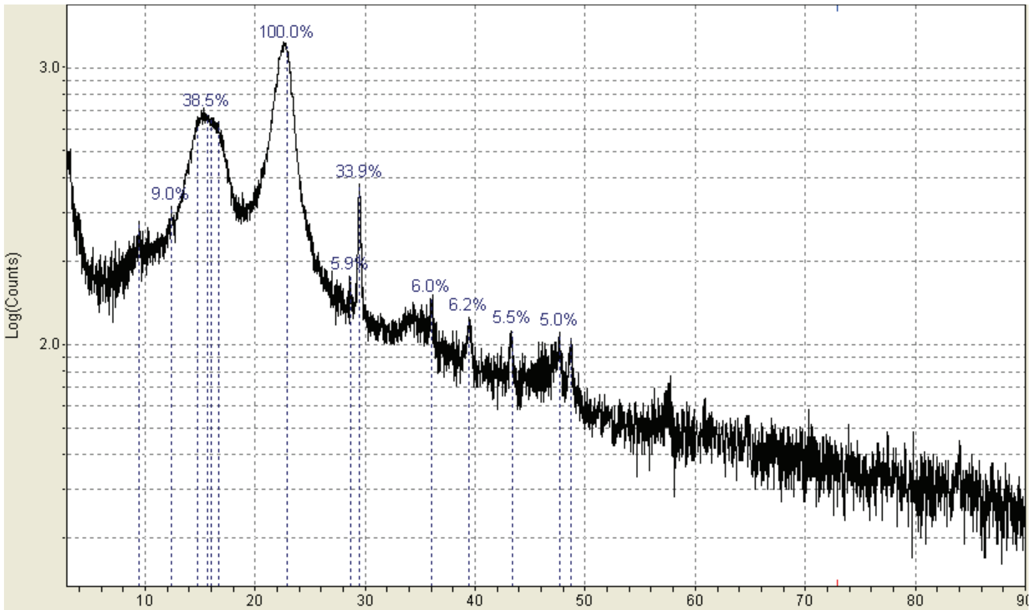
I average:



Peak Search Report (6 Peaks, Max P/N = 10.1)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.220	5.8166	507	108	16.2	5639	12.5	2.2
22.860	**3.8871**	**428**	**666**	**100.0**	**44940**	**100.0**	**10.1**
29.499	3.0256	122	206	30.9	3906	8.7	5.7
35.922	2.4980	103	32	4.8	561	1.2	1.4
39.440	2.2829	81	38	5.7	765	1.7	1.7
43.261	2.0897	72	34	5.0	731	1.6	1.6

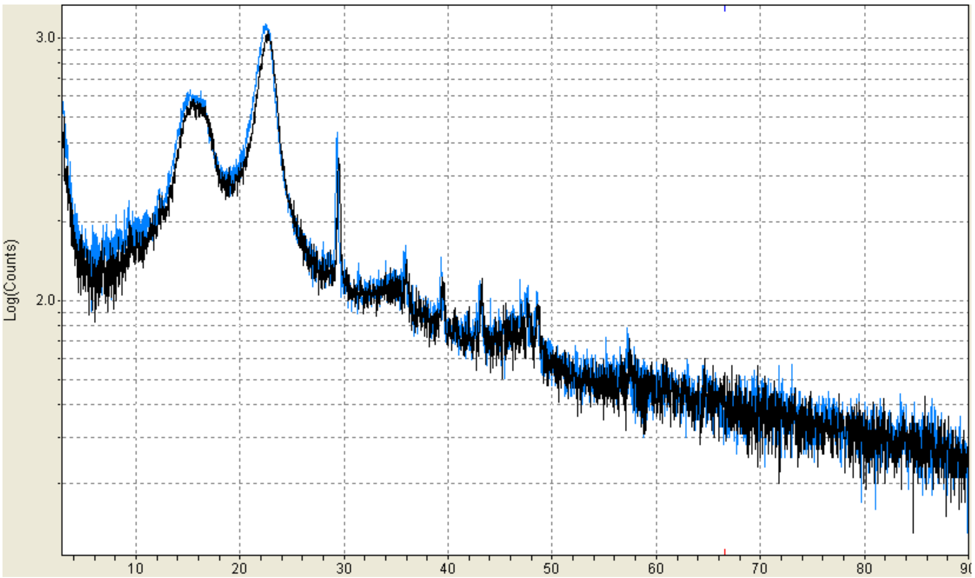
I-1



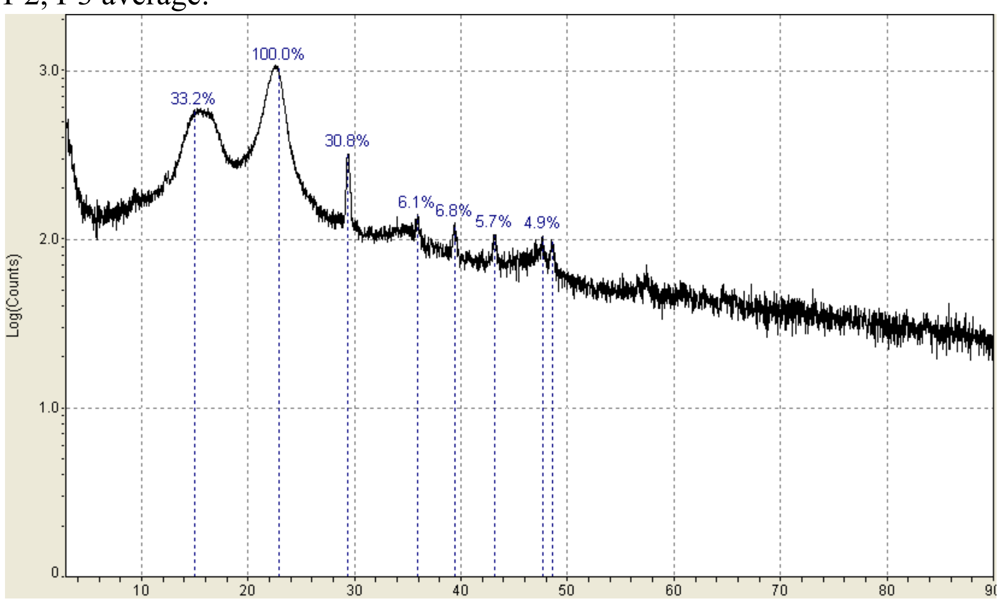
Peak Search Report (14 Peaks, Max P/N = 10.5)
[I-1-1 Fast3-90 05Dec2018.raw] I11 05Dec2018Fast - FORS 6641 Fast Scan
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
9.483	9.3192	204	74	10.1	1009	2.1	2.2
12.439	7.1104	247	66	9.0	863	1.8	1.9
14.761	5.9965	398	225	30.9	6487	13.4	4.5
15.619	5.6688	398	281	38.5	22953	47.4	5.4
16.040	5.5211	398	255	35.0	11810	24.4	5.0
16.720	5.2980	398	238	32.6	7078	14.6	4.7
22.879	**3.8838**	**476**	**729**	**100.0**	**48438**	**100.0**	**10.5**
28.681	3.1100	133	43	5.9	316	0.7	1.6
29.500	3.0255	131	247	33.9	3602	7.4	6.4
36.004	2.4924	102	44	6.0	740	1.5	1.8
39.482	2.2805	80	45	6.2	1162	2.4	2.0
43.361	2.0851	72	40	5.5	727	1.5	1.9
47.740	1.9035	73	37	5.0	745	1.5	1.7
48.719	1.8676	66	39	5.3	700	1.4	1.9

I-2, I-3:



I-2, I-3 average:

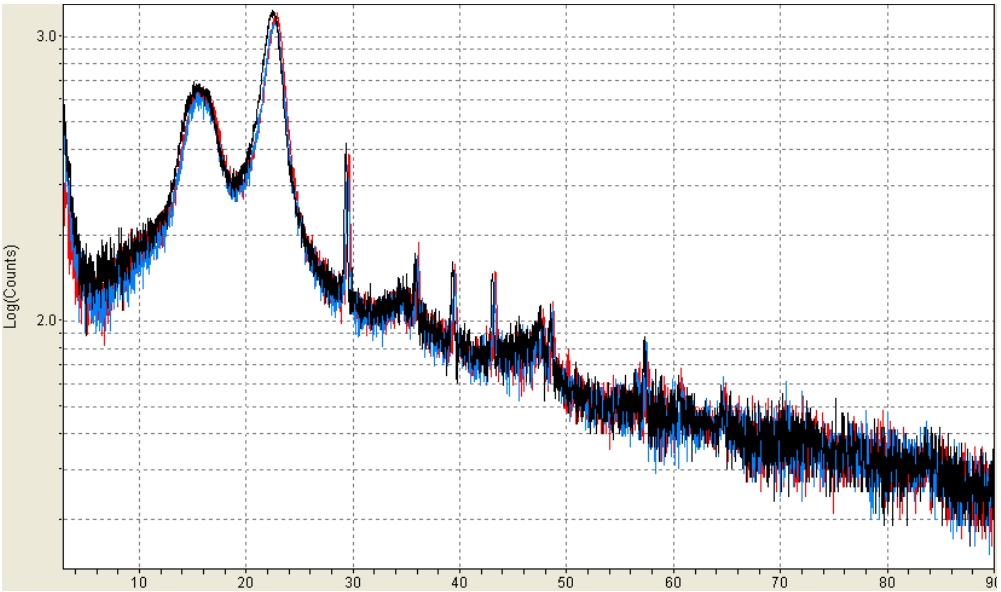


Peak Search Report (8 Peaks, Max P/N = 9.9)

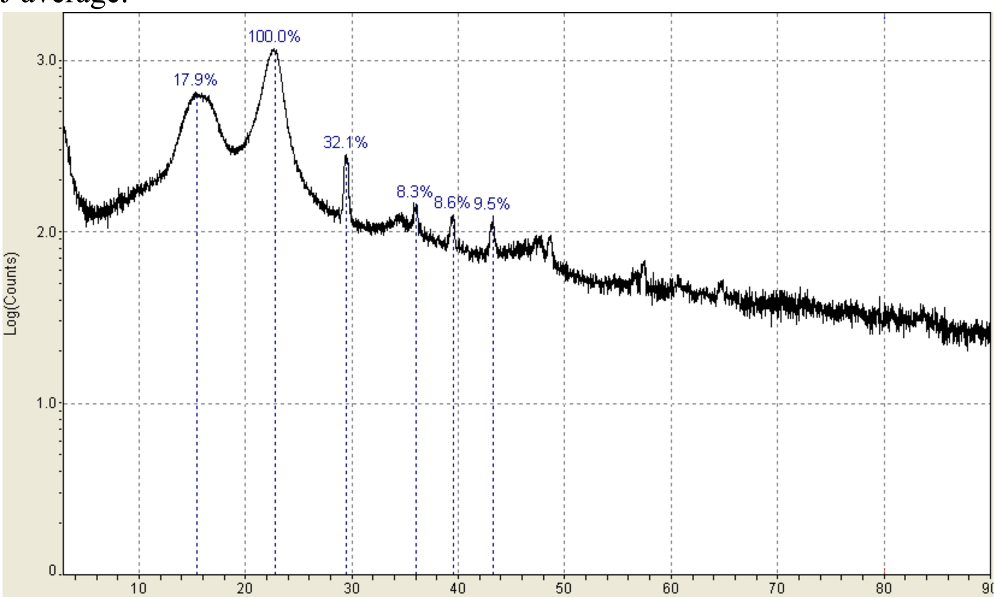
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
14.942	5.9243	362	214	33.2	6570	15.3	4.4
22.860	**3.8871**	**404**	**643**	**100.0**	**43041**	**100.0**	**9.9**
29.400	3.0355	121	198	30.8	3949	9.2	5.5
35.961	2.4953	100	39	6.1	617	1.4	1.7
39.439	2.2829	80	44	6.8	747	1.7	2.0
43.182	2.0933	69	37	5.7	881	2.0	1.8
47.698	1.9051	73	32	4.9	530	1.2	1.6
48.560	1.8733	65	33	5.1	569	1.3	1.7

J-1, J-2, J-3 fast scan:



J average:



Peak Search Report (6 Peaks, Max P/N = 7.4)
PEAK: 47(pts)/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

Theta	d(Å)	BG	Height	H%	Area	A%	P/N
15.418	5.7422	561	91	17.9	3235	11.0	1.8
22.760	**3.9039**	**646**	**506**	**100.0**	**29311**	**100.0**	**7.4**
29.481	3.0274	117	162	32.1	3813	13.0	4.9
36.081	2.4873	102	42	8.3	898	3.1	1.7
39.580	2.2751	82	43	8.6	937	3.2	1.9
43.299	2.0880	74	48	9.5	917	3.1	2.2

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