Finding a Natural Alternative from Forest Resources for Plastic Single Use Utensils

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Suggesting a Natural Alternative from Forest Resources for Plastic Single Use Utensils

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An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Science in Forestry

Faculty of Natural Resources Management

Lakehead University

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Dr. Mathew Leitch	Mr. Pat Donahue
Major Advisor	Second Reader

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ABSTRACT

Way-Nee, G.S. 2019. Finding a Natural Alternative from Forest Resources for Plastic Single Use Utensils. Lakehead University. Pp. 46.

Keywords: *Betula papyrifera, Populus tremuloides, Tilia americana, Fomitopsis cajanderi, Fomitopsis pinicola, Trametes pubescens,* Decay, Swelling, Utensil, Natural, Plastic, Environmental sustainability.

The use of plastics by society has increased tremendously due to the high durability of the product and low cost of production. High production has changed many products being made of natural materials such as wood to being created from this polymer material. One of the most common single use plastics is plastic utensils such as the cutlery provided by fast-food chains. To suggest the best alternative to plastics, a standardized decay and swelling test was completed on three different potential wood species. *Betula papyrifera, Populus tremuloides,* and *Tilia americana* were each tested for both decay and swelling. In the decay test, each of the wood species were tested against three decay fungi, *Fomitopsis cajanderi, Fomitopsis pinicola,* and *Trametes pubescens.*

Over the four-month test duration, each of the 10 trials for each combination declined in weight excluding the control blocks. Two of the three fungi decayed *Betula papyrifera* the most. The statistical analysis of the results showed that there is no statistical significance between the different wood species in the experiment. However, *Fomitopsis cajanderi* showed the most decay for each of the wood species compared to the other fungi. The difference in fungi was deemed to be statistically significant by the 2-way anova. This is of interest because *Fomitopsis cajanderi* primarily targets conifer species in a natural setting. The lab setting may have provided an easier environment for the fungi to decay the hardwood compared to the harsh natural environment. The environmental benefit of wooden single use utensils to reduce the current 40 billion plastic single use utensils now produced each year globally could be significant.

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ACKNOWLEDGMENTS

I would like to thank the Faculty of Natural Resources Management. Thanks to Dr. Mathew Leitch for his guidance through this whole process of completing my fourth-year honours thesis. I would also like to thank my second reader, for taking time out of their busy schedule to review and provide suggestions to improve this thesis. In addition, I would like to acknowledge the helpful contributions made by Dr. Leonard Hutchison. The large amount of help with completing the decay test was greatly appreciated.

INTRODUCTION

The impacts that anthropogenic activity have had on the planet has been well documented with scientific evidence. Since the industrial revolution, the planet has suffered from the increased use of resources, some natural and some non-renewable (Goudie &Viles 1997). The industrial revolution allowed populations to grow at a rate faster than ever seen before on the planet (Goudie & Viles 1997). This was possible due to the reduction in land needed to sustain one person due to the increase in utilization intensity of resources (Goudie & Viles 1997). These resources have continued to be depended upon for human life in almost all products used by society (Goudie & Viles 1997, Barnes *et al.* 2009).

Plastic production came after the industrial revolution, but it is a revolutionary material that became extremely popular for multiple uses (Barnes *et al.* 2009). These plastic products offer a cheap alternative to many less durable materials. This economic advantage has been the catalyst for the massive increase in plastic use (Geyer *et al.* 2017). The explosion in production has created enormous amounts of plastic in the world, and all this plastic, when it has served its use, remains undecomposed for years to come (Geyer *et al.* 2017). We are just beginning to understand the detrimental damages this use of plastic has on ecosystems, and animals around the world (Barnes *et al.* 2009). This new knowledge has created an anti-plastic movement to reduce usage, and find alternative materials for plastic.

This topic of eliminating single use plastics is very important for the fight to better care for our planet. Unfortunately, this topic has not been very prominent in the news until just recently (Barnes *et al.* 2009). With much documented damages that these

single use plastics like bags, utensils, cups have on ecosystems, this is a problem that needs to be solved sooner rather than later. Plastics are very resistant to breaking down and therefore create tremendous amounts of garbage that will not disappear in a lifetime (Gautam & Caetano 2017). The possibility of having a suitable alternative, which comes from a natural source, would reduce the problem greatly (Gautam *et al.* 2009). Wood offers a good natural substitute material for plastic utensils.

The opportunity to do research on this topic and suggest a solution from potential forest timber is of great interest and has motivated the topic of this thesis. Interest in sustainable and environmentally friendly alternatives for everyday items has always been prevalent (Geyer *et al.* 2017). Suggesting some alternative materials offers valuable knowledge to potential operations which are interested in wooden utensils.

The data used will be found through experimental research. All the research and work will be done in lab excluding the retrieval of wood for the experiment. Two species, birch and poplar, are sourced from the Hogarth plantation in Thunder Bay, Ontario. The basswood samples are from private property in Peterborough, Ontario with approved consent from the homeowner. Once these different woods are cut into trial cubes, the durability test will be performed in lab with the supervision of Dr. Hutchison. A swelling test will be completed to identify the amount of change occurring in the wood when exposed to water. This will help to determine which of the species provides the best properties for potential food grade uses.

In the literature review section, past research using durability, and swelling/shrinkage tests on some of the same species used, will be looked at for comparison data. This will be useful to compare the past research with results found in

this thesis research. Other research considered will be any past attempts of making a natural alternative to harmful plastic cutlery. In addition, finding some research about the potential hazards of using the plethora of plastic which society currently consumes and what impact this has on our planet. This research will be able to provide validity to my analysis and help prove the importance of finding an alternative to plastic.

OBJECTIVE AND HYPOTHESIS

The objective is to suggest the best wood species to use as an alternative to single use plastic utensils out of the three species of interest (Birch, Poplar, Basswood). More specifically, concluding which of the three species has the best characteristics to be used in a potential value added production of single use wooden utensils. It is expected that the birch is going to prove to be the best potential alternative to plastics due to its quick decay characteristics.

LITERATURE REVIEW

PLASTICS

One product that has been used by modern society in large amounts are plastics. Plastic was first produced in the 1950s and has had one of the most significant impacts on the planet of any material (Barnes *et al.* 2009). The plastic problem has gained increasing attention recently but has been a known issue for many years (Barnes *et al.* 2009). One of the primary resources used in plastic production is fossil fuels. These non-renewable resources are environmentally harmful when combusted (Geyer *et al.* 2017). Plastics are used due to their light-weight, cheap cost of production, and durability (Geyer *et al.* 2017). However, this durability is detrimental to the environment when plastics are discarded (Barnes *et al.* 2009). To date, it is estimated that 8300 million metric tons of plastics have been produced (Geyer *et al.* 2017). Approximately 79% of these plastics are discarded as garbage, which can either take the path to a landfill or await decomposition in the natural environment (Geyer *et al.* 2017). This massive amount of waste is a long-term problem because of the lengthy decomposition rates of plastic. Depending on size, plastic items can take hundreds or even thousands of years to decompose completely (Barnes *et al.* 2009).

In the United States of America, the most produced polymer products fall under the durable goods category (Barnes *et al.* 2009). These durable goods are defined by Barnes *et al.* (2009) as a product used for more than 3 years. The second highest produced plastic products are non-durable goods (Barnes *et al.* 2009). These items are used for less than three years then discarded into the garbage. In the USA, only 9% are being recycled regularly with the clear majority of recyclable plastics ending up in

landfills (Geyer *et al.* 2017). Plastic single-use utensils are a growing concern as part of this "non-durable goods" group (Barnes *et al.* 2009). Each year, 40 billion plastic utensils are produced (Gautam & Caetano 2017). This vast industry specializes in uses for usually less than an hour, then discarded and take hundreds of years to perish. Finding an alternative to these utensils, which would diminish this decomposition time is of interest to reduce the environmental impacts of this massive industry.

WOOD

There is the potential for a possible substitute from many varieties of natural products which is easier on the environment. Wood is an abundant natural resource, which could provide a natural material to combat the amounts of plastic utensils (Gautam & Caetano 2017). The benefit of the single-use natural utensils is the short time frame of use. The durability of plastic is not required as the tool is not needed to last longer than for a meal (Gautam & Caetano 2017).

Wood is a commonly utilized material for many products. Wooden utensils would offer a competitive alternative that decomposes much quicker than plastics (Gautam & Caetano 2017). Attempts to create this kind of cutlery has been made before. Aspenware, originally for British Columbia, opened a production facility in Northern Ontario around 2013 (Ross 2013). These utensils were created with two pieces of veneer laminated together with an adhesive applied (Ross 2013). Research by Gautam & Caetano (2017) has been done on the possibility of natural alternatives, although they focus on options from tropical environments such as Areca nuts, Sal leaves, Coconut and banana fibres, and Coconut shells. With little research found on which species is the best fitted for single-use utensils, it is of interest to test which of the three species

(*Populus tremuloides*, *Betula papyrifera*, *Tilia americana*) in this experiment would be the best suited to be used for utensils.

The measure most important to determine which would have the least impact on the environment is the species ability to decompose quickly. Different species have different levels of resistance to decay (USDA 2002). No native wood species are entirely immune to different types of wood decay (Panshin & De Zeeuw 1980). The quicker the utensil is decomposed, the quicker the materials are returned to the earth (Schmidt 2006). Research has been completed (shown in table 1) on the resistance to decay of heartwood in different species (Panshin & De Zeeuw 1980, USDA 2002).

Table 1 The three-different species of interest are all classified as slightly or non-resistant.

Wood species	Decay resistance
Betula papyrifera	Slighty or non-resistant
Populus tremuloides	Slighty or non-resistant
Tilia americana	Slighty or non-resistant

Source: Panshin & De Zeeuw 1980

Sapwood is the part of the tree with the fewest tannins and chemicals (Panshin & De Zeeuw 1980). This part of the wood would be used to make the food grade utensils. Less information is known about the resistance of different species sapwood. One study found by Eslyn & Highley (1976) stated that sapwood in many hardwoods was found to be more susceptible to decay than softwood species. None of the species that are in this thesis was tested, however, all the hardwoods used were vulnerable to decay. The sapwood of all species is vulnerable to deterioration due to the lack of extractives in the wood compared to heartwood (Highley 1995, Panshin & De Zeeuw 1980). Wood rot comes in different varieties depending on the different species of fungi (Schmidt 2006).

FUNGI

Brown rot is caused when the fungus consumes the cellulose and the hemicellulose while the lignin remains untouched (Schmidt 2006, USDA 2002, Panshin & De Zeeuw 1980, Bowyer *et al.* 2007). These fungi affect the wood creating a brown or reddish colour (Bowyer *et al.* 2007). Brown rot fungi is less common than white rot in North America, only 7% of the species discussed in the book by Schmidt (2006) caused brown rot. This type of fungus is most commonly found on softwoods, although have been found on hardwoods as well (Panshin & De Zeeuw 1980). Two of the three fungi used in this thesis are brown rot-producing fungi. *Fomitopsis cajanderi*, and *Fomitopsis pinicola* both do not consume the lignin and produce brown rot (Phillips 2010).

White rot is the second type of decomposition by fungi. The cellulose, hemicellulose, and lignin are all consumed by the fungi (Schmidt 2006, USDA 2002, Panshin & De Zeeuw 1980, Bowyer *et al.* 2007, Eslyn & Highley 1976). This type of rot is more common than brown rot (Schmidt 2006). This rot tends to infest dead hardwood tissue the most and rarely infects conifers (Panshin & De Zeeuw 1980). The decay results in a white discoloration, which is characteristic of de-lignified cellulose (Bowyer *et al.* 2007, Schmidt 2006). In this experiment, only *Trametes pubescens* classifies as a white rot fungus (Phillips 2010).

All these species of fungi are classified as specific wood decaying fungi (Schmidt 2006). These three species are found in the natural environment, which is where the utensils would be discarded, and have the most detrimental impact on the environment.

SPECIES

Durability tests are done commonly on different wood species and products to determine how they will stand the tests of time while in use (Bower *et al.* 2007). Much of the research found was on wood that had been altered in some way to attempt to increase its acceptable time in service. Heat treated wood and pressure treated wood had much research investigating how durable different species were against specific fungi. For the interest of this study, there was some broad research discovered on the natural durability of untreated wood in the natural environment. Many of the sources had tables created to rank different species into resistant, moderately resistant, or non-resistant categories (Davis *et al.* 1994, Freschet *et al.* 2012, Eslyn *et al.* 1985, Highley 1995). All the research agreed that the three-species tested in this thesis, *Betula papyrifera*, *Tilia americana,* and *Populus tremuloides* were all ranked as being non-resistant to fungal decay as shown in table 1 (Panshin & De Zeeuw 1980, USDA 2002).

Untreated white birch has been studied to determine the evenness of the fungal decay resulting from different species of fungi (Davis *et al.* 1994). In their paper, Davis *et al*. (1994) found that the lignin and carbohydrate components were degraded evenly by the white rot species. One of the species of decay used was *Trametes versicolor* which is closely related to one of the species used in this experiment, *Trametes pubescens*. Out of the three fungi species used in the Davis *et al.* (1994) study, *Trametes versicolor* had the highest scale for weight loss for samples. It occasionally showed 84% weight loss while the other species showed 49% at the most (Davis *et al.* 1994). This is of interest as it uses the same weight loss measurement that is used in this thesis. There

were limited results found on the decay of white birch, however, a study by Freschet *et al.* (2012) investigated the decay properties of downy birch (*Betula pubescens*) compared with other tree species. These results provide a hint as to what is expected in the paper birch trials. One of the other species tested was *Populus tremula* which could also be compared to *Populus tremuloides*. It was found that both species had a negative linear relation when comparing wood relative density and time (Freschet *et al.* 2012). The birch trial showed the wood reached 50% density (the half-life) at 13 years. The poplar species was much quicker to reach the half-life as it only took eight and a half years (Freschet *et al.* 2012). This may point to the poplar decaying quicker than the birch meaning it could have less of an environmental impact.

One paper (Eslyn *et al.* 1985) found on basswood (*Tilia americana*) echoed the results found in the broad statements on decay found in Panshin & De Zeeuw (1980) and USDA (2002). Eslyn *et al.* (1985) tested the length of time that wood of different species could be used above ground before decay would compromise the lumber to be unusable. There were trial points set up in a few States with some tests failing in Wisconsin (Eslyn *et al.* 1985). This paper looked explicitly at fence posts, but the untreated nature of the wood is still quite useful. The decay vectors used in the study were brown-rot and white-rot fungi (Eslyn *et al.* 1985), although, they were different species than the ones used in this research. Both the sapwood and heartwood of basswood was found to have an average service life of only four years (Eslyn *et al.* 1985). This was ranked as the lowest species in a tie with sweetgum out of over ten species (Eslyn *et al.* 1985). There were no exact weight loss measurements made as it was just interested in the serviceability of the wood. For comparison sake, the study also

looked at species within the same genus as the other species of interest in this thesis. Eslyn *et al.* (1985) ranked *Populus balsamifera* and *Betula alleghaniensis* as part of the least resistant of the woods with service years all under seven years.

A follow-up research paper was published by Highley (1995), which reassessed the test plots that failed in Wisconsin by Eslyne *et al.* (1985). This colder climate increased the average service life for all species (Highley 1995). Basswood longevity increased to eight years for heartwood products and ten years for sapwood (Highley 1995). Basswood remained at the lowest end of the spectrum for serviceability (Highley 1995).

The last species, *Populus tremuloides*, has been researched, like basswood, for service uses. The paper by González *et al.* (2008) looks at the changes in decomposition rates of aspen stakes in different climates and forest types. These experiments were run in the natural environment for periods of four years (González *et al.* 2008). Tropical sites were found to be the best for encouraging decomposition; two years into the experiment, the aspen stakes had only, on average, four percent mass remaining (González *et al.* 2008). In boreal and temperate locations, the study found an average of 83 percent mass remaining after four years of decay (González *et al.* 2008). These results match with Panshin & De Zeeuw (1980) and USDA (2002) as listing *Populus tremuloides* as a species which is non-resistant to fungal deterioration.

SWELLING

Wood changes size and shape whilst water moves in and out of wood cell walls (Panshin & De Zeeuw 1980, USDA 2002) The fibre saturation point dictates the amount

of water that can be absorbed by a piece of wood (Panshin & De Zeeuw 1980). Once the fibre saturation point is reached, no more water can be absorbed by the piece of wood as the maximum amount of water is being held. Each different species displays different responses to moisture. This swelling in the wood increases the size of the piece of cutlery and could potentially alter the integrity of the glued laminate pieces. It is favourable to have a lower swelling potential in wood being used for utensils. Panshin and De Zeeuw (1980) note that the largest dimensional changes occur in wood during the first drying cycle. The difference in species affects the difference in water absorption levels (Schroeder 1971). Schroeder (1971) examines the changes in water absorption depending on different species. American basswood, paper birch, and trembling aspen (identified as quaking aspen by Schroeder) was included in the study. The results for weight loss due to drying are found on page 22 table 1 (Schroeder 1971). The volumetric shrinkage was found by drying a "green" sample (completely saturated) until the sample is completely dry. This was converted to a percentage to show the potential volume of water or swelling for each species. Schroeder (1971) found that paper birch had a volumetric shrinkage of 16.2%, American basswood being 15.8%, and trembling aspen having the lowest shrinkage/swelling at 11.5%. Another paper by Balatinecz & Kretschmann (2001) record a similar shrinkage/swelling value for poplar of 11-12%. Although these results suggest that trembling aspen may be best suited for utensil use based on the low absorption of water, Balatinecz & Kretschmann (2001) also talk about how poplar is commonly high in tension reaction wood. Tension wood commonly has high occurrence of fibres flicking up when wet which causes unappealing features if being used for utensils.

MATERIALS AND METHODS

WOOD PREPARATION

To begin the research, cubes of wood of each species had to be made. These cubes must be as close to $2cm^3$ as possible due to the standards set for this durability test (American Society for Testing and Materials 1993). These cubes were created with the assistance of Dr. Mathew Leitch in the Lakehead University Wood Science and Testing Facility (LUWSTF) workshop. First, logs of birch and poplar were milled with the LUWSTF portable mill into 2.5cm thick boards. Next, precise cuts were made in the LUWSTF workshop to get the cubes the correct size of $2cm^3$. The basswood samples were collected from southern Ontario. These samples were milled using a band saw to the most accurate of my abilities.

The durability test preformed on the cubes is a standardized test (four-month minimum experiment time, 120ml of vermiculite and 70ml of 2% malt extract broth is added to each bottle), which was completed with assistance from Dr. L. Hutchison in the Pathology Lab. The experimental design had 40 different trials per species, 120 trials in total. Three different wood decay fungi were inoculated on ten cubes of each species while ten cubes for each species were untouched to be used as controls.

The cubes were numbered one to 120 with a marker directly on the block. The 120 cubes were then placed in aluminum weigh boats corresponding with each of the numbers. The four trays of cubes were dried in an oven for three days at 100^oC to ensure a 0% moisture content. Once dried, the weight was taken of each cube to the closest milligram.

DURABILITY TEST

Isolates of *Fomitopsis cajanderi, Fomitopsis pinicola,* and *Trametes pubescens* were grown on petri dishes a couple weeks before the inoculation date to allow time to develop. The petri dishes were filled with 2% malt extract and were cultured in a controlled temperature of 20^{o}C. Before the blocks could be inoculated, 120 Quorpak bottles were prepared for the experiment. Each bottle was given a number one through 120. Next, each bottle got 120ml of vermiculite which was purchased from a local floral store. Each bottle then was filled with 70ml of 2% malt extract that was prepared by Dr. Hutchison. This malt promotes fungal growth while the vermiculite provides the nutrients the fungi need. Each cube was placed in the matching numbered Quorpak bottle and covered in the vermiculite. With the lids of the bottles put on loosely and covered in aluminum, the caps of the bottles were numbered once again to ensure a permanent label after the autoclave process. The bottles were put into the autoclave for one hour at 121^{o}C at 1.7kg/cm^{2} pressure (Figure 2).

On Friday November 2nd, 2018, the experiment was inoculated with each specific fungus. The work station is shown in figure 1. Sterilizing was a main priority during inoculation to ensure cross contamination of the samples was avoided. The transfer hood was wiped down with 70% alcohol for this reason. With supervision from Dr. Hutchison, plugs were carefully cut using a 7mm diameter cork-borer from the petri dishes containing the fungi. The cork borer was dipped in 70% alcohol, flamed and air cooled in-between uses on different petri dishes. According to the experimental design, each bottle was inoculated with the proper fungi. One at a time, each bottle opening was flamed under a Bunsen burner, then using sterile forceps, two fungi plugs were placed

directly beside the block of wood on either side with the mycelium facing the cube. The blocks were then covered by the vermiculite once again, the cap was tightened and the aluminum foil was placed around the top. When a change of fungus was needed, the whole work station was wiped down with 70% alcohol once again.

Figure 1 Set up for inoculation process with Bunsen burner, 70% alcohol for sterilization, fungi, and Quorpak bottles.

After inoculation was complete, the trials were placed in an incubator in the pathology lab for about four months.

Figure 2 Prepared Quorpak bottles being put into the autoclave.

On February 27th, 2019, the experiment was harvested. This involved removing each of the 120 cubes from the Quorpak bottles and getting a dry weight measurement. Each cube was carefully taken out of the vermiculite substance and many showed many signs of decay. Discoloration was common along with visible mycelium in the bottles (Figure 3) indicating that decay had taken place. When each block was extracted, the excess vermiculite and mycelium were scrapped off the trials to ensure just the wood was being weighed. This proved difficult to maintain precision as the different fungi acted differently and some needed more force to be removed while others made the wood very soggy and much care needed to be taken to not scrape away the wood by accident.

Figure 3 Visible mycelium in with a decaying sample.

The cubes were then placed in individually numbered weigh boats and returned to the drying oven. On March 1st, 2019, the dry weights of the decayed blocks were taken. With these difference in weights from the non-decayed blocks, statistical analysis was done to better understand the results.

SWELLING TEST

A wetting experiment was also conducted to test the amount of swelling that occurs in the different species. The 30 control blocks that were used in the decay test were also used for the swelling test. Each block was dried and weighed to the 10,000th of a gram. Next, each cube's volume was found by conducting a water displacement test. The cube was placed on the end of a pin and held under water level in a container on a scale. The scale provides measurements of grams, which is equivalent to the samples volume in cm^3. By taking the weight/volume, the dry density of the cubes was found. This process was repeated for each one of the control cubes for each species. Once all the dry data was complete, the 30 cubes were submerged in a container of

water and held underwater by a grate for about one week. The cubes saturated during the week by absorbing water into the wood fibres and cell walls. The same process of weighting the blocks and obtaining a volume and density was completed for the wet cubes. The results were compared between the dry and wet volumes to calculate a swelling % for each of the trials as well as the dry and wet density. Swelling was determined by the following equation:

Swelling, % = (change in dimension from dry size x 100)/dry dimension (Panshin and De Zeeuw 1980)

RESULTS

The results found from the durability, and swelling test will be presented in a variety of tables and figures. A summary table for each of the experiments is provided (tables 2 & 6) with the raw data shown in the Appendices. Also, the statistical significance of the results will be stated to show the validity of the results.

DURABILITY TEST

The combination that yielded the highest weight loss was *Betula papyrifera* being decayed by *Fomitopsis cajanderi.* This trial had an average weight loss of 24.012% over the ten trials. For each species, the *Fomitopsis cajanderi* proved to be the best fungi for decay of the sample. For both the *Fomitopsis* fungi, the *Betula papyrifera* had the most decay compared with the other two wood species. The *Trametes pubescens* was observed to have the most decay in the *Tilia americana* trials with an average of 11.29% decayed.

Table 2 Summary table of decay test showing average change in weights for each of the four trials for each of the species with % mass lost.

Tree Species	Fungus	October 22nd Average (g)	March 1st Average (g)	Average Percent Mass Loss (%)
Betula papyrifera	Control	4.405	4.449	0.972
	Fomitopsis cajanderi	4.292	3.260	**-24.012**
	Fomitopsis pinicola	4.414	3.740	-15.323
	Trametes pubescens	4.215	3.898	-7.548
Populus tremuloides	Control	3.471	3.508	1.077
	Fomitopsis cajanderi	3.281	2.386	**-27.030**
	Fomitopsis pinicola	3.381	2.738	-18.815
	Trametes pubescens	3.457	3.285	-4.891
Tilia americana	Control	4.030	4.004	-0.507
	Fomitopsis cajanderi	3.999	3.194	**-20.183**
	Fomitopsis pinicola	4.318	3.873	-10.168
	Trametes pubescens	4.244	3.765	-11.290

The statistical analysis for the decay tests were done using IBM SPSS software. A two-way anova was conducted along with a Tukey Post Hoc test to test for the significance of these results. Table 3 shows the results of the anova. A significance result of <0.05 proves significance. The only significant result is the difference in fungi, which has a close to zero significance value. The change in species and the species-fungi relationship show no statistically significant results. In table 4, the results of the post hoc Tukey test is shown. This test is done to further investigate the significance between different species relationships within a significant anova result. The significance values in Table 4 displays that between all three fungi and the control there is a significant statistical difference. The significant results in both table 3 and table 4 are highlighted and shown in bold.

Table 3 Results of a two-way anova done on the decomposition data.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	15.064[a]	11	1.369	15.785	0.000
Intercept	24.363	1	24.363	280.826	0.000
Species	0.125	2	0.063	0.722	0.488
Fungi	13.992	3	4.664	53.760	**0.000**
Species * Fungi	0.947	6	0.158	1.819	0.102
Error	9.370	108	0.087		
Total	48.796	120			
Corrected Total	24.433	119			

a. R Squared = .617 (Adjusted R Squared = .577)

Table 4 Results from Tukey post hoc test for significance between trials.

	(I) Fungi	(J) Fungi	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	cont	fomc	.92873*	0.076050	**0.000**	0.73028	1.12719
		fomp	.60550*	0.076050	**0.000**	0.40705	0.80395
		tram	.34077*	0.076050	**0.000**	0.14231	0.53922
	fomc	cont	-.92873*	0.076050	**0.000**	-1.12719	-0.73028
		fomp	-.32323*	0.076050	**0.000**	-0.52169	-0.12478
		tram	-.58797*	0.076050	**0.000**	-0.78642	-0.38951
	fomp	cont	-.60550*	0.076050	**0.000**	-0.80395	-0.40705
		fomc	.32323*	0.076050	**0.000**	0.12478	0.52169
		tram	-.26473*	0.076050	**0.004**	-0.46319	-0.06628
	tram	cont	-.34077*	0.076050	**0.000**	-0.53922	-0.14231
		fomc	.58797*	0.076050	**0.000**	0.38951	0.78642
		fomp	.26473*	0.076050	**0.004**	0.06628	0.46319

SWELLING TEST

The swelling test results are displayed in table 5. This summary shows that *Betula papyrifera* had the largest percentage of swelling at 16.36%. Although the

swelling % was highest, the moisture content was lowest. *Betula papyrifera* had the highest swelling with *Tilia americana* the second highest (14.1%), and *Populus tremuloides* swelled the least at only 12.92%. These results were reverse order when ranked by moisture content.

Table 5 Summary table of swelling test with dry and wet volumes, swelling, and moisture content averages for each of the three species.

Species	Dry volume average (cm3)	Wet volume average (cm3)	Swelling (%)	Moisture Content (%)
Betula papyrifera	8.16	9.47	16.36	106.54
Populus tremuloides	7.82	8.82	12.92	148.81
Tilia americana	7.24	8.27	14.10	120.07

The results of the anova deemed no significance in any of the swelling results (Table 6). The difference in species swelling had a significance of 0.107 which is much larger than the standard of 0.05 for significant results.

Table 6 Univariate two-way anova results to test significance for swelling data.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	130.895[a]	2	65.447	2.436	0.107
Intercept	6380.575	1	6380.575	237.444	0.000
Species	130.895	2	65.447	2.436	0.107
Error	725.542	27	26.872		
Total	7131.493	30			
Corrected Total	856.437	29			

a. R Squared = .153 (Adjusted R Squared = .090)

A Tukey post hoc test was also run to look for significance between trials (Table 7). It was not expected to have any of the trials to show statistical significance due to the species not being significant in the two-way anova (Table 6). The Tukey test confirmed

this with no combination of species showing significance. The closest was *Betula papyrifera and Populus tremuloides* which had an alpha of 0.091>0.05.

Table 7 Results of Tukey post hoc test to test significance between trials.

(I) Species		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
bw	pt	5.1034	2.32995	0.091	-0.6735	10.8803
	ta	3.3509	2.38180	0.352	-2.5545	9.2564
pt	bw	-5.1034	2.32995	0.091	-10.8803	0.6735
	ta	-1.7525	2.26497	0.722	-7.3683	3.8633
ta	bw	-3.3509	2.38180	0.352	-9.2564	2.5545
	pt	1.7525	2.26497	0.722	-3.8633	7.3683

Based on observed means.
The error term is Mean Square(Error) = 26.872.

DISCUSSION

The objective of this thesis was to suggest the best alternative to single use plastic utensils from three species options. The goal was that the decay test would show a clear advantage for one of the species which would decay much faster than any of the others. The swelling test was then going to be used as a second measure to hopefully reinforce this selection. Unfortunately, no statistical significance was shown between any of the tree species (Table 3). Due to the lack of significance, the confidence in the suggested species drops below the 95% confidence threshold. This means the difference between species is lower and there is not a clear winner in either the decay or the swelling tests. This leads to the need for other factors to determine which species is superior for cutlery.

Depending on the fungus decaying the wood, the best wood species changed. *Betula papyrifera* shows the most decay (Table 2). These blocks that were decayed by *Fomitopsis cajanderi* were decayed close to a quarter of their weight on average. This large amount of decay shows the potential for birch decay to occur quickly and efficiently over short periods of time such as in this experiment (four months). Birch is denser than basswood (Wisconsin Department of Natural Resources 2017) or poplar (Balatinecz & Kretschmann 2001), but still not dense compared to many hardwoods (Davis *et al.* 1994) which makes it a quick decaying material because it is easy for the mycelium to infiltrate the cells. This relatively low density is a feature of all three of the species which is why they were selected for this trial (Wisconsin Department of Natural Resources 2017, Balatinecz & Kretschmann 2001, Davis *et al.* 1994). Birch also does not have many extractives in the wood which is known to slow down decay (Panshin &

De Zeeuw 1980). Due to these good decay properties, and the results showing that birch decayed the quickest, based on this thesis, birch would be the species that would have the lowest impact on the environment as it would be decayed the quickest.

The hypothesis of the thesis was inconclusive. The birch, as hypothesized decayed the quickest. However, because the statistical analysis showed no significant difference between wood species, the conclusions cannot be made with a 95% confidence. Therefore, the hypothesis cannot be confirmed.

However, birch showed the highest amount of swelling when submerged in water for one week. This could be a negative when used as a utensil material. Most utensils are two pieces of thin veneer pressed together with glue to make the cutlery (Ross 2013). This swelling in the birch could affect the bond between the two pieces of wood. The swelling alters the shape of the wood (Panshin & De Zeeuw 1980). The results match with what Schroeder (1971) found. The swelling percentages were comparable values and both studies ranked the three species the same. *Betula papyrifera* at 16.2% (Schroeder 1971) – 16.36% (Table 5). *Tilia americana* at 15.8% (Schroeder 1971) – 14.10% (Table 5). Finally, *Populus tremuloides* at 11.5% (Schroeder 1971) – 12.92% (Table 5). For this reason, the wood with the least amount of swelling would be beneficial for cutlery use. Although, utensils are typically made with an edible adhesive coating that limits the amount of water contact with the wood (Ross 2013). Along with the short duration of use for single use utensils, the amount of swelling occurring in the wood should not be an issue.

The Freschet *et al*. (2012) study suggested that *Populus* may be the quickest decomposer which was incorrect in this study as each of the fungal species showed more

decomposition occurring in the *Betula papyrifera* trials than the *Populus tremuloides* (Table 2). Birch was ranked best for decay but worst for swelling. With both tests showing insignificance, we are unable to draw conclusions from this thesis. No significant findings in the difference species does not mean nothing was of interest from the results. The one significantly different set of data was the difference in decay between the three different fungi.

The fungal decay was the only significant result found. The fungi that showed the superior decay was *Fomitopsis cajanderi*. Even just a visual inspection of the decayed blocks (Figure 4), lots of decay had occurred on these blocks compared to the rest of the trials. Davies *et al*. (1994) found staggering results for a decay fungus in the same family as *Trametes pubescens* with decay rates listed as 84%. This is a large difference from the results in this thesis for *Trametes pubescens* which highest decay value was 11.29%. However, the *Fomitopsis cajanderi – Betula papyrifera,* and *Trametes pubescens* results found in this thesis are difficult to compare with the study by Davis *et al*. (1994) because of the vastly different time frames. This study was only about four months while the Davis study was up to 13 years.

Figure 4 *Populus tremuloides* trial block decayed by *Fomitopsis cajanderi*.

Even though this result was not of necessary interest in the objective of the thesis, it is still a fascinating result. The characteristics of *Fomitopsis cajanderi*, as a brown rot, say that this fungus almost exclusively establishes on dead conifer wood (Panshin & De Zeeuw 1980, Phillips 2010). The outcome that this fungus would out decay the likes of white rot fungi such as *Trametes pubescens* was unexpected due to white rot commonly infecting dead hardwood (Panshin & De Zeeuw 1980). This contrasting result could be due to the decomposing conditions made available due to being in a laboratory setting (Calisi & Bentley 2009). In this experiment, the conditions were ideal for the fungi with plenty of nutrition from the vermiculite and fungal growth encouraging 2 % malt extract. In addition, the fungi did not need to compete with other species or bacteria in the experiment setting, which could be a reason that *Fomitopsis cajanderi* is found only on conifers Panshin & De Zeeuw (1980) and Phillips (2010) note that brown rot does not consume the lignin of the wood which causes the brown rot. This fungus could be a weak competitor and must grow on dead conifers. These laboratory conditions could be unattainable in the natural environment which could be

why this species of fungus is typically not found on hardwoods and are more specialized for conifers.

This information is important to understand these different fungi and having a better understanding of their potential for decay when given the correct conditions. The results found in this thesis could be useful for understanding a quicker way to decay wood. Understanding that *Fomitopsis cajanderi* can decay hardwoods makes it a versatile decomposer. These results offer a better understanding of the capabilities of this brown rot fungi which is uncommon to be found on hardwood tissue (Panshin & De Zeeuw 1980). More research would be valuable in discovering the potentials for this adaptable wood decay fungi.

This plastic problem is not going away and alternatives need to be found for the benefit of the environment (Geyer *et al.* 2017). This is an important issue that wood could offer a possible alternative. Based on the results presented in this thesis, any of the three-species tested could be used as a material for a natural utensil, which would decompose much faster than any plastic. More research in the future would be very beneficial in figuring out the best species to use. Looking at the fibre characteristics would be useful to see because for utensils the wood which has the least amount of raised fibres would have the least amount of chance for slivers. Poplar is known to have a high amount of tension wood (Balatinecz & Kretschmann 2001). Trends show that faster growing species usually have higher quantities of tension wood due to the need for added stability with the fast growth (Wisconsin Department of Natural Resources 2017). Along with *Populus tremuloides, and Tilia americana* have a very quick growth rate which results in a large amount of tension wood present (Wisconsin Department of

Natural Resources 2017). *Betula papyrifera* shows quick growth rate but remains dense compared to the other two species with less tension wood present (Green *et al.* 1999 & Panshin and De Zeeuw 1980).

Tension wood is characteristic of being more sensitive to moisture and shrink and swelling (Green *et al.* 1999). The fibres flick up when exposed to moisture (Green *et al.* 1999). The fast growth characteristics, creates lots of fibres that do not lie flat when moistened (Panshin & De Zeeuw 1980). This high amount of fibre flick (Balatinecz & Kretschmann 2001) would be unappealing for a potential alternative for utensils as this would make the cutlery not smooth.

Other factors such as a cost analysis for the different species and availability close to a potential production plant would be valuable once a company is serious about bringing this plan to fruition.

Additionally, if this experiment had run for a longer period, it is expected that there would be the possibility of significant results between the species of wood with more decay occurring. For example, in the study by Davies *et al*. (1994) which found much higher decay rates reaching up to 84% over the 13-year period.

Since the decay and swelling tests turned out to be insignificant, this lack of difference raises the question of other factors that could distinguish which species is superior for utensils. More research is needed into these factors but one of the main differences is the wood fibres which seem to have lots of tension wood and high fibre flick in *Populus tremuloides* and *Tilia americana* and less in *Betula papyrifera (*Balatinecz & Kretschmann 2001 & Green *et al*. 1999). This is the area which new

research would really be beneficial to show potential statistical significant separation between the species to be able to confirm or reject the hypothesis.

CONCLUSION

Environmentally conscious decisions are more and more common these days as the effects that anthropogenic activities are having on the planet are becoming more visible. Society is noticing these changes and documenting them well, like the change in the climate around the globe. The potential to reduce the effects of this harmful anthropogenic activity by changing single use utensils to a natural material offers a huge opportunity to reduce the impact this massive industry has on the environment. This thesis looked at finding the best alternative to these plastic utensils out of *Betula papyrifera, Populus tremuloides,* and *Tilia americana.* Through a durability test and a swelling test, the three-species were ranked in both categories. No statistical significance was found for either of the two experiments. Although, by looking at the data of the decay test (table 2), *Betula papyrifera* looks like it would have the least amount of impact on the environment due to its quick decay time. More research would need to be completed to confirm this hypothesis with statistically significant results.

The different fungi trials were found to be statistically significant with *Fomitopsis cajanderi* decaying the wood cubes the quickest. This is of interest as this fungus is typically never found on hardwood species in the natural environment but in the laboratory, it outcompeted hardwood specialists. More research is needed to understand this occurrence. This could suggest that this fungus could be utilized as a versatile decomposer for a variety of wood species. One major question that this thesis

has uncovered is if would be viable to use this fungus to speed up the decomposition of wooden utensils in a type of utensil compost project.

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APPENDICES

APPENDIX I – Dry and decayed weights of the three tested wood species.

Trial number	Species	Fungi Species	Dry weight (October 22nd)	Decayed weight (March 1st)	diff
1	Bw	Control	4.180	4.215	0.035
2	Bw	Control	4.714	4.755	0.041
3	Bw	Control	4.499	4.547	0.048
4	Bw	Control	4.195	4.218	0.023
5	Bw	Control	4.172	4.203	0.031
6	Bw	Control	4.438	4.463	0.025
7	Bw	Control	4.152	4.177	0.025
8	Bw	Control	4.526	4.591	0.065
9	Bw	Control	4.785	4.894	0.109
10	Bw	Control	4.388	4.422	0.034
11	Bw	*Fomitopsis cajanderi*	4.181	2.72	-1.461
12	Bw	*Fomitopsis cajanderi*	4.242	3.533	-0.709
13	Bw	*Fomitopsis cajanderi*	4.546	3.545	-1.001
14	Bw	*Fomitopsis cajanderi*	4.475	3.481	-0.994
15	Bw	*Fomitopsis cajanderi*	4.229	2.615	-1.614
16	Bw	*Fomitopsis cajanderi*	4.314	3.368	-0.946
17	Bw	*Fomitopsis cajanderi*	4.024	3.394	-0.630
18	Bw	*Fomitopsis cajanderi*	4.295	3.224	-1.071
19	Bw	*Fomitopsis cajanderi*	4.124	3.426	-0.698
20	Bw	*Fomitopsis cajanderi*	4.489	3.294	-1.195
21	Bw	*Fomitopsis pinicola*	3.980	3.333	-0.647
22	Bw	*Fomitopsis pinicola*	4.744	4.191	-0.553
23	Bw	*Fomitopsis pinicola*	4.227	3.719	-0.508
24	Bw	*Fomitopsis pinicola*	4.437	3.572	-0.865
25	Bw	*Fomitopsis pinicola*	4.460	3.344	-1.116
26	Bw	*Fomitopsis pinicola*	4.294	3.226	-1.068
27	Bw	*Fomitopsis pinicola*	4.413	3.659	-0.754
28	Bw	*Fomitopsis pinicola*	4.994	4.618	-0.376
29	Bw	*Fomitopsis pinicola*	4.020	3.795	-0.225
30	Bw	*Fomitopsis pinicola*	4.569	3.943	-0.626
31	Bw	*Trametes pubescens*	4.337	3.837	-0.500
32	Bw	*Trametes pubescens*	4.111	3.798	-0.313
33	Bw	*Trametes pubescens*	4.163	3.77	-0.393
34	Bw	*Trametes pubescens*	3.964	3.54	-0.424
35	Bw	*Trametes pubescens*	3.890	3.588	-0.302
36	Bw	*Trametes pubescens*	4.562	4.211	-0.351
37	Bw	*Trametes pubescens*	4.047	3.874	-0.173

38	Bw	*Trametes pubescens*	4.311	4.082	-0.229
39	Bw	*Trametes pubescens*	4.527	4.353	-0.174
40	Bw	*Trametes pubescens*	4.239	3.929	-0.310
41	Pt	Control	3.496	3.539	0.043
42	Pt	Control	3.080	3.142	0.062
43	Pt	Control	3.558	3.585	0.027
44	Pt	Control	3.524	3.599	0.075
45	Pt	Control	3.461	3.516	0.055
46	Pt	Control	3.524	3.574	0.050
47	Pt	Control	3.659	3.662	0.003
48	Pt	Control	3.266	3.267	0.001
49	Pt	Control	3.591	3.596	0.005
50	Pt	Control	3.552	3.601	0.049
51	Pt	*Fomitopsis cajanderi*	3.370	2.831	-0.539
52	Pt	*Fomitopsis cajanderi*	3.181	2.879	-0.302
53	Pt	*Fomitopsis cajanderi*	3.151	2.89	-0.261
54	Pt	*Fomitopsis cajanderi*	3.121	2.665	-0.456
55	Pt	*Fomitopsis cajanderi*	3.537	1.374	-2.163
56	Pt	*Fomitopsis cajanderi*	3.244	1.247	-1.997
57	Pt	*Fomitopsis cajanderi*	3.335	2.577	-0.758
58	Pt	*Fomitopsis cajanderi*	3.112	1.958	-1.154
59	Pt	*Fomitopsis cajanderi*	3.472	3.02	-0.452
60	Pt	*Fomitopsis cajanderi*	3.291	2.423	-0.868
61	Pt	*Fomitopsis pinicola*	3.373	3.019	-0.354
62	Pt	*Fomitopsis pinicola*	3.331	2.804	-0.527
63	Pt	*Fomitopsis pinicola*	3.404	2.813	-0.591
64	Pt	*Fomitopsis pinicola*	3.354	2.561	-0.793
65	Pt	*Fomitopsis pinicola*	3.418	2.495	-0.923
66	Pt	*Fomitopsis pinicola*	3.544	2.434	-1.110
67	Pt	*Fomitopsis pinicola*	3.226	2.796	-0.430
68	Pt	*Fomitopsis pinicola*	3.220	3.013	-0.207
69	Pt	*Fomitopsis pinicola*	3.381	2.96	-0.421
70	Pt	*Fomitopsis pinicola*	3.558	2.48	-1.078
71	Pt	*Trametes pubescens*	3.712	3.416	-0.296
72	Pt	*Trametes pubescens*	3.638	3.2	-0.438
73	Pt	*Trametes pubescens*	3.446	3.424	-0.022
74	Pt	*Trametes pubescens*	3.554	3.549	-0.005
75	Pt	*Trametes pubescens*	3.290	3.293	0.003
76	Pt	*Trametes pubescens*	3.345	3.317	-0.028
77	Pt	*Trametes pubescens*	3.326	3.199	-0.127
78	Pt	*Trametes pubescens*	3.440	3.034	-0.406
79	Pt	*Trametes pubescens*	3.405	3.284	-0.121
80	Pt	*Trametes pubescens*	3.414	3.134	-0.280
81	Ta	Control	3.644	3.596	-0.048

82	Ta	Control	4.900	4.833	-0.067
83	Ta	Control	4.787	4.755	-0.032
84	Ta	Control	3.237	3.258	0.021
85	Ta	Control	4.191	4.146	-0.045
86	Ta	Control	4.854	4.805	-0.049
87	Ta	Control	2.871	2.893	0.022
88	Ta	Control	2.842	2.868	0.026
89	Ta	Control	4.277	4.242	-0.035
90	Ta	Control	4.699	4.645	-0.054
91	Ta	*Fomitopsis cajanderi*	3.851	3.237	-0.614
92	Ta	*Fomitopsis cajanderi*	4.518	3.705	-0.813
93	Ta	*Fomitopsis cajanderi*	3.126	2.538	-0.588
94	Ta	*Fomitopsis cajanderi*	4.496	3.39	-1.106
95	Ta	*Fomitopsis cajanderi*	3.324	2.68	-0.644
96	Ta	*Fomitopsis cajanderi*	3.927	3.338	-0.589
97	Ta	*Fomitopsis cajanderi*	4.155	3.07	-1.085
98	Ta	*Fomitopsis cajanderi*	4.141	3.424	-0.717
99	Ta	*Fomitopsis cajanderi*	3.665	2.548	-1.117
100	Ta	*Fomitopsis cajanderi*	4.784	4.009	-0.775
101	Ta	*Fomitopsis pinicola*	4.127	3.886	-0.241
102	Ta	*Fomitopsis pinicola*	4.502	3.9	-0.602
103	Ta	*Fomitopsis pinicola*	4.411	3.406	-1.005
104	Ta	*Fomitopsis pinicola*	3.215	2.983	-0.232
105	Ta	*Fomitopsis pinicola*	4.152	3.907	-0.245
106	Ta	*Fomitopsis pinicola*	3.919	3.635	-0.284
107	Ta	*Fomitopsis pinicola*	4.513	3.714	-0.799
108	Ta	*Fomitopsis pinicola*	4.849	4.541	-0.308
109	Ta	*Fomitopsis pinicola*	4.298	4.006	-0.292
110	Ta	*Fomitopsis pinicola*	5.196	4.756	-0.440
111	Ta	*Trametes pubescens*	4.286	2.858	-1.428
112	Ta	*Trametes pubescens*	4.062	3.432	-0.630
113	Ta	*Trametes pubescens*	2.977	2.738	-0.239
114	Ta	*Trametes pubescens*	4.449	4.176	-0.273
115	Ta	*Trametes pubescens*	4.326	3.893	-0.433
116	Ta	*Trametes pubescens*	4.591	4.037	-0.554
117	Ta	*Trametes pubescens*	4.521	4.241	-0.280
118	Ta	*Trametes pubescens*	4.984	4.593	-0.391
119	Ta	*Trametes pubescens*	4.734	4.436	-0.298
120	Ta	*Trametes pubescens*	3.509	3.246	-0.263

APPENDIX II –Raw data for the swelling test.

Species ID	Species	dry weight (grams)	dry vol. (cm3)	dry density (g/cm3)	wet weight (grams)	wet vol. (cm3)	wet density (g/cm3)	Swelling% (%)	MC wet %
1	Bw	4.086	8.05	0.508	8.521	9.31	0.915	15.652	108.547
2	Bw	4.385	8.74	0.502	9.096	10.02	0.908	14.645	107.439
3	Bw	3.861	7.48	0.516	7.354	7.97	0.923	6.551	90.476
4	Bw	4.125	7.78	0.530	8.478	9.38	0.904	20.566	105.505
5	Bw	3.540	6.93	0.511	8.764	9.61	0.912	38.672	147.531
6	Bw	4.416	8.69	0.508	9.294	9.93	0.936	14.269	110.451
7	Bw	4.190	8.2	0.511	8.737	9.39	0.930	14.512	108.503
8	Bw	4.511	8.74	0.516	9.350	10.38	0.901	18.764	107.271
9	Bw	4.487	8.64	0.519	9.190	9.8	0.938	13.426	104.816
10	Bw	4.376	8.36	0.523	7.919	8.91	0.889	6.579	80.956
AVERAGE		**4.198**	**8.161**	**0.514**	**8.670**	**9.47**	**0.916**	**16.364**	**106.542**
41	Pt	3.471	7.96	0.436	8.302	8.9	0.933	11.809	139.158
42	Pt	2.634	6.43	0.410	6.812	7.43	0.917	15.552	158.595
43	Pt	3.510	8.49	0.413	8.867	9.53	0.930	12.250	152.657
44	Pt	3.447	8.27	0.417	8.871	9.3	0.954	12.455	157.324
45	Pt	3.164	7.65	0.414	8.084	8.69	0.930	13.595	155.467
46	Pt	3.291	7.91	0.416	8.073	9.13	0.884	15.424	145.289
47	Pt	3.424	8.05	0.425	8.314	8.93	0.931	10.932	142.838
48	Pt	3.185	7.64	0.417	8.181	8.74	0.936	14.398	156.894
49	Pt	3.315	7.91	0.419	8.135	8.79	0.925	11.125	145.370
50	Pt	3.383	7.86	0.430	8.034	8.78	0.915	11.705	137.445
AVERAGE		**3.282**	**7.817**	**0.420**	**8.167**	**8.822**	**0.926**	**12.924**	**148.811**

81	Ta	3.166	6.97	0.454	7.258	7.81	0.929	12.052	129.243
82	Ta	4.496	8	0.562	9.204	9.27	0.993	15.875	104.706
83	Ta	4.312	7.67	0.562	9.108	9.05	1.006	17.992	111.227
84	Ta	2.933	7.23	0.406	7.446	8.15	0.914	12.725	153.858
85	Ta	3.744	7.35	0.509	8.080	8.39	0.963	14.150	115.789
86	Ta	4.481	7.85	0.571	8.870	8.94	0.992	13.885	97.965
87	Ta	2.537	6.42	0.395	6.559	7.3	0.898	13.707	158.494
88	Ta	2.464	6.57	0.375	6.543	7.29	0.897	10.959	165.521
89	Ta	3.786	6.74	0.562	7.943	7.71	1.030	14.392	109.832
90	Ta	4.343	7.6	0.571	8.792	8.76	1.004	15.263	102.448
AVERAGE		**3.626**	**7.24**	**0.497**	**7.980**	**8.267**	**0.963**	**14.100**	**120.071**