NEW PROTOCOL FOR SPECIES MIX TESTING IN RETAIL MULCH SAMPLES

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Abstract. Many millions of bags of mulch are sold at retail in the United States each year. Most mulch products claim to be of a certain species, with cypress being perhaps the most widely marketed. Unfortunately, it is practically impossible for the average consumer to know with certainty whether a product is indeed the species listed on the packaging. Claims of misleading behavior by some producers raise the question of whether species mix should be more closely monitored. Regulators charged with ensuring fair competition and consumer welfare, however, do not have an accurate means to determine species content. It would be difficult, if not impossible, to determine the species mix for 100% of the wood particles in a package of mulch because of the inability to identify species of the smallest particles, and the impracticality of 100% sampling in the intended use. We propose and develop a new method to allow analysts to estimate the percentage of a given species in samples of mulch, with a focus on cypress. This case study illustrates our methods and highlights the challenges in accurately determining species mix in this type of wood product. We purchased and tested 10 bags of cypress mulch obtained from six different states. Results indicate that one producer was filling some bags with only 50% cypress and others with no cypress. Consumers may therefore suffer as they receive a lower valued species, whereas honest competitors are also harmed. The wood science community could help regulators and consumers by developing a method by which small particles of wood could be positively identified as to species. Improved methods for species identification are relevant for a wide variety of purposes ranging from identifying consumer products to upholding the US Lacey Act.

Keywords: Mulch, species mix, cypress, regulators.

INTRODUCTION

Mulch is one of the many wood-based products that are sold in large quantities via retail outlets. Consumers buy bags of prepackaged mulch in a variety of forms ranging from hardwood bark nuggets to colored wood. Some mulch products claim to be of a certain species, with cypress being perhaps the most widely marketed. Unfortunately, some of the largest mulch manufacturers have been accused of fraudulent behavior with respect to species mix, and it is difficult, if not impossible, for consumers to know with certainty whether the product is indeed the species listed on the packaging.

Regulators at federal and local levels also have difficulty determining whether a mulch product contains the species as stated on the packaging. The Federal Trade Commission (FTC), for example, is charged with oversight of marketing materials and retail packaging claims. State "weights and measures" departments have authority over consumer products from a physical measurement perspective (ie does the package contain the exact amount stated).

Correspondence with the FTC and multiple Weights and Measures units determined that

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although species mix claims are often viewed with suspicion, those regulators have no practical, scientific means by which to determine whether a mulch product contains the stated species. Other regulators, such as those charged with enforcing the Lacey Act, must also determine species of wood products they are investigating (Wang et al 2010). Regulators and industry participants in search of greater transparency in the timber trade, for example, have choices ranging from wood anatomical analysis to DNA barcoding to determine species and origin (Lowe et al 2016). However, there appear to be no practical means for determining species mix with small particle sizes such as those seen in mulch. The economic feasibility of conducting expensive tests such as isotopic analysis (eg Kagawa and Leavitt 2010) would also seem to be a barrier for low-value products such as mulch.

The primary problem is simply one of determining and collecting a proper statistical sample of the mulch mixture, assuming some percentage of the mix can in fact be properly identified. Whereas larger particles may show some unique, identifiable characteristic specific to a particular species, smaller particles may not. In addition, each package of mulch product contains perhaps tens of thousands of particles, of which multiple species could make up the mixture. Product standards specify that for a mulch to be identified and branded as a species-specific mulch mix, at least 51% of the contents of each bag must be of the branded species. Therefore, the certifying agency must have a methodology to collect and identify a statistically significant sample size from a population-representative number of bags to make an accurate appraisal of species compliance.

Our goal with this project was 2-fold: first, to look for evidence of species discrepancies in cypress mulch and then to determine whether species mix could be accurately estimated in retail packages of mulch. Because no known tests were available, we developed a new, unique means to test species mix in a wood product containing multiple species and a wide variety of particle sizes. The purpose of this study was to detail those methods and discuss limitations in testing species mix of

mulch products sold at retail to consumers. We use cypress mulch as a case study to illustrate our methods and to highlight the challenges in accurately determining species mix in this type of wood product.

Mulch Background

Homeowners and professionals apply mulch to landscaping for benefits ranging from better water efficiency to promotion of plant growth (Gruda 2008). Mulch sold at retail is a large industry with estimated US sales of one billion dollars. Mulch producers are significant users of "waste" wood (Falk 1997) that may come from, for example, mill residue (eg Keegan et al 1999; Murphy et al 2007; Elser and Michael 2018) or even urban areas (Lyon and Bond 2014). Most mulch sold at retail is packaged in 2-cubic foot bags; these products are distinguished from bulk mulch sales that are often purchased by the cubic yard and were not considered in this study.

There are a number of large, national mulch brands sold in retail chains such as Lowe's and Home Depot. Many other brands are sold as "private label" products in which the mulch producer contracts with a retail chain to produce the product and place it in packaging unique to that retailer.

Cypress. Cypress wood is generally considered highly resistant to decay, making it valuable for a multitude of uses (Bowers and Melhuish 1988). Cypress has become a popular species for landscaping mulch because of these characteristics, although clear-cutting of southern US swamp lands where cypress grows can be problematic from an ecosystem perspective (Ewel et al 1989). Southern US states such as Louisiana have large quantities of cypress that can be used for mulch or even as biomass feedstocks (Sharma et al 2017).

It is noteworthy that cypress is promoted by the mulch industry as being superior to other wood species. Cypress is more expensive to procure than other species (eg southern pines), so manufacturers may have an economic incentive to replace some percentage of mulch mix with cheaper, more abundant species. If mulch producers are including

at least some noncypress species in all their products, then this deceptive practice would result in greater profits, while also harming the consumer. These practices would also seem to be a form of unfair competition in that they harm the "honest" producers that do not follow deceptive practices, while also causing diminution in consumer views and goodwill of true cypress mulch.

Legal issues. Numerous mulch producers have been accused of fraudulently misrepresenting the amount of mulch sold in each of the bags. Other legal claims against producers include violation of Consumer Fraud and Deceptive Trade Practices Acts of the various states. Large retailers that sell bagged mulch products have also been charged with similar violations. State-level Weights and Measures departments tasked with oversight of volumetric measurement of mulch products sold to consumers have issued many "stop sale" orders against mulch producers.

No known legal proceedings, however, have been brought against a company for misrepresenting the species mix included in bags of mulch; we believe this is in large part because of the lack of a species mix testing protocol.

Current mulch testing protocol. National Institute of Standards and Technology (NIST) Handbook 133, "Checking the net contents of packaged goods", is the acknowledged "procedural guide for the compliance testing of net content statements on packaged goods." Government regulators (eg Weights and Measures staff) depend on the handbook to provide specific protocols for testing of packaged products of liquids, gases, and even food products. Wood-based products in the handbook include firewood, paper plates, and mulch. However, NIST Handbook 133 does not provide a protocol to address species mix, so we therefore had to develop our own methods.

METHODOLOGY

As stated previously, there was no known published methodology for sorting a wood-based product such as mulch that comprises various particle sizes for the purpose of determining species mix (ie what percentage of the product is made up of any given species). Because we assumed it would be infeasible to identify the small, sawdust size particles, we needed a method that would allow for extrapolation of sampled content to the entire bag of mulch. We tested various methods and eventually determined that the following methodology would be appropriate for the sortation process.

Weight Determination by Particle Size

An accurate and reliable sortation procedure is necessary to sort the contents of a bag of mulch into various particle sizes. Some of those particle sizes would be large enough to identify using typical wood identification procedures, but some percentage is always too small to identify. Only by having knowledge of weights and percentages of the various particle sizes could we hope to extrapolate from a sampling of particles to the entire bag.

The separator device we used is designed and built to meet the ANSI/ASAE standard S424 (ANSI 2017; Lammers et al 1996). The separator machine has five screening trays with progressively smaller holes. The largest particles stay on top (screen #1) and the smallest drop to the bottom pan (6th level) as the machine shakes. The operator loads the top of the machine with mulch from a 2-cubic foot retail bag, then turns on the separator for 2 min as per the ANSI standard. The mechanics of the machine cause all trays to shake, thus causing particles to drop down through the various levels until they can no longer pass through a screen. Screen hole size was as follows: screen #1 = 19 mm, screen #2 = 12.7 mm, screen #3 = 6.3 mm, screen #4 = 3.96 mm, and screen #5 = 1.17 mm. Particles captured on each tray after a separator run were placed in different plastic bags so that their contents could be weighed.

Species Determination and Extrapolation

Two technical issues now faced our efforts. First, a method of identifying a representative number of particles had to be established and confirmed.

Second, some feasible determination of minimum sample size to extrapolate species composition to the entire bag of mulch had to be developed.

Species determination. For visual identification of wood species, a transverse view, or cross-section of the wood particle, provides the most reliable source of unique features. Hoadley (1990) discusses the relative value of examining wood specimens with a hand lens, and the additional value and ease of preparing microscopic sections for more precise identification of the species. However, given that for this particular identification task of validating species mix, the number of required identifications is much higher than the usual wood identification task, a quicker and more practical technique is needed.

Hand lens identification of the particles from the #1 and #2 screens was possible for the largest of the particles, but it was very much hit-or-miss depending on each particle's dimension. Particles from the smaller screen sizes were not identifiable with a hand lens.

It was discovered that with slight preparation of particles on a bench sander, the transverse surface of most particles from screen sizes 1-4 could be "cleaned up" for examination under a microscope (Fig 1). This preparation consisted of holding the transverse surface of each particle perpendicular
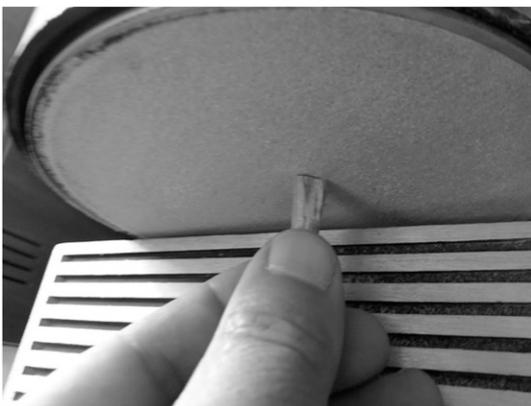

Figure 1. Technique for transverse surface preparation of mulch particle for identification.

to the sanding disk surface and slightly touching the surface to the rotating sander disk. The resulting particle surface could then be analyzed for rudimentary identification under a microscope equipped with digital image capture and zoom.

This type of species identification is generally most successful at a genera level; it is most likely not effective at a species level. However, for this particular certification task, mulch products are marketed as a genus-specific product; therefore, it is necessary only to determine individual particles at the genus level in most cases. For the case in question, it was necessary to determine whether a particular mulch product had a certain percentage of "cypress" (assumed to mean *Taxodium distichum*, bald cypress) as opposed to any other type of wood.

The concept of identifying a unique genera from all others, as is the case in a "branded" product, somewhat simplifies the sampling problem. In cases like this, all that must be determined is what percentage of the product mix, by weight, comprises one particular species as opposed to all others. Therefore, often a single unique identifying factor, combined with other situational circumstances, will allow for the proper determination.

For example, we examined one bag of mulch purchased from a retailer in Austin, TX. We knew that *T. distichum* is a softwood characterized by a lack of resin canals (Fig 2) (Thomas 1972). The only other species of softwood with this distinguishing characteristic in the geographic region of Texas is eastern red cedar, *Juniperus virginiana*. *J. virginiana* has a distinctly different color and odor compared with *T. distichum*, and it was easily determined that no cedar was present in the mulch mixture. Much of the mix did contain softwood of similar color; however, under the microscope, resin canals were easily seen in these alternative particles (Fig 3). Our investigation was then simplified to examining a representative sample, separating those with resin canals from those without, and making the proper calculations to determine an estimate of percentages of each in the bag sampled.
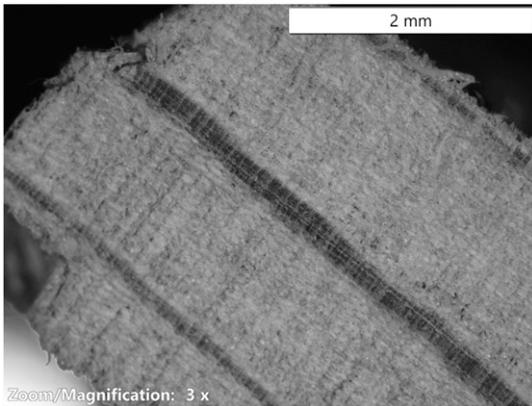
Figure 2. Particle identified as bald cypress, *Taxodium distichum*, by presence of an abrupt earlywood/latewood transition, coarse texture, and lack of resin canals.

This process proved effective, and we were able to sample, prepare, and identify several hundred specimens per bag in a relatively short period of time, typically about 1 d.

RESULTS

We initially tested 10 bags of a nationally distributed branded cypress mulch product, obtained from six different states, in our wood anatomy laboratory to establish our methodology for further quantification. Examination of the largest wood pieces suggested that all bags contained at
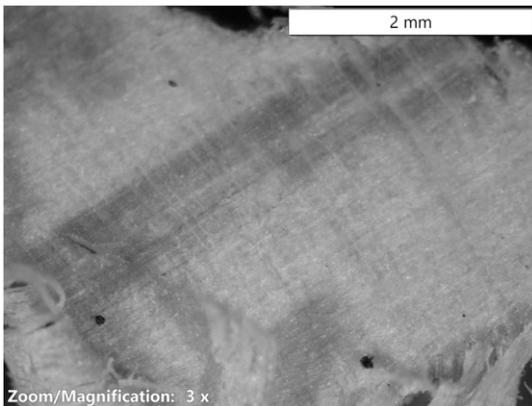

Figure 3. Particle identified as noncypress, probably a species of *Pinus*, by the presence of resin canals and more gradual transition of earlywood to latewood.

least some noncypress species. We applied our in-depth testing procedure to two of the bags and found that one of the bags, purchased in Austin, TX, contained roughly 50% cypress, with the remainder being lower valued pine. A bag purchased in Laredo, TX, contained no cypress, despite being labeled as cypress mulch.

Results for the Austin mulch sample are shown in Tables 1 and 2 to illustrate the methodology. Table 1 contains the results of subjecting the entire contents of the bag to the screening procedure, by five equal-sized "runs" of the material to allow for efficient screening. The actual mulch weights were then used to calculate the percentage weights by screen size for calculations at the next step. For this bag of mulch, 51.6% of the sample was screen sizes 1 and 2, 31.0% was screen sizes 3 and 4, and 17.3% was screen sizes 5 and 6.

We then took subsamples of each of the screen sizes to perform the identifications. Our plan was to try to attempt identification of 100 particles of each size; this was adjusted as the particles allowed. The thought was that 100 samples of each size were both a large enough sample and a reasonable number to allow for ongoing certification efforts. More discussion on sample size determination will follow in the Discussion section of the article. Table 2 shows the results of our identification efforts and extrapolation calculations.

Table 2 reveals that most of the mulch mix was either *T. distichum* or a *Pinus* species. A small component was some other genera or unidentifiable. Particles from screens 5 and 6 were too small to be identified. The next-to-last column of Table 2 was calculated using the following Eq 1:

Percentage of Total Bag

= Percentage of Identified Sample by Weight *

Percentage of Total Weight, Entire Bag, by Screen Size (Table 1) (Eq 1)

From screens #1 and #2, which held the largest particles, we determined that 31.4% of the total

Table 1. Determination of relative weights of mulch samples by screen size.

| | Actual mulch weights | | | | | | Percentage of total weight by screen size |
	Run 1	Run 2	Run 3	Run 4	Run 5	Total	
#1	1.312	0.596	1.720	1.600	0.714	5.942	18.6
#2	1.422	1.634	2.634	2.999	1.842	10.531	33.0
#3	0.388	1.246	1.820	1.212	1.874	6.540	20.5
#4	0.616	0.484	0.790	0.724	0.738	3.352	10.5
#5	0.932	0.372	0.732	0.716	0.688	3.440	10.8
#6	0.720	0.184	0.400	0.408	0.356	2.068	6.5
Total lbs	—	—	—	—	—	31.873	—
Total kg	—	—	—	—	—	14.460	—

bag weight was pine and only 19.2% was cypress (Table 2). Therefore, the half (by weight) of the bag represented by the largest particles was considerably more pine than cypress.

Screen components #3 and #4, representing 31.0% of the weight of the bag (Table 1), both contained more particles of cypress, but by weight, cypress (16.4%) only slightly outweighed the pine (12.6%) (Table 2). Because the specific gravity of cypress and pine is roughly the same, this can only mean that the size of the cypress particles in each screen portion was smaller, on average, than that of the pine particles. This agrees with the findings of screens #1 and #2 and indicates that the cypress wood tended to refine to smaller particle size during the mulching process than the pine.

We used this logic to make an important assumption for screen sizes #5 and #6. By using the particle size and count trends from the screens for which the species could be determined (in our study, screens 1-4), we could apply an assumption of the percentage of each species that followed those trends to determine an approximate percentage of each species in the fines in an easy and timely manner. The lower portion of Table 2 shows three different assumptions of the results of these trends and the impact it has on the final determination of the total percentage of each species in the mix.

As was mentioned at the beginning of this section, we applied the same procedure to a bag of mulch from Laredo, TX. Those calculations were much simpler; no cypress at all was identified in the bag. The remaining eight bags contained estimated cypress percentages ranging from 30% to 60%.

DISCUSSION

We found that it would be difficult, if not impossible, to determine the species mix for 100% of the wood particles in a package of mulch. This is because of the inability to identify species of the smallest particles and the impracticality of 100% sampling in the intended use.

We developed and used a new method to sort the product by particle size and estimate species mix by weight. Even with our new method, it would be very difficult to legally "prove" with a high degree of confidence that a specific percentage or volume of the retail bags is cypress or any other species. This was demonstrated by the explanations of the assumptions of species composition for smaller particles used in our calculations. However, the confidence in the findings can be improved by some determination of a statistically significant sample size. This could be accomplished over a period of continued monitoring and data gathering. Two different sample sizes would need to be established: first, the number of particles identified by screen size from each bag, and second, the number of bags to be sampled of per unit of time from a specific mulch operation. Both sample size requirements could be determined statistically through design and implementation of a certified testing program and maintenance of ongoing data collection.

Table 2. Results of particle identification, weight of each component of the sample, and extrapolation to the entire weight of the bag.

Screen	Species	Tally	Weight (gm)	Percentage of sample by weight	Percentage of total weight	Percentage of bag	Total weight (kg)
1 and 2	Cypress	61	16.99	37.2	—	19.2	2.78
	Pine	60	27.78	60.9	—	31.4	4.54
	Other	2	0.62	1.4	—	0.7	0.10
	No ID	2	0.22	0.5	—	0.3	0.04
Subtotal	—	—	45.61	—	51.6	—	7.46
3 and 4	Cypress	90	9.18	52.8	—	16.4	2.37
	Pine	51	7.04	40.5	—	12.6	1.81
	Other	1	0.12	0.7	—	0.2	0.03
	No ID	23	1.04	6.0	—	1.9	0.27
Subtotal	—	—	17.38	—	31.0	—	4.48
Sensitivity analysis (1) on fines assumption							
5 and 6	Cypress	—	—	50.0	—	8.7	1.25
	Pine	—	—	50.0	—	8.7	1.25
Subtotal	—	—	—	—	17.3	—	2.50
Whole bag	Cypress	—	—	—	—	44.24	6.40
	Pine	—	—	—	—	52.62	7.61
	Other	—	—	—	—	0.92	0.13
	No ID	—	—	—	—	2.11	0.31
Total	—	—	—	—	—	99.90	14.45
Sensitivity analysis (2) on fines assumption							
5 and 6	Cypress			75.0		13.0	1.88
	Pine			25.0		4.3	0.63
Subtotal	—	—	—	—	17.3		2.50
Bag	Cypress	—	—	—	—	48.6	7.02
	Pine	—	—	—	—	48.3	6.98
	Other	—	—	—	—	0.9	0.13
	No ID	—	—	—	—	2.1	0.31
Total	—	—	—	—	—	99.9	14.45
Sensitivity analysis (3) on fines assumption							
5 and 6	Cypress	—	—	90.0	—	15.6	2.25
	Pine	—	—	10.0	—	1.8	0.25
Subtotal	—	—	—	—	17.3	—	2.50
Bag	Cypress	—	—	—	—	51.16	7.40
	Pine	—	—	—	—	45.70	6.61
	Other	—	—	—	—	0.92	0.13
	No ID	—	—	—	—	2.11	0.31
Total	—	—	—	—	—	99.90	14.45

However, even in the absence of a statistically significant sample size, this method was proven adequate to identify and quantify for industry and regulators that some mulch products contain species other than that which is advertised, and that the percentage of the stated species is sometimes less than the required level.

We acknowledge that mulch bags are sold on volume, not weight, and that our methods (eg proof of species mix) are based in large part on weight. Our results suggest that some mulch manufacturers are taking advantage of the volume measure used in retail packaging and are stocking the largest volume portion of the bag (ie larger pieces) with the lower cost noncypress substitute. As noted in the following texts, this practice has implications for consumer welfare and fair competition.

Implications

We are confident that many consumers are not getting bags that contain only cypress wood. Our samples suggested that although some bags likely contain slightly more than 50% cypress, others contain no cypress at all. This clearly implies there is misrepresentation on the retail packaging if the consumer believes they are receiving an exclusively cypress product. It appears that the tested manufacturer is including at least some noncypress species in all their products, although the bags imply that the product is 100% cypress (some packaging states "cypress blend"). Cypress is more expensive than other woods, so this deceptive practice results in potentially greater profits for the producer, whereas providing the consumer less mulch product value than they could reasonably expect.

These practices would also seem to be a form of unfair competition in that they harm the "honest" producers that do not follow deceptive practices, while also causing diminution in consumer views and goodwill of true cypress mulch. If regulatory (state or federal) bodies will maintain that a producer's packaging implies that their cypress product is wholly or mostly cypress, then it would appear there may be a legal case against these producers.

The wood science community could help regulators and consumers by developing a method by which small particles of wood could be positively identified as to genus and/or species. Genus/species identification is relevant for a wide variety of purposes ranging from combatting illegal logging in the tropics (Dormontt et al 2015) to upholding the US Lacey Act and Convention on International Trade in Endangered Species (Wiedenhoeft and Baas 2011).

The procedure used in this study proved effective because genus-level identification with clearly identifiable differentiation at low-power magnification was all that was necessary to determine the conclusion of the study. Because of this, statistically significant testing could be designed and implemented for this case and similar cases. However, species-level identification of small

wood particles from the same genus could be much more difficult, time-consuming, and expensive. For cases of this sort, statistical significance for legal purposes might be impossible to attain.

Finally, an implication for industry is that mulch manufacturers should become much better at process management, quality control, and perhaps procurement to avoid practices that draw the ire of stakeholders. Lean manufacturing, for example, is a corporate activity of continuous improvement applicable to the wood industry (Ray et al 2006) that could assist even small mulch manufacturers to more accurately meet species mix and product volume as promoted on packaging.

CONCLUSIONS

This article describes a new methodology for estimating the species mix in a wood product composed of various small sample sizes. This is valuable in the context of mulch sold at retail because it appears that mulch producers are including at least some noncypress species in their products, although the bag labeling, as well as marketing materials, implies that the product is 100% cypress. Cypress wood is more expensive than other species, so there is an incentive to use cheaper woods such as pine. It is also noteworthy that cypress is promoted by the industry as being superior to other wood species and is sold at a premium because of such factors as natural color, rot resistance, and resistance to insect infestation. Consumers believe they are receiving a superior wood species but would not get the protection and benefits if the product contains significant volumes of pine or other inferior species.

Regulators charged with protecting environmental or consumer interests need assistance from the wood science community. This is commonly seen with international trade in timber products and illegal logging (Dormontt et al 2015) and would appear to also be true with challenges such as those discussed in this article. Adequately protecting the interests of consumers who purchase wood-based products, while assisting regulators, is an important

service that should be provided by the wood science community.

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