Foamed articles based on potato starch, corn fibers and poly(vinyl alcohol)

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Abstract

Single-use packaging materials made of expanded polystyrene (EPS) have been identified as suitable items to be replaced by biodegradable materials. Plates made with EPS represent a source of non-degradable waste that is difficult to collect and to recycle. Potato starch based foamed plates have been prepared by a baking process. Presently, foam plates have been prepared by baking aqueous mixtures of potato starch, corn fibers, and poly(vinyl alcohol) (PVA) inside a hot mold. The effects of the addition of corn fibers, a co-product of bio-ethanol production, on mechanical properties and moisture resistance of potato starch based foamed plates were investigated. The addition of corn fiber to potato starch batter increased baking time and an increased batter volume is needed to form a complete tray. The mechanical properties of the trays decreased with added corn fiber. In previous studies PVA has been added as aqueous solution to improve strength, flexibility, and water resistance of baked starch trays. In this study, 88% hydrolyzed PVA was added as a powder in the mixture, avoiding the time consuming and costly step of pre-dissolving the PVA. The addition of PVA to potato starch batters containing corn fiber mitigated the reduction in tensile properties seen in trays with added corn fiber. Starch-based trays produced with a high fiber ratio and PVA, showed improved water resistance.

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Keywords: Starch; Poly(vinyl alcohol); Fiber; Foam; Biodegradable; Packaging

1. Introduction

The waste management problems associated with petroleum-based synthetic plastics have provided the opportunity to focus on environmentally compatible materials derived from renewable sources that can serve in some applications as substitutes of petroleum-based polymers [1−3]. Degradable-plastic composites are emerging materials that offer benefits to the environment [4−7], thus minimizing waste that would be otherwise deposited in landfills.

In USA, the Biobased Products Act of 2000 encourages the tripling of the use of biobased materials and energy by 2010. The increasing demand for low priced agricultural commodities such as corn and wheat are also promoting factors [8]. In Europe, the European Commission has posed recently a Directive 1999/31/EC “on the landfill of waste” according to which a progressive reduction is planned for the amount of the organic biodegradable fraction in the municipal solid waste to

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1 Names are necessary to report factually on available data: however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name USDA implies no approval of the product to the exclusion of others that may also be suitable.

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a level of 75% in year 2006, 50% in year 2009, and 35% in year 2016 of the total organic fraction present in the municipal solid waste in the year 1995 [9].

Single-use packaging materials have been identified as suitable items to be replaced by biodegradable materials from renewable resources, leading to ecological benefits. Several hundred billion single-use containers made by extruded polystyrene or coated paperboard are used to serve a variety of food products or as packaging, generating a stream of non-degradable waste difficult to collect and to recycle.

Materials derived from agriculture are emerging as promising substitutes for petroleum-based plastics for a variety of applications [10–13]. Thermoplastic starch has a low initial cost (0.25–0.6 US$/kg) and large availability, thus it is receiving a great deal of interest for the production of disposable items [14]. Starch foams with insulating properties that are similar to polystyrene foam have been industrially developed by extrusion process. Lacourse and Altieri described the extrusion of modified high amylose starches, water, and up to 10% PVA into expanded foams that have been utilized for the production of loose-fill as commercial packaging [15–17].

In this process, a starch feedstock with relatively low moisture content (14–16%) is cooked in a matter of seconds rather than minutes, as required by conventional baking methods that use a feedstock with much higher moisture content [18]. Starch-based foams have practical mechanical properties, but they are difficult to mold into shaped products. They will have a greater commercial potential if the extrusion process were more amenable to making molded foam articles, such as food and beverage containers, and if it were compatible with fiber or other reinforcing materials. Glenn and Orts described a method of forming molded starch foams with a cellular structure using a compression/explosion process [19]. Further development of this technology is necessary to determine the commercial potential.

Molded foam products have also been produced by a baking process similar to that used in making wafer cookies [20,21]. The process involves placing a measured amount of a dough-like material containing 70–80% by weight moisture in a heated mold. Steam generated from the moisture of the dough acts as the blowing agent to create foam inside the mold. A starch-foamed article is formed when the starch gelatinizes and dries. Tiefenbacher showed that dough formulations made of a composite of water, starch, plant fibers, and other food additives could be baked into trays that were lightweight with good thermal insulation [20]. The foam trays had promising characteristics but were susceptible to moisture. Shogren et al. observed that blends of starch and polyvinyl alcohol improved the moisture resistance of baked foams [22,23]. Recently, commercial production of a baked food container with a hinged lid has begun to be marketed [24]. The containers are made of a composite of potato starch, water, wood fiber, CaCO₃, release agents, thickeners and having a moisture resistant coating. The hinged food containers are attractive, completely degrade in composting conditions, and are a viable replacement for hinged containers made of extruded polystyrene and coated paperboard. On the other hand, these products have shown a strong sensitivity to moisture both in dry and wet climate conditions, and cost competition with polystyrene items is still a limiting factor for commercialization. Natural fibers can be added to composites to impart stiffness, increase degradability, and lower cost to the final item. A recent paper reported that calcium carbonate addition did not improve foaming but increases the density of the final product [19].

Particularly, the market related to single-use products such as cups, containers, transplanting-pots, cutlery, etc., appears suitable for the applications of these types of composites. In this paper, corn fibers, a by-product of ethanol production of corn fermentation, have been evaluated as fillers for foamed tray production. The USA is the largest producer of ethanol from cereal grains. Annual ethanol production from corn and wheat is estimated to be in the order of 1.7 billion gallons/year, and this volume is expected to increase further in the future. After the fermentation and ethanol extraction process, a large amount of corn fiber is left as a co-product. Corn fiber is an industrial name given to the pericarp fraction of the corn kernel. Because of the inefficiency in the milling process during removal of the pericarp, some of the kernel endosperm is also removed. This means that not only does corn fiber contain pericarp, it also contains starch and protein from the endosperm. Corn fiber is a fibrous material with 60% residual moisture content. Its main use is in animal feeds. The wet corn fibers are about $15 a ton, the dried ground fibers (about 10 mesh) are about $50 a ton.

2. Materials

Unmodified food grade potato starch was obtained from Avebe America, (Princeton, NJ) and had a moisture content of 11%. Polyvinyl alcohol (PVA Airvol 205S and Airvol 523S) was purchased from Air Products & Chemicals Inc., (Allentown, PA). Airvol 205S (PL) was 88% hydrolyzed and had an average molecular weight of 31,000–50,000. Airvol 523S (PH) was 88% hydrolyzed and had an average molecular weight of 85,000–124,000. Both PVA samples were S-grade powders and had a moisture content of 5–6%. Guar gum and magnesium stearate were purchased from Sigma Chemical Company (St. Louis, MO). Corn fibers were from Williams, (Pekin, IL) and had a moisture content of 59% as received. Composition of the dried corn fiber was 0.6% fat, 12.0% protein, 36.0% starch, 34.4% hemicellulose, 13.8% cellulose, 12.6% crude fiber, and 0.6% ash. Before using the corn fiber, it was
layered on metal trays and dried overnight in a forced air oven at 50 °C. After drying, the fibers were ground in an Alpine pinmill (Augsburg 160Z model, Germany, U/m 18,000). The ground fibers were sifted and that fraction passed through an 8x (0.188 mm) sieve was collected. The dried and ground corn fibers had moisture content of 8%.

2.1. Preparation of foams trays

Starch, corn fibers, magnesium stearate and PVA were dry mixed using a Kitchen Aid mixer with a wire whisk attachment. Batters not containing PVA or having less than 50-weight parts of corn fibers had guar gum (1% by weight of starch) added to prevent the starch from settling. Enough water was added to the mixture to reach the desired solids content and stirred at room temperature for 10 min at medium speed (speed setting 2). Foam trays were prepared using a lab model-baking machine (model LB TRO) supplied by Franz Haas Machinery of America, (Richmond, VA). This machine consists of two heated steel molds, the top of which can be hydraulically lowered to meet the bottom mold during baking. Dimensions of the mold were 217 mm long, 134 mm wide, 19 mm deep, and 3 mm (plate separation). A 60-cm³ plastic syringe with an enlarged opening was used to dispense the batter into the open mold. Enough batter was drawn up into the syringe and dispensed into the mold to just fill the mold after foaming and form a complete tray. Baking temperature was set at 200 °C. Baking time was the minimum required to avoid soft or bubbled trays and it varied from about 120 to 180 s.

2.2. SEM (scanning electron microscopy)

Tray samples were mounted on aluminum stubs using graphite-filled tape and vacuum coated with gold-palladium. Specimens were examined with a JEOL JSM 6400V scanning electron microscope.

2.3. Thermogravimetric analysis (TGA)

A Mettler TA4000 System consisting of TG50 furnace, M3 microbalance, and TA72 GraphWare was used for thermogravimetric measurements. Samples (about 10 mg) were heated from 25 °C to 600 °C at a 10 °C/min scanning rate, under nitrogen atmosphere (flow rate about 200 ml/min). The onset temperature ($T_{on}$) was determined as the temperature corresponding to the crossover of tangents drawn on both sides of the decomposition trace and the residue was evaluated as the residual weight at 600 °C.

2.4. Trays testing

After baking, the trays were conditioned for one week at 23 °C and 50% relative humidity (RH) before mechanical testing. Flexural modulus in the three-point bending mode was determined following ASTM D790, using a Universal Testing Machine (Instron Model 4201). Crosshead speed was 25 mm/min and the support span was 50.8 mm. Data reported are an average of 5–8 trays. Density of the conditioned foamed trays was calculated by dividing tray volume (98 cm³) into the mass. Ultimate properties (breaking stress and strain) could not be measured using a three-point bend test. Whole trays subjected to a circular load usually showed a clear break and, therefore, ultimate properties could be measured. The test was performed with the Universal Testing Machine equipped with a cylindrical load (35 mm diameter) and a cylindrical base (80 mm i.d.). The probe was lowered onto the tray until a load of 0.5 N was reached and then lowered at 30 mm/min until the tray failed. Testing software (Instron series IX, ver. 5) was used to calculate the maximum load at

<table>
<thead>
<tr>
<th>Sample Batler</th>
<th>Starch (%)</th>
<th>PL a (%)</th>
<th>PH b (%)</th>
<th>Corn fiber (%)</th>
<th>Arabic gum (%)</th>
<th>MgSt c (%)</th>
<th>Solid batter (%)</th>
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<tbody>
<tr>
<td>St</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>3.0</td>
<td>33</td>
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<tr>
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<td>-</td>
<td>28.9</td>
<td>-</td>
<td>1.7</td>
<td>33</td>
</tr>
<tr>
<td>SiCF100</td>
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<td>-</td>
<td>-</td>
<td>44.8</td>
<td>9.0</td>
<td>1.4</td>
<td>30</td>
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<tr>
<td>SiCF150</td>
<td>36.5</td>
<td>-</td>
<td>-</td>
<td>54.7</td>
<td>7.3</td>
<td>1.5</td>
<td>28</td>
</tr>
<tr>
<td>SiPL</td>
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<td>-</td>
<td>16.2</td>
<td>-</td>
<td>54.7</td>
<td>0.8</td>
<td>2.4</td>
</tr>
<tr>
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<td>57.8</td>
<td>11.6</td>
<td>-</td>
<td>28.9</td>
<td>-</td>
<td>1.7</td>
<td>33</td>
</tr>
<tr>
<td>SiPLCF100</td>
<td>44.8</td>
<td>9.0</td>
<td>-</td>
<td>44.8</td>
<td>-</td>
<td>1.4</td>
<td>30</td>
</tr>
<tr>
<td>SiPLCF150</td>
<td>36.5</td>
<td>7.3</td>
<td>-</td>
<td>54.7</td>
<td>-</td>
<td>1.5</td>
<td>28</td>
</tr>
<tr>
<td>SiPH</td>
<td>80.6</td>
<td>-</td>
<td>16.2</td>
<td>-</td>
<td>54.7</td>
<td>0.8</td>
<td>2.4</td>
</tr>
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<td>SiPHCF50</td>
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<td>-</td>
<td>11.6</td>
<td>28.9</td>
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<td>1.7</td>
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<tr>
<td>SiPHCF100</td>
<td>44.8</td>
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<td>9.0</td>
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<td>1.4</td>
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<tr>
<td>SiPHCF150</td>
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<td>-</td>
<td>7.3</td>
<td>54.7</td>
<td>-</td>
<td>1.5</td>
<td>28</td>
</tr>
</tbody>
</table>

a PVA = A205S (PL).
b PVA = A525S (PH).
c MgSt = magnesium stearate.
failure ($F_m$) and displacement at failure ($L_m$). Water absorption tests were performed on cutting selected trays into 76.5 × 14 rectangles and soaking them in excess deionized water at 25 °C for 30 min. Changes in the sample weights were measured.

3. Results and discussion

3.1. Processing and morphology

Batters were prepared with variable amounts of potato starch, PVA, and corn fiber, as reported in Table 1. PVA is usually added to the tray batter as a 10% aqueous solution which is prepared by stirring and heating in water at 80–90 °C for 3 h. In the present study we evaluated the possibility of adding PVA directly to the dry mixture, thus avoiding the time and energy used in dissolving PVA prior to mixing. For this reason a less hydrolyzed (88%) PVA was used. This PVA had greater water solubility and was purchased as a powder for easier dispersion in water. Both types of PVA were easily dispersed in the batter, and trays prepared with dry PVA were not significantly different from trays prepared using PVA in solution.

As previously reported, when foam trays are prepared using the baking process enough batter is needed so that, upon baking, the batter foams and fills the mold and a complete tray can be formed [25]. The batter needed to form a complete tray and the time needed to bake the trays are reported in Table 2. The amount of batter needed to fill the mold and form a complete tray and the baking time needed to completely dry the tray increased with increasing fiber content. The amount of batter necessary to make a complete tray increased from 50 cm³ for batter containing no corn fiber to 85 cm³ for batter containing 54.7% fiber. The increase in batter volume needed to make a tray is likely due to the corn fiber not participating in the foaming. Because a specific amount of starch is needed to foam and fill the mold, the amount of starch replaced by corn fiber in the batter would have to be made up by the addition of more batter to the mold. The added corn fiber also increased batter viscosity. This increase in viscosity would also diminish foaming and thus require greater amounts of batter to produce a tray. Using the higher molecular weight PVA in batters containing the highest amount of fiber did show a slight decrease in batter volume needed to produce a tray. This was due to the higher molecular weight PVA which provided better foaming during the baking process, thus not requiring as much batter.

Baking time increased from 140 s for trays containing no corn fiber to 190 s for trays containing 54.7% corn fiber (Table 2). The increase in baking time is probably due to the increase in batter needed to make a tray. This increase in batter would lead to more water having to be evaporated during baking. Baking time is also likely influenced by the amount of the corn fiber in the batter. Corn fiber is assumed to dry slower than the gelatinized porous foamed starch. Adding PVA to the batter slightly decreased the baking time needed to make a tray, except for trays containing equal amounts of corn fiber and starch. The increase in batter viscosity seen with increase in corn fiber also contributed to the increase in baking time. Increases in batter viscosity would slow the movement of water during drying part of

### Table 2

<table>
<thead>
<tr>
<th>Sample</th>
<th>Batter volume (ml)</th>
<th>Baking time (sec)</th>
<th>Sample</th>
<th>Batter volume (ml)</th>
<th>Baking time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>St</td>
<td>50</td>
<td>140</td>
<td>StPLCF100</td>
<td>80</td>
<td>180</td>
</tr>
<tr>
<td>StCF50</td>
<td>75</td>
<td>160</td>
<td>StPLCF150</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>StCF100</td>
<td>80</td>
<td>180</td>
<td>StPHb</td>
<td>65</td>
<td>120</td>
</tr>
<tr>
<td>StCF150</td>
<td>85</td>
<td>190</td>
<td>StPHCF50</td>
<td>70</td>
<td>140</td>
</tr>
<tr>
<td>StPLa</td>
<td>65</td>
<td>120</td>
<td>StPHCF100</td>
<td>80</td>
<td>180</td>
</tr>
<tr>
<td>StPLCF50</td>
<td>75</td>
<td>140</td>
<td>StPHCF150</td>
<td>80</td>
<td>180</td>
</tr>
</tbody>
</table>

a PL = PVA A205S.

b PH = PVA A523S.

### Table 3

<table>
<thead>
<tr>
<th>Material</th>
<th>Volatiles (%)</th>
<th>$T_m$ (°C)</th>
<th>Peak 1</th>
<th>Peak 2</th>
<th>Residue (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato starch</td>
<td>6</td>
<td>290</td>
<td>303</td>
<td>75</td>
<td>19</td>
</tr>
<tr>
<td>PL</td>
<td>3</td>
<td>299</td>
<td>324</td>
<td>80</td>
<td>444</td>
</tr>
<tr>
<td>PH</td>
<td>3</td>
<td>287</td>
<td>328</td>
<td>79</td>
<td>441</td>
</tr>
<tr>
<td>CF</td>
<td>5</td>
<td>261</td>
<td>296</td>
<td>48</td>
<td>349</td>
</tr>
<tr>
<td>St</td>
<td>4</td>
<td>292</td>
<td>322</td>
<td>82</td>
<td>–</td>
</tr>
<tr>
<td>StCF100</td>
<td>3</td>
<td>275</td>
<td>317</td>
<td>60</td>
<td>355</td>
</tr>
<tr>
<td>StPL</td>
<td>4</td>
<td>281</td>
<td>310</td>
<td>82</td>
<td>–</td>
</tr>
<tr>
<td>StPLCF100</td>
<td>4</td>
<td>278</td>
<td>310</td>
<td>68</td>
<td>390</td>
</tr>
<tr>
<td>StPH</td>
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<td>285</td>
<td>321</td>
<td>80</td>
<td>–</td>
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<tr>
<td>StPHCF100</td>
<td>4</td>
<td>287</td>
<td>319</td>
<td>61</td>
<td>360</td>
</tr>
</tbody>
</table>

$T_m$ = Onset temperature, Peak 1 = first decomposition peak, Peak 2 = second decomposition peak, Residue = residue weight % at 600 °C, $T$ = temperature, WL = weight loss, PL = PVA A205, PH = PVA A523, CF = corn fibers.
the baking process. No differences were seen in the baking time for either of the PVAs used. Batters containing fiber with equal amounts of starch or less were able to be made into trays without cracks. Trays containing the greatest amount of fiber were very brittle and difficult to foam, probably because the high fiber content increases viscosity and resistance to expansion. Increasing fibers content of the batters increased batter viscosity and impeded the foaming process.

Fig. 1. Decomposition curves for PVA-PH, potato starch, and corn fiber.

Fig. 2. Decomposition curve of a sample tray StPHCF100.

Fig. 3. SEM of the cross-section of trays; (a) 100% potato starch tray (St), (b) potato starch tray containing 28.9% corn fiber (StCF50), (c) potato starch tray containing 44.8% corn fiber (StCF100), (d) potato starch tray containing 54.7% corn fiber (StCF150). Black arrow and arc show outer skin.
Thermogravimetric analysis was performed on raw materials and some representative trays to define thermal stability and to investigate interaction among the different components. Thermal characteristics are reported in Table 3. Fig. 1 shows the decomposition curves for PVA-PH, potato starch, and corn fiber. PVAs (PL, PH) and potato starch (St) have a similar decomposition onset temperature (290 °C), while corn fibers (CF) have a lower onset temperature (260 °C). Nevertheless, all these materials are suitable to be processed at 200 °C. After volatiles in the trays were lost, PVA and CF decomposition occurs in two steps while potato starch decomposition mostly occurs in one step with a decomposition peak placed at 303 °C. Trays composed of potato starch, PVA, and corn fiber show an intermediate onset temperature that attest to some interactions among the components. In particular for sample StPHCF100 (Fig. 2), the onset temperature is almost the same as potato starch and PH. The decomposition peak is placed at a temperature (319 °C) higher than CF alone (296 °C), and is the result of the overlaying of single decomposition peaks, thus suggesting positive interactions among the components. Tray decomposition starts at a temperature largely suitable for practical applications, such as fast food trays, also for trays with a large content of corn fibers.

Scanning electron micrographs of foam trays containing starch, CF, and PVA are shown in Fig. 3. Micrographs of a cross-section of a potato starch tray (Fig. 3a) show that the foam has sandwich type structure with dense outer skins containing small cells comprising the surface of the foam. The interior of the foam has large cells with thin-walls [22,23]. Corn fiber interferes with foaming during baking. As a result, when the concentration of corn fiber increases, the foam’s cell formation is changed. When corn fibers are added to the formulations the outer skin contains fewer small cells. Foam trays containing over 50% corn fiber contain few small cells in their outer skin. In the interior the cells are smaller and the foam becomes denser (Fig. 3b and c). When trays contain over 50% corn fiber, foaming has been essentially stopped and the trays have few internal cells.

Fig. 4. SEM of the cross-section of trays; (a) potato starch tray containing 16.2% PVA-PH (StPH), (b) potato starch tray containing 11.6% PVA-PH and 28.9% corn fiber (StPHCF50) (c) potato starch tray containing 9% PVA-PH and 44.8 corn fiber (StPHCF100). Black arrow and arc show outer skin. White arrow shows cell walls.
cells (Fig. 3d). As a result, the density of the trays increases as corn fiber increases. A 10–30% PVA addition to potato starch batter is known to improve strength, flexibility and water resistance [23] of the finished foam trays. Adding PVA to the trays containing corn fiber also provided some additional foaming ability. Trays containing only potato and PVA had thinner skins and larger cells with thicker walls (Fig. 4a). Trays containing PVA and corn fiber showed better interior foam structure (Fig. 4b and c), especially trays with the higher fiber content. The outer skin of trays containing corn fiber show compressed and bounded fibers which may improve moisture resistance of the final item in comparison with fiber free starch-based trays (Fig. 5).

Adding corn fiber to the trays lowers their mechanical properties. The force needed to break the trays decreased from 75 N for trays containing no corn fiber to less than 20 N for trays containing 54.7% corn fiber (Fig. 6a). The added fiber is acting as a nonreinforcing filler and as such is diluting the starch in the tray, which is the load bearing material. The shape of the added corn fiber, which is mostly spherical in nature, does not add any reinforcement. For corn fiber to be an effective filler, it needs to have a more elongated structure. Aspen fiber with a high aspect ratio has been shown to improve the strength of baked starch foams when added in concentrations up to 30% [26,27]. The addition of the high molecular weight PVA (PH) mitigates the decrease in tray strength associated with the addition of fiber (Fig. 6a). Trays made with PVA-PH and up to 48% corn fiber have tray strengths approximately the same as trays made with only potato starch. The lower molecular weight PVA (PL) did not perform as well. When the weight of the tray was taken into account the PVA-PL samples performed worse than trays containing no PVA-PL (Fig. 6b). When the strength of the tray was calculated in Newtons per gram, the ability of high molecular weight PVA to improve tray strength is confirmed. However, when corn fiber is added trays performed statistically no better than trays without PVA.

Fig. 5. SEM of tray containing starch and fiber showing fiber on the outer edge of the tray. Arrow points to corn fiber on the surface of tray.

Fig. 6. Force required to fracture tray: (A) maximum force at yield; (B) maximum force per gram at yield. Bars indicate mean ± average standard deviation.
with PVA-PL, their flexibility decreased initially when the trays contained 28.9% corn fiber, but did not decrease further upon the addition of more corn fiber. Trays containing only starch and PVA-PH were the most flexible. Shogren et al. [23] showed that PVA was a good choice for providing tray flexibility. As corn fiber was increased, the flexibility of trays containing PVA-PH also decreased. However, owning to its ability to added flexibility to bake starch trays, trays containing PVA-PH and 28.9% fiber were just as flexible as starch trays containing no corn fiber. Further additions of corn fiber to trays containing PVA-PH showed further reductions in flexibility. Corn fiber initially increased the flexural moduli of the trays containing no PVA (Fig. 8). As would be expected with a filler. At higher levels of fiber the flexural modulus declined. This loss of modulus with greater fiber content is probably due to the lack of foaming taking place inside the trays. Trays with no interior foaming would be easier to bend and thus have a lower modulus when tested by three-point bending. Trays containing PVA did not show much change in flexural modulus with increasing fiber content.

The combination of corn fiber and PVA significantly limited the water absorption of the foams (Table 4). The PV-PL probably did not perform as well because it is more water sensitive than PVA-PH. The addition of PVA without corn fiber did not decrease water absorption in the foams. The addition of corn fiber without PVA also did not decrease water absorption in the foams.

### 4. Conclusion

Potato starch based trays can be foamed with a relatively high content of corn fibers. Corn fiber is not a reinforcing fiber for starch-based foam trays. The tensile strength and flexibility of the trays decrease with increasing fiber content. The addition of PVA to the formulations mitigates the reduction in tensile properties seen when corn fiber was added alone. Increasing the fibers content increases batter viscosity, thus increasing baking time. The fiber also interferes with foaming so additional batter volume is needed as corn fiber increases to form complete trays. PVA can be added to the formulation as a dry powder, avoiding the time and energy consuming step of dissolution. The addition of corn fibers and PVA together decreases the water absorption in the foam. The largest decrease in water absorption was seen with the addition of high molecular weight PVA. Corn fiber along with the addition of PVA to potato starch is a viable option to improve moisture resistance of foamed trays. Trays containing 28.5% corn fiber and PVA-PH had tensile properties that were the same as trays containing only starch, but with better water resistance. For corn fiber to have a greater impact on starch foam trays, the aspect ratio of the fiber needs to be changed so the fiber will have more reinforcing properties.
References


