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The heat insulating properties of potato starch extruded with addition of chosen by- products of food industry

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The study was aimed at determination of time of heat transition through the layer of quince, apple, linen, rose pomace and potato pulp, as well as layer of potato starch and potato starch extruded with addition of above mentioned by-products. Additionally the attempt of creation a heat insulating barrier from researched raw material was made. The heat conductivity of researched materials was dependent on the type of material and its humidity. Extruded potato starch is characterized by smaller heat conductivity than potato starch extruded with addition of pomace. The obtained rigid extruded starch moulders were characterized by higher heat insulating properties than the loose beads. It is possible to use starch and by-products of food industry for production of heat insulating materials.

Keywords: potato starch, extruded potato starch, fruit pomace, potato pulp, heat insulation.

INTRODUCTION

The food-vegetable branch of food industry generate pomace as a waste during raw juice production. The mass of pomace can be as high as 25% of raw material mass. Although it is considered as a waste it contains many valuable components, such as fiber, pectins, fats and waxes, mineral compounds and coloring agents. The main course of fruit-vegetable industrial waste treatment was composting or application as additive to livestock feeding. They can be also used for production of fiber, pectin and fruit tea[1, 2]. Currently new ways of pomace treatment are being searched, but not as a waste, rather as a by- product which can be reused and processed. These methods will additionally lower the environmental burden.

The potato pulp is a by-product of potato starch production. Dried potato pulp is mainly used a voluminous fodder for domestic livestock[3].

One of the new applications of potato pulp or pomace is its use in production of biodegradable materials[4]. Currently the packaging industry is in blossom but rapid increase of plastic waste creates necessity to create biodegradable a packaging material. One of the methods to obtain the biodegradable material is the addition of natural or modified starch to synthetic polimers[5, 6]. Among many others starch can be modified or prepared, for production of package material, by extrusion[7, 8]. Starch extrudates can be used for production of foil or foam. Nevertheless it should be noted, that the foil obtained from mixture of starch and synthetic material are characterized by worsened mechanical properties, and increased water absorption and solubility[9, 10]. These aspects are irrelevant in production of foams not intended for contact with humidity. Those foams can be used as package empty space filling, for protection from mechanical damage and thermal insulator. The thermo insulating properties of foams is caused by the air closed in the pores of material[11]. The thermo insulation of materials increases with decreasing volume of individual closed pores. Proper temperature of starch extrusion produces light and highly aerated material. This type of starch structure can be applied (as 20% share) in production of polyurethane foam, which is used as heat insulation in construction and refrigeration[12].

The possible application of starch and by-products of food industry, for production of a biodegradable packaging material is an interesting problem[13]. This type of material would be characterized by high thermal insulation, which predefines its use for temperature fragile products. Effective application would allow to reduce the amount of non-degrading packaging materials, as well as increased use of food industry by- products, which would positively affect the environment.

The study was aimed at determination of time of heat transition through the layer of quince, apple, linen, rose pomace and potato pulp, as well as layer of potato starch and potato starch extruded with addition of above mentioned side products. Additionally the attempt to create a thermo insulating barrier from researched raw material was made.

MATERIAL AND METHODS

The materials used in experiment were: potato starch produced by PEPEES S.A. in Łomża in 2011; ground linen pomace produced by Oleofarm in 2011; dried and ground apple, quince and rose pomace prepared in 2011, obtained from Departament of Fruit, Vegetable and Cereals Technology of Wrocław University and Life Sciences; dried and ground potato pulp from PPZ Niechlów S.A. produced in 2011.

The preparation of the material consisted of mixture preparation from starch with addition of 5% and 10% pomace or pulp moistened to water content of 25%. The obtained preparations were subject of extrusion in single-screw extruder, Brabender type 20 DN, with the screw of compression rate 2:1 and round nozzle of 3 mm diameter. The rotation speed of screw was set to 80 rev/min, while the speed of material feeding was set to 40 rev/min. The preparations were extruded in three variants of temperature: 50, 60, 70 [°C], 90, 100, 120 [°C], 140, 150, 160 [°C], (accordingly: loading zone, plastic zone, head zone). Directly on extruder exit the preparations were granulated by knife rotating at a speed of 120 rev/min. The expansion rate of obtained extruded material was calculated as a ratio of extruded material diameter to diameter of extruders nozzle.

The main concept of the experiment was observation of time needed for temperature equalization in layer of starch, pomace and pulp, of water content 8% or 25%, as well as in layer of extruded starch with 5% or 10% addition of pomace or pulp.

The preparations were placed in copper cylinder, of 4cm diameter, to height of 4 cm and bashed with piston. The sample was covered with insulating material and thermocouple probe was pierced to depth of 2 cm. The prepared cylinder was placed in water bath of 70°C. Time needed for temperature increase was measured in following ranges: 30–35°C, 35–40°C, 40–45°C, 45–50°C. The obtained results were averaged and subject of statistical analysis.

In order to obtain stiff thermo insulating barriers the extruded starch was weighted to the form identical to copper test cylinder. The preparation was then transferred to evaporating dish and moistened by addition of water in mass of 5% of total dry mass. The preparation was than thoroughly mixed to homogeneous moisture, and then transferred to form. The beads were bashed with piston to compress and unify the structure of shape. In order to maintain the space for thermocouple, before solidification, the metal pin, of diameter equal as thermocouple, was placed in the geometric center of sample. The shapes were than left in forms in room temperature for 12 hours, in order to dry and solidify completely to concrete structure. The shapes were weighed and their density was calculated.

The time of temperature equalization inside the shapes were conducted with above described method.

The obtained results were subject of statistical analysis in Statistica 10.0. A one- and two-way, two-factorial ANOVA tests were carried, and homogeneous groups were determined with Duncan test at a significance level of $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

The Figure 1 presents the dependency of temperature equalization time in the layer of material from its type and moisture. Thermo insulating properties of material are strictly dependent from its type. The quince pomace presented the worst thermo insulating properties while the 8% humidity potato starch was characterized with the longest time of heat transmission. These results could be influenced by chemical composition, structure of material and the level of compression in cylinder. Although the level of grinding was similarly set the size of particles were diversified. The starch is composed of

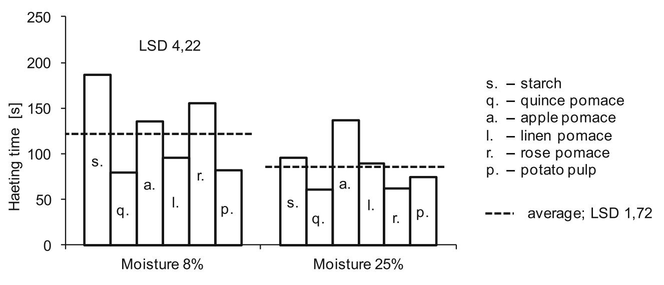

Figure 1. Dependency heat time transition through layer of material from its type and moisture

granules, while pomace are mostly fiber and cellular walls. The differences in form could effect in the adhesion of particles, which could impact the thermo insulating properties. The thermo insulating properties of powdery materials are also influenced by their moisture.

Apart from shape, the thermo insulating properties of research material are influenced by chemical composition. The potato starch is the most chemically homogenous natural starch. The potato starch granules does not contain proteins nor fats, and are composed from packed glucose chain[14]. Their size is relatively big (5–110 μm) and semi-crystalline in structure[15]. The thermo insulation properties of starch (at 8% moisture), greater than observed for pomace or potato pulp, are caused by their chemically homogenous composition, uniform density of oval granules, as well as intertwined crystalline an amorphous layers. The pomace and potato pulp are characterized by more diversified chemical composition. The potato pulp is an production waste after removal of starch and water soluble non-starchy substances. The dry mass of potato pulp consists of about 37% of starch, trapped in the cell walls residues, as well as cellulose 17%, hemicellulose, pectin 17%, other fiber substances 7% and proteins 4%[16], but do not form ordered structure. Similarly, the researched apple, quince and rose pomace are characterized by not uniform chemical composition. Comparison of chemical composition with potato pulp present greater content of monosaccharaides, but lack the starch. The apple pomace, which presented the greatest thermo insulation properties at 25% humidity, contain pectin[1]. It is assumed that water soluble pectin filled the structure of pomace, which effected in thermo insulation similar for 8 and 25% humidity. Similar effect was observed for linen pomace, which contain fats residues[17].

This is caused by conductive properties of water. Nevertheless the expected high differences of heat conductivity, between materials of 8 and 25% water content, were observed only for potato starch and rose pomace. The remaining materials heat conductivity was minimally influenced by moisture.

The researched starch was subject of extrusion in three different temperature. The extrusion is a process where material is treated by high temperature, pressure and mechanical forces[18]. Due to processing, depending on the parameters, the starch granules are torn apart, spatially rearranged and their degree of crystallinity changed, which effects their physiochemical properties. According to literature of the subject, increased temperature of extrusion enlarged the level of starch expansion. The obtained beads had increased volume and less regular shape, caused by air bubbles closed in extrudates structure. The literature also mentions that materials of porous structure, with trapped air, are characterized by greater insulation properties[11]. This suggests that beads obtained in the highest temperature of extrusion would have better heat insulating properties, than, denser beads obtained from lower temperature extrusions. The conducted heat conductivity tests proved that beads obtained from starch and starch with additions, which were extruded in the highest temperatures (140, 150, 170°C), were characterized with greater heat conductivity than preparations obtained in lower temperatures of extrusion (Figs. 2–6). Ait Saada et al.[19] informs, that among porous materials,

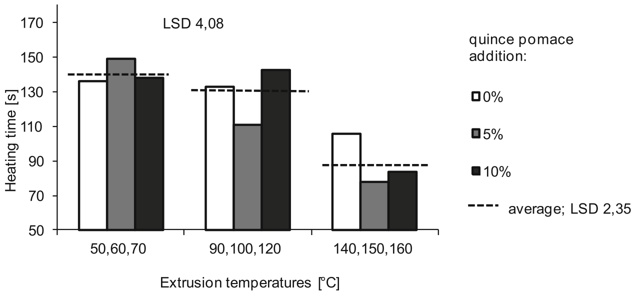

Figure 2. Dependency heat time transition through layer of extruded starch (beads) from addition of quince pomace and extrusion temperatures

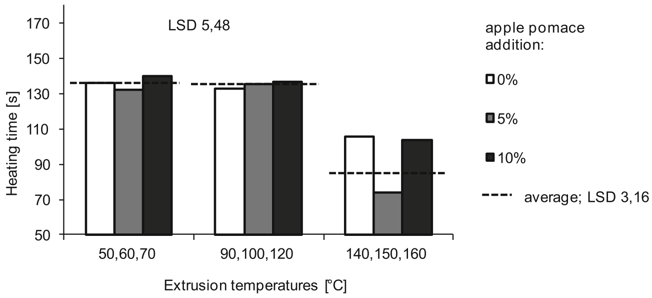

Figure 3. Dependency heat time transition through layer of extruded starch (beads) from addition of apple pomace and extrusion temperatures

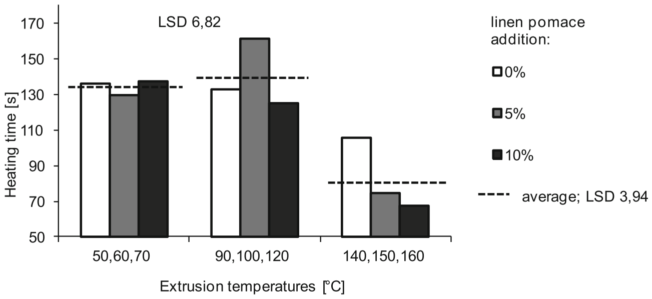

Figure 4. Dependency heat time transition through layer of extruded starch (beads) from addition of linen pomace and extrusion temperatures

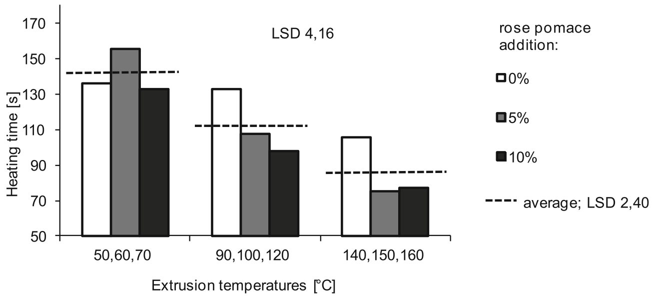

Figure 5. Dependency heat time transition through layer of extruded starch (beads) from addition of rose pomace and extrusion temperatures

the best insulating properties are obtained with presence of small and closed air spaces[19], while the beads obtained in the third variant of extrusion were characterized with high volume and expansion (Fig. 7). Additionally large and irregular dimensions of beads, obtained in high temperature extrusion, caused their ineffective packing in measure cylinder. Big spaces between beads can enable the convection process, which allows transition of heat through tested sample. The beads obtained in lower

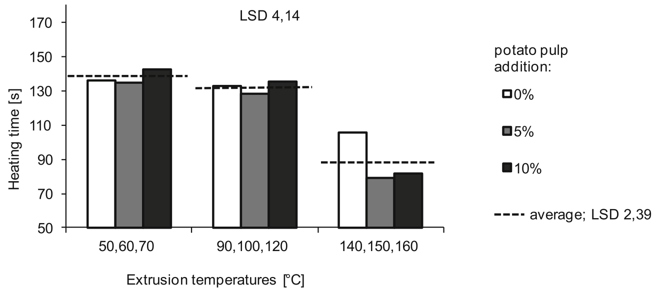

Figure 6. Dependency heat time transition through layer of extruded starch (beads) from addition of potato pulp and extrusion temperatures

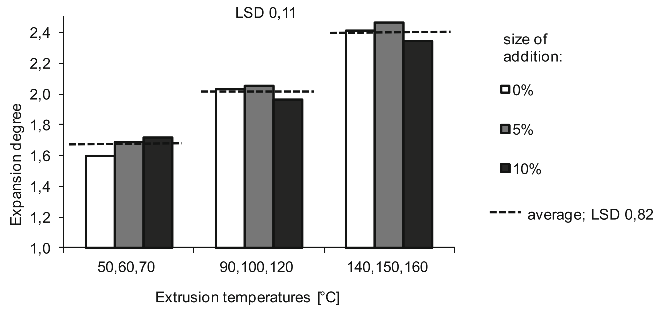

Figure 7. Dependency of expansion ratio from size of addition and extrusion temperatures

temperature of extrusion were characterized by lesser expansion ratio, smaller size and more regular shape, which prevented formation of large free spaces in the measure cylinder.

The literature data describes that extrusion temperature influences both expansion ratio, as well as change in structure of extruded starch material. With the increasing temperature of extrusion the progressive degradation of starch chain is observed, which lowers the viscosity and water absorption, increases the water solubility of extruded starch and change of its mechanical properties[20, 21]. The extrusion in the highest of researched temperatures resulted in significant change of extruded materials structure, which in effect increased the thermal conductivity of the obtained material. It can be assumed that high temperature of extrusion affected not only the starch, but also the structure of pomace. This theory is confirmed by increased thermal conductivity of material obtained with addition of pomace in the highest temperature of extrusion.

The starch extruded with addition of pomace had diversified insulating properties, which were dependent from the type and share of addition. All of additives researched in the experiment, when compared to extruded potato starch, decreased the thermo insulating properties of extruded material (Fig. 8). It is assumed that the addition of fiber and pectins tightens the structure of extruded starch. The fiber fills the empty space of extrudate and facilitates the heat conduction.

The Figure 8 illustrates the dependency of heat transition time through layer of extruded starch from its form. The sample from loose packed beads statistically faster conducted heat than sample formed from dense shapes, which was a better insulator. During the process of shape forming the surface solubility of starch took place. The increased solubility was caused by extrusion[21]. During drying the beads merge forming highly agglutinated

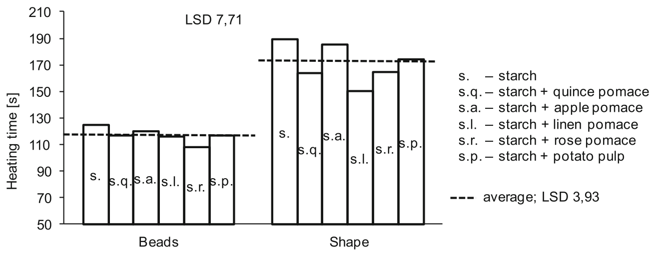

Figure 8. Heat transition time through layer extruded starch (beads) and shapes

shape of roller, which diameter corresponds to copper cylinder in measure unit. When compared to beads tested loosely, the shapess made of extrudates had statistically greater ability of heat insulation. It is presumed that empty space between extruded beads were linked with dissolved starch chains, which hampered the heat convection, while numerous pores filled with insulating air were still present. The method of starch beads forming to shapes were specifically chosen, to obtain rigid and durable form while simultaneously maintain inner structure of beads. Additionally the dependency between type of addition and thermo insulating properties was observed. The longest equalization of temperature was observed for shapes obtained from starch only and from starch with addition of apple pomace. The lowest heat conductivity for shapes was observed for shapes obtained with application of linen pomace, although this additive didn't influence heat conductivity during loose beads analysis. It is assumed that fat contained in linen pomace[17] prevented effective structure sealing of created shapes.

Figure 9 presents the dependency of density of shapes from the size of addition and extrusion temperatures. The greatest values were observed for shapes made of beads obtained in lower temperature of extrusion. This beads were characterized by lesser expansion ratio.

The conducted research presented new, interesting possibility on utilization of starch and side products of fruit-vegetable industry. Those raw materials can be broadly used, with particular emphasis on obtainment of least environmentally hazardous materials, characterized by valuable functional properties and easy disposal.

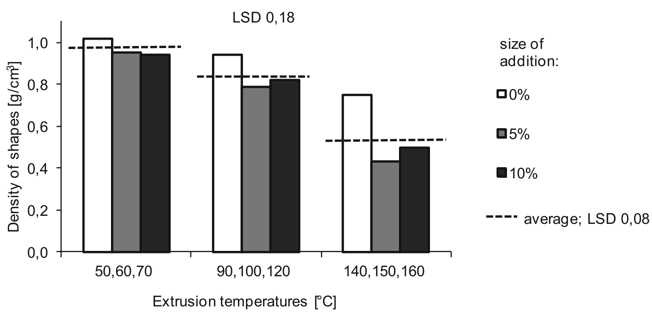

Figure 9. Dependency of bulk density shapes from size of addition and extrusion temperatures

CONCLUSION

Starch and pomace from quince, apple, linen and rose, as well as potato pulp are characterized by diverse heat conductivity dependent from type of material and moisture. The extruded potato starch is characterized with slower heat conduction than potato starch extruded with addition of pomace. The best thermal insulation properties from extruded starch samples were observed for low temperature of extrusion. Rigid moulders obtained from extruded starch were characterized with better thermo insulating properties than loose beads. It is possible to utilize starch and side products of food industry for production of thermo insulating material.

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