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Review:

Biodegradable packaging in the food industry

Übersichtsarbeit:
Biologisch abbaubare Verpackungen in der Lebensmittelindustrie

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Summary

This paper provides an overview of the development, use and future trends of biodegradable packaging, types of biopolymers, the properties of biodegradable packaging, the concept of biodegradability, bio-technology production and packaging advantages and shortcomings of. In the opening statement, described the concept of packaging in general and how biodegradable packaging developed through history. The chapter on biopolymers shows that all types of biopolymers are used for the production of bio-packaging and how we share it. The next two chapters relate to the properties of biodegradable materials and distribution of bio-packaging shapes. A special place in the work occupies a section of biodegradation and composting, which clearly illustrates the mechanism of biodegradation but also clarifies the concept compostable and biodegradable plastics. The last two chapters deal with the technology of production of biodegradable packaging and a brief analysis of the advantages and disadvantages biodegradable packaging. An important component of this work is a questionnaire on the awareness and importance of using biodegradable packaging with students at four faculties of the University of Mostar.

Keywords: biodegradable packaging, polymers, degradation

Zusammenfassung

Dieser Artikel soll einen Überblick über die Entwicklung, die derzeitige Nutzung und zukünftige Trends biologisch abbaubarer Verpackungen geben. Des Weiteren über Biopolymere, der biologischen Abbaubarkeit, Produktionstechnologien und über Vor- und Nachteile biologisch abbaubarer Verpackungen informieren. Zu Beginn des Artikels wird über Verpackungen im Allgemeinen und über die Entwicklung der biologisch abbaubaren Verpackung im Laufe der Zeit berichtet. Das Kapitel über Biopolymere zeigt, dass alle Arten von Biopolymeren für die Herstellung von Bioverpackungen verwendet werden und wie diese eingeteilt werden. Die nächsten beiden Kapitel beziehen sich auf die Eigenschaften von biologisch abbaubaren Materialien und die Verbreitung von biologischen Verpackungsformen. Eine Sonderstellung in der Arbeit hat der Abschnitt des biologischen Abbaus und Kompostierung, der den Mechanismus des biologischen Abbaus verdeutlicht, aber auch das Konzept kompostierbarer und biologisch abbaubare Kunststoffe darstellt. Die letzten beiden Kapitel beschäftigen sich mit der Produktionstechnologien und einer kurzen Analyse der Vor- und Nachteile biologisch abbaubarer Verpackungen. Ein wichtiger Bestandteil dieser Arbeit ist ein Fragebogen zum Bewusstsein und zur Bedeutung der Verwendung von biologisch abbaubaren Verpackungen mit Studierenden an vier Fakultäten der Universität von Mostar.

Schlüsselwörter: biologisch abbaubare Verpackungen, Polymere, Abbau

Introduction

Packaging is any product that is used to hold, protection, handling, delivery and presentation of goods, from raw materials to finished products, from producers to consumers. Packaging is usually divided according to the basic raw material of which is produced according to the type of packaging material can be divided into metal, glass, polymer, paper cardboard, wood, textile, multilayered, ceramic and other types.

Food packaging must meet a number of conditions, such as legislation, safety and many other conditions as well as functionality since it is required to be innovative, easy to use and attractive design. One of the main tasks of packaging in the food industry is to protect the product of chemical, mechanical and microbiological impact, and also allows the freshness of the product and keeps all its nutritional value. The key point in food packaging is that the packaging is an integral part of the production, preservation, storage, distribution, and at the present time and an integral part of the preparation of foods. The properties of the food product are only possible to maintain proper selection of appropriate packaging and packing process (Stričević, 1982).

The aim of the paper is importance of raising awareness of people to live properly and responsibly, in harmony with nature, manage packaging and encourage the production of biodegradable packaging. Finally, it would be presented to the survey, which was conducted on students of undergraduate study natural sciences and medical sciences at the University of Mostar.

Development of bioplastic

Today, at the beginning of the 21st century, great importance is given to products from renewable sources, for their positive impact on nature. Generally increasing awareness among consumers worldwide to conventional plastic products, although very useful, creating huge damage to the environment, water resources, and the entire ecosystem. Accumulation of plastic in the environment, reduction of arable land, wear oil wells, releasing gases during incineration have prompted efforts to develop biodegradable packaging / plastics (Mohatny et al, 2015).

The largest sector in the demand for bio-packaging is the food industry. The rapid development of the industry has led to problems with non-degradable packaging, but it takes time, work and patience while reorienting them to bio-packaging (bioplastic) (Platt, 2006).

In addition to efforts to find a replacement for plastic supports the development and cardboard packaging produced only from renewable sources (Kolybaba 2003, Narayan, 2006).

The main leaders in composting are Germany and the Netherlands, where for a very long time composting is carried out effectively and successfully, all thanks to national programs to support and develop people's consciousness (Mohatny, 2005, Platt, 2006).

Biopolymers

Biomaterials (biopolymers) are polymers produced from renewable sources. Biopolymers are manufactured from plant raw materials, in the first place, but in recent times and of animal. Their main feature is their biodegradability. Classified in many ways such as, chemical structure, origin, methods of synthesis, cost-effectiveness, application, etc. (Davidovic and Savic, 2010).

Polymers from renewable resources are different from natural polymers because their synthesis is induced intentionally. Conventional polymers are not biodegradable because of long chains of molecules that are too big and too well connected to each other to make them able to separate the microorganisms to break down. Unlike conventional, polymers made from natural plant materials from wheat, potato or corn starches have molecules that are easily microbiologically degradable. For 1 kg of bio-plastics should be 1 to 2 kg of maize and 5 to 10 kg of potatoes, which means that 500 000 tons of bio-plastics per year requires 50,000 to 100,000 hectares of soil. At the same time, it means the destruction of large areas of forest/rainforest to cultivated plants for the production of biodegradable materials (Goodship and Ogar, 2004).

Thanks to their natural origin, natural polymers are all inherently biodegradable since for each enzyme a polymerase whose activities produce a natural polymer, and there is depolymerase capable of catalyzing the decomposition of the polymer (Scholz and Khemani, 2006).

Classification of biopolymers

The traditional way of dealing with biodegradable packaging materials is divided into three generations based on historical development.

First generation

The first generation of material was used for shopping bags, consisting of synthetic polymers such as low density polyethylene (LDPE-low density polyethylene) with a proportion of 5–15 % starch fillers and pro-oxidizing and auto-oxidative additives. Later these materials decompose or bio-fragment into smaller molecules that are not biodegradable. Such materials have created a very bad image of bio materials especially for consumers who were convinced that they played in terms of biodegradability (Chiellini, 2008). Low density polyethylene-LDPE produced in 1933 by Imperial Chemical Industries (ICI) using high pressure process via free radical polymerization. Its production uses the same methods today. It is estimated that about 5.7 wt% of LDPE can be recycled. LDPE is in the range defined by the density of 0.910 to 0.940 g/cm^3. Non-reactive at room temperature, except in the action of strong oxidizing agents and some solvents cause swelling. Excellent resistance to acids, alcohols, esters, and a base, followed by resistance to various aldehydes, ketones and vegetable oils, and low is resistant to halogen hydrocarbons. They are stable up to a temperature of 80 °C. It is produced in transparent or opaque variations, and is quite flexible and tough, but also fragile. It is used for general purposes (packaging for juices) or for industrial purposes (corrosion resistant materials, welding machine, etc. (Malpass, 2010).

Second generation

The second generation of biomaterials comprises a mixture of pre-gelatinized starch (40–70 %) and low density polyethylene (LDPE) with the addition of the hydrophilic copolymer such as ethylene acrylic acid, polyvinyl alcohol and vinyl acetate, which are used to compact. Complete degradation of starch takes 40 days and the degradation of the whole of the above-mentioned film lasts 2–3 years.

Third generation

The third generation of the material fully consists of biomaterials and can be divided into three main categories according to the origin and production methods:

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1. Polymers extracted/isolated directly from biomass
2. Polymers produced by classical chemical synthesis and bio-monomers
3. Polymers obtained directly from natural or genetically modified organisms (Chiellini, 2008).

Third generation biopolymers those are interesting for this study can be divided into three main categories according to their origin and method of production:

Polymers extracted/isolated directly from biomass

This category of biopolymers is most present on the market. Polymers of this category are obtained from plants, marine and domestic animals. Examples are polysaccharides, such as cellulose, chitin and starch, whey protein, casein, collagen, soy protein, myofibrillar proteins of animal muscle, etc., can be used alone or as a mixture with synthetic polyesters such as polylactic acid (PLA). The most prevalent category that is used in food packaging is cellulose-based paper. There appears also regenerated cellulose film (cellophane paper) and cellulose acetate. Hemicellulose, the second most abundant plant polymer in the world, is in its infancy as a biomaterial research for food packaging (Grondahl et al, 2006).

Starch

From raw materials annually renewable, based on starch are most used. Green plants such as potatoes, corn, wheat and rice are the raw materials for the production of biopolymers. Starch as the main component in them, it is potentially the most acceptable biodegradable polymer material due to its low cost, availability, and because it is produced from renewable sources. How is not a thermoplastic material, is used in mixtures with non-biodegradable polymers and biodegradable materials. The nature of the crystal grains in the form of 15–100 microns in diameter after extraction, the crystal structure is distorted to him pressing, heat, mechanical work and plasticizers such as water, glycerol and other polyols to make the thermoplastic starch (Bastioli, 2005). Plastic-coated starch (known as thermoplastic starch or TPS) is usually obtained by destroying or plastic coating of native starch with water using the thermo-mechanical energy in a continuous extrusion process. TPS can be manufactured in the same way as traditional plastics, but the sensitivity to water vapor and low mechanical properties render it useless for many applications. TPS achieves equilibrium properties after a few weeks (Averous et al, 2004).

Mixing starch with aliphatic polyesters improves its workability and biodegradation. The combination of starch with a water soluble polymer such as polyvinyl chloride (PVC) is used for the production of starch film (Adeodato Vieira et al, 2011).

This generation of plastics made from starch is completely biodegradable. From biodegradable plastics based on starch are made of different bags and sacks, rigid packaging such as hot-formed trays and containers, as well as products for filling gaps in packages. This material successfully replaces polystyrene and polyethylene in many applications (Rustogy and Chandra, 1998).

Chitin and chitosan

Chitin is the second most abundant polysaccharide after cellulose and differs from it only by the OH group. The most abundant in the cell walls of the skin of insects, the shells of shellfish and insects, and can be found in the cell walls of some fungi. Chitosan is actually deacetylated derivative of chitin (Clarnival and Halleux, 2005). Both are applied to produce various biodegradable films for packaging, and the largest they use as an edible coating to prolong the shelf-life of fresh fruits and vegetables (Zhao and Mc Daniel, 2005). Chitosan has a very poor mechanical properties and resistance to water.

More recently used composite films formed by mixing chitosan and starch showing good properties when it comes to water vapour and mechanical properties. Chitin and chitosan have good antimicrobial properties to a variety of fungi, yeasts and bacteria found in food and thus enable good use as materials that produce biodegradable packaging for food packaging, in particular, are important for prolonging the shelf-life of foods (Chiellini, 2008).

Other plant proteins

The two most common vegetable proteins used in the production of biodegradable packaging are chickpeas and isolated soy protein. Other proteins that are used include those extracted from wheat, pistachios, peas and sunflower (Dean and Yu, 2005). Other polymers based on proteins such as albumin, casein, fibrinogen, silk and elastin are taken into account due to its biodegradability as a raw material for the production of biodegradable packaging. Unfortunately they have not found wide use because they are difficult to process, do not melt without decompression, and difficult to mix with other polymers due to incompatibility and processing them is expensive unlike other polysaccharides (Battacharya et al, 2005).

Soybeans

Films made from isolated soy protein are very sensitive to moisture and is not strong. Adding stearic acid of about 25 % to improve properties of tensile and thermal properties and reduced moisture sensitivity (Lodha and Nteravali, 2005). More recently it was discovered that the soy protein together with glycerol, gellan gum, or K-carrageenan suitable for the production of biodegradable/edible soybean-based packaging containers (trays) (Mohareb and Mittal, 2007). Always in the production of such packaging must pay attention to the barrier properties to moisture because most hydrophilic in nature. Work on the properties of these materials is demanded because they have not yet come across a great application in production but is thought to want in the future. Collagen covers (intestine) for now remain the only widely applied product based on proteins. It is believed that the film based on a protein found extensive application as edible films in future also (Guilbert and Cuq, 2007).

Polymers produced by conventional chemical synthesis of bio-monomers

It is possible to get a large range biopolyesters by chemical synthesis. In theory, all previous packaging materials can be replaced by new types derived from renewable monomers, but the question of economic viability (Kobayashi, 2010, Berezina and Martelli, 2014).

The most famous of these groups biopolymer is polylactic acid (PLA-polylactide). PLA is biodegradable thermoplastic linear polyester, for its properties similar to polystyrene. The raw material for obtaining the lactic acid is obtained by fermentation of glucose or starch from another source. As a source of carbohydrate may be used corn, wheat or alternatively whey and molasses (Wackett, 2008).

There are several routes to useful industrial (or high molecular weight) PLA (Woo et al, 1995).

There are the two principal monomers lactic acid and lactide. The most common way to the PLA is a ring-opening polymerization of lactide with various metal catalysts (typically tin (II)-ethyl hexanoate) in solution or as a suspension. The reaction metal catalyst often causes racemization of PLA, reducing stereospecificity with respect to the starting material.

The second time the PLA is a direct condensation of lactic acid monomer. This procedure should be carried out at a temperature lower than 200 °C because above this temperature in the formation of low molecular weight materials. Direct condensation is carried out in steps, where the lactic acid in the first oligomerizes PLA oligomers. Thereafter, the polycondensation is carried out in solution or the melt where the short oligomeric units combine to give a high molecular weight polymer chain. Removing the water using vacuum or azeotropic destilation favors to polycondensation during transesterification. Even higher molecular weight can be obtained by careful crystallisation of the crude polymer from the melt. The carboxylic acids and alcohols, the last group are concentrated in the amorphous area of the solid polymer can be reacted.

Polymerization of the mixture of L- and D-lactide typically leads to the synthesis of poly-DL-lactide (PDLLA), which is amorphous. The use of a catalyst can result in PLA exhibiting crystallinity. In addition to lactic acid and lactide is used and lactic acid O-karoboksihidrid (Kricheldorf et al, 1983). In aerobically degrades completely over the lactic acid into water and carbon dioxide, and the biodegradation favorable conditions for 3–4 weeks (Mahalik and Nambiar, 2010).

PLA is mainly processed into thermoformed pads and containers for packing and serving food, films, transparencies and bottles and other packaging blown, but also mixed with other materials to improve their. PLA excellent water vapor-permeable which is important in the packaging of fresh food, which is necessary for the water vapor which evaporates quickly while reducing disturbance of the packaging. Is largely processed into thermoformed pads and containers for packing and serving food, films, transparencies and bottles and other packaging blown, but also mixed with other materials to improve their.

An example of the good properties of the variety of raspberry "Polana" which during storage maintains a stable concentration of anthocyanins in all combinations of packaging with PLA thickness of 25 or 40 microns (polypropylene boxes in PLA bags and cardboard boxes in the PLA bags) Unlike polypropylene box with holes and cardboard boxes . PLA bags thickness 25 micrometers maintain optimal gas composition (10 to 20 % CO_2 and 5 to 10 % O_2) for storing raspberries (Seglia et al, 2009).

Polymers obtained directly from natural or genetically modified organisms

Many bacteria accumulate these polymers as a source of energy and as a carbon reserve. This group includes polyhydroxyalkanoates (PHAs) and bacterial cellulose. PHAs are polyesters that are part of the living oraganizama structure, hydrophobic and insoluble in water.

Their characteristics are most associated with the properties of the monomer building blocks of which which a wide variety of different biopolymer can be synthesized by microbial fermentation. Enzyme PHA-polymerase catalyzes the reaction of polymerization HA in the PHA within the cell. The overall biochemical pathway of synthesis carried out in the cell in a series of enzyme reactions.

PHA, which synthesizes type *Alcaligenes, Azotobacter, Bacillus, Halobacterium, Rhizobium* and many other micro-organisms can be produced in large quantities biotechnologicaly, renewable substrate, using fermentation and known physical and chemical processes extracted from biomass after production. Depending on the bacteria and the carbon source, the polyhydroxyalkanoate may be manufactured from rigid brittle to plastic to rubber-like polymer. Have similar properties such as propylene and polyethylene, elastic and the thermoplastic (retained upon cooling forms) (Zivkovic, 2009).

The most common is the use of derivative polyhydroxybutyrate labeled PHB. PHB is biodegradable polyester linear prepared by bacterial fermentation of sugar or lipid. It can be used for food packaging, cosmetics and pharmaceutical products, as well as in agriculture. The aerobic conditions are completely degraded into water and carbon dioxide. Biodegradation in favorable conditions takes 5–6 weeks (Botana et al, 2010).

Apart from renewable, biodegradable plastics can be produced from synthetic polymers by using bacteria. The bacterium *Pseudomonas putida* converts styrene monomer in the polyhydroxyalkanoate (PHA), biodegradable plastic which has a wide range of applications. PHA is water insoluble, biodegradable material and compostable whose improvement works intensively before its commercialization (Chiellini, 2008).

Properties of biodegradable materials

Materials were based on the need to be useful in the food packaging industry so as to their physical and mechanical properties enable their eligibility and the application of a certain degree, but it also applies largely to prices.

Barrier properties

Poor barrier properties (especially humidity resistance) of the traditional and most widely used biomaterials (paper, cellulose films, and cellophane) are all known and is therefore necessary to mix these materials with synthetic polymers to achieve the desired barrier properties for packaging of many foodstuffs. Biomaterials made of polysaccharides having poor barrier properties when it comes to water vapor and other polar substances in a large proportion of the humidity, but at low or middle portion of humidity create good properties to oxygen and other non-polar substances such as various flavors and oils. Moisture vapor transmission rate was prepared from the starch material is 4–6 times higher than conventional materials made from synthetic polymers. Materials made of arabinoxylan as barley a low permeability as regards oxygen and CO_2 and a high permeability in the case of water vapor (the fluorinated materials are less surface hydrophilic such or yet to be finalized).

Some of barrier properties (Tab. 1) where the biomaterial and oil derived materials eg., PLA (polylactic acid) has a moisture vapor transmission rate 3–5 times greater than that of PET (polietilentetraftalat), LDPE (low density polyethylene), HDPE (high density polyethylene) and OPS (oriented polystyrene). PLA has improved barrier properties to oxygen from PS (polystyrene), but not as well as PET.

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TABLE 1: *The barrier properties of polymers to bio-based and those derived from oil (Chiellini, 2008).*

Polymers	Transfer rate of oxygen mL m^{-2} day^{-1} at 0 % relative humidity)	Moisture vapor transmission rate (g m^{-2} day^{-1} at 100 % relative humidity)	Temperature (°C)	Material thickness (mm)
OPLA (Oriented polylactic acid)	56.33	15.30	22	4.6
PLA (Polylactic acid)	200	66	23	0.1
PLA-M (Polylactic acid average molecular weight)		210 (at 90 % relative humidity)	25	0.25
PLLA + SiOx (Polylactic acid medium molecular weight silicic compounds + hydrocarbons)	84–99	34–40 (at 37.8 °C)	23	0.1
PHB (Polyhydroxybutyrate)	183	1.16	30	1
PHBV (Poly-hydroxybutyrate and hydroxy valerate)		1.39	30	1
PET (Polyethyleneterephthalate)	9.44	3.48	22	4.6
OPS (Oriented polystyrene)	532	5.18	22	4.6
LDPE (Low density polyethylene)		7.9	38 (at 90 % relative humidity)	0.75
LDPE+ 5% starch		36.85	38 (at 90 % relative humidity)	0.75

Experimental methods try to determine which materials have superior properties and are carried out and also the mixing of different types to obtain a better packing material.

Current restrictions

The main problem was the most-used for food packaging are their properties, processing and price. In particular, brittleness, low temperatures at which creates distortion, low resistance during processing (excluding PHA polymers) and their barrier properties, particularly to water vapor, limiting their use. In recent years, the price drops and they certainly will decline in the future and with time should increase process optimization and efficiency of plants for the production of such material. The limited availability of raw materials is still one of the most pressing problems that hinder the development of such materials. However it is unlikely that will be enough to PLA and to meet the needs of the food industry for some time.

PHA (polihidroksialkonati) has similar moisture vapor transmission rate as well as materials made from petroleum.

PHB (polyhydroxyalkanoates) has better barrier properties to oxygen from the PET and PP (polypropylene), and adequate barrier properties when it comes to fat and fragrances for products with a short shelf life.

Barrier properties of gases in most bio-materials depend on the ambient humidity, or PLA and PHA are exceptions.

Mechanical properties

The mechanical properties of most organic material similar to the materials derived from petroleum. For example properties of the PLA are defined by molecular weight of the polymer chain structure (linear with respect to the branched), the degree of crystallization etc. Orientation PLA improves the mechanical strength and heat stability, a different molecular weight and crystallization result of soft and elastic to hard and high strength materials. The amorphous and poorly crystallized PLA has a transparent, shiny surface; a highly crystalline PLA has an opaque surface. In Table 1 is avaliable to the melting temperature is 130–180 °C, and in the glassy form exceeds already at a temperature of 40–70 °C.

The physical properties of PHA copolymer depend of the composition and molecular structure of the copolymer. PHB is generally hard, highly crystalline thermoplastic polymer which most resembles the isotactic PP because of its mechanical properties. As such polymer PHB generally rigid and brittle, the introduction of the HV (hidoksivaleratne subunit) copolymers improves his mechanical properties so that it reduces the level of crystallization and melting temperature resulting in a decrease or increase in hardness toughness and resistance to impact. It is evident that a variety of PHA used in various applications due to its properties and a melting temperature which is 50–180 °C.

Methods for improving functionality

It is necessary to develop new techniques and processes to improve the barrier properties of bio-packaging. For example, the addition of bio-nanocomposite material shows that the improved mechanical properties of bio-materials and coating SiOx compounds with PLA material reduces moisture vapor transmission rate of 60 %. There are many applications of different techniques that improve different properties when it comes to these materials or to achieve this and applied in the future requires more effort and research that will help to these materials even more products and use (Chiellini, 2008).

Biopackaging forms

Biodegradable packaging is produced in several different forms to adapt to the requirements for packaging and storage of various products currently the most biodegradable gels, films, bags, boxes with lids and trays.

Biodegradable gel

The gels are commonly used to prevent microbial contamination, such as a hydrogel, the hydrogel chemical and polymeric network (IPN) (Farrisa et al, 2009). In lettuce, for example, impregnating gel no visible positive effects on maintaining the quality and content of pectic substances while the fruits of Solanum muricatum, protective gel positive effect on maintaining the beta-carotene (Schreiner et al, 2003). Radish gel coat starch-based proved effective to maintain the content of pectin while the same is not performed well for content Glucosinolate. It has been found that a combination of hydrogels for various polymeric materials reduce the service life of certain fruits, probably due to migration of water from the surrounding area (Garcia and Barrett, 2002). White extruded ginseng extract has good potential to maintain the concentration of antioxidants if used together with biodegradable stretch film (Rico et al, 2007).

Biodegradable films

Biodegradable films are designed with the intention of replacing the polyethylene film used for different purposes, from various industrial films, packaging products to the bag for the collection of organic waste. Such materials have better properties than traditional non-degradable plastics. They are resistant to moisture, warm organic materials for a period of several weeks or even months without changes in physical properties. This allows greater flexibility composting program. Good as a replacement for current films used in storage, transport and packaging of the product and are completely biodegradable. In addition, do not contain polyethylene, do not leave residues after composting and are made from renewable biomaterials (polyester derived from corn dextrose). A comparative study of the permeability of the biodegradable film for oxygen and carbon dioxide as a form of packaging for the fruit of tomatoes showed that films with low permeability negatively affected the quality of the fruit. However, when the permeability of the biodegradable films is into line with the respiration of the fruit, the prevention of contamination by microorganisms and insects achieved a positive effect on the durability and quality (Muratore et al, 2005).

Compared with polyphenol foil, biodegradable film permeability is significantly decreased. Two kinds of experimental films have been applied to freshly chopped pineapple and melon and observed for their influence on the microbiological quality control of the fruit during storage at 10 °C. The types of films that were used in this study are commercial plastic stretch film and experimental methyl-cellulose film that includes vanilla as a natural antimicrobial agent. Fresh sliced fruit, without any foil wrapping was used as a control. Methyl-cellulose film had inhibitory effect against *Escherichia coli,* and the yeast was reduced was recorded. Methyl cellulose films with vanillin increased the intensity of the yellow color with pineapple. Pineapple which was guarded in an ordinary commercial plastic film had a larger amount of ethanol. However, with pieces of pineapple coated biodegradable film with vanillin recorded a decrease of ascorbic acid by 90 % (Sungsuwan et al, 2008).

Biodegradable bags

The production technology is based on the use of biomaterials, namely polyester obtained from dextrose corn as the main raw material. Thus was obtained 100 % biodegradable packaging, which is the influence of microorganisms in conditions such as normal composting degraded organic material to carbon dioxide and water. By using natural raw materials, are not diminished physical properties of this product, but on the contrary, they are improved. Biodegradable bags are strong, flexible, resistant to breakage and damage, and resistant to moisture and temperature changes because of its raw material composition, the largest application with the food industry. Tests show that these bags are safe packaging, and can be used for the storage and packaging of food products. The addition of certain additives, the use of bags extends to other industrial branches.Prednost application of biodegradable bags is not only the functionality but also the fulfillment of all the rules of environmental protection. Upon completion of use bags as packaging, the bags when disposing of the land or compost decomposable to carbon dioxide and water, over a period of several weeks, and at the same time does not diminish the value of the resulting compost, which makes this container substantially different from previously known polyethylene (Nampoothiri et al, 2010).

Biodegradable boxes with lids

Box with a cover made of bi-oriented polystyrene, produced from corn. Such packaging is biodegradable after 47 days, depending on the conditions, and the process does not release harmful substances into the environment. It is crystal clear, allowing better visibility of contents, and is resistant to grease and withstands temperatures from –60 °C to +80 °C. PLA containers significantly better maintain fruit quality blueberries from standard ventilated switching containers at temperatures between 10 and 23 °C (Alemar et al, 2008).

Trays for fruits and vegetables

It was found that salad, and sliced broccoli, tomatoes, sweet corn and blueberries can be successfully kept in biodegradable trays of pulp wrapped in foil packaging of poured-caprolactone. Such patches are resistant to moisture but brittle. Correspond to the products during freezing them does not change their structural properties well (Makino and Hirata, 1996).

Biodegradable packaging with silver

Silver is used in the fight against infection and deterioration even in ancient Greece and Rome. In the 19th century botanist von Nagel found that small concentrations or silver particles have an antibacterial effect. Silver is used today in the food packaging system. Food longer maintains the quality texture, improve its storage capacity and maintain food security addition of silver in the packaging. Silver as an element in the production of biodegradable

TABLE 2: *Mechanical properties of bio-based polymers and polymers derived from oil (Chiellini, 2008).*

Polymers	Melting point T_m (°C)	The temperature of the glass transition T_g (°C)	Young's model of elasticity (kN mm^{-2})	Tensile strength (N mm^{-2})	Elongation at Break (%)
Starch	110–115		0.6–0.85	35–80	580–820
PLA (polylactic acid)	130–180	40–70	3.5	48–53	30–240
PHA (polyhydroxyalkanoates)	70–70	–30 do 10	0.7–1.8	18–24	3–25
PHB (polyhydroxybutyrate)	140–180	0	3.5	25–40	5–8
PHBV (polyhydroxybutyrate and hydroxyvalerate)	100–190	0–30	0.6–1	25–30	7–15
PHB (at 20 °C) (polyhydroxybutyrate)	180	4	3.5	43	5
PHBV (at 20 °C) (polyhydroxybutyrate and hydroxyvalerate)	145	1	1.2	20	50
PET (polyethylenetetraphthalate)	245–265	73–80	2.8–4.1	48–72	30–300
PS (polystyrene)	100	70–115	2.3–3.3	8–20	100–1000
LDPE (Low Density Polyethylene)	110	–30	0.2	10	620
PP (polypropylene)	176	0	1.7	3.8	400

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packaging has antibacterial role. It damages the cell walls, cell membranes and cytoplasm of bacteria. More recent studies have found that silver also affects the replication of DNA. Silver may be incorporated in the biopolymer in the form of pure silver, silver coated, or in the form of microparticles. Biodegradable film with silver is preferred over any other packaging materials because of its suppleness and exceptional adhesion ability to fruit. It is used for packaging fresh fruit and vegetables, as well as for storage and transportation of food. The product meets the requirements on sanitary objects that come into direct contact with food (Tokic et al, 2011, Otoni et all, 2016).

Biodegradation and composting

Biodegradation is the biochemical material conversion process in the water, biomass, carbon dioxide or methane in terms of the action of microorganisms. The process of biodegradation of the polymer consists of two steps. First, the process of reducing the polymer chain breaking of carbon bonds in terms of the effect of heat (degradation rate depends on temperature), humidity and the presence of microorganisms. Second, part of the process of biodegradation process begins when shorter chains become energy sources of microorganisms (bacteria, fungi or algae). This process is in full sense confirmed as biodegradation only when carbon compounds become food and microorganisms are transformed into water, biomass or carbon dioxide (Barone and Arikan, 2007).

Composting is an ancient method of converting organic matter remains in the fertile humus. Organic substances which improve soil structure formed from organic waste valuable help to retain moisture, the soil more breathable, increase soil microbiological activity, enriching it with nutrients and increase the resistance of plants to pests and diseases (Mondini et al, 2004).

It is a biological process in which the controlled conditions of elevated temperature and activity of certain microorganisms (composting cycle), there is a degradation of polymers to biobased as fast as the others decomposition of organic waste, resulting in a water, carbon dioxide and compost. The resulting organic compost is completely environmentally neutral and in agronomic terms shall have the same characteristics as other compost. The process of composting is a key segment of dealing with organic waste and return the remains of biodegradable materials in the new use (Xi et al, 2016).

The mechanism of biodegradation of polymers

- Degradable polymers – the chemical structure is changed under the influence of moisture, oxygen
- Biodegradable polymers – are broken down under the influence of naturally occurring microorganisms
- Hydrolytic degradable polymers – are degraded by hydrolysis
- Oxidation degradable polymers – are broken down by oxidation
- Photodegradable polymer – breaks down under the influence of natural light. Under the influence of photooxidation comes to breaking chemical bonds. This is a reaction involving radicals – chain reaction
- Thermal degradable polymers – thermally degradable (Jakobek, 2014).

Biodegradable plastic

Biodegradation of plastic happens if biological system (the body) uses organic materials, plastics as a source of nutrients. Microorganisms identify biodegradable plastics as food and consume and digest. Biodegradable plastics can be based on renewable raw materials – biomass (eg, starch) or non-renewable – fossil raw materials (eg, oil) processed by chemical or biotechnological processes. Source or process that produces biodegradable plastic does not affect the classification of biodegradable plastics.

- speed and the degree of degradation, in addition to the chemical composition of, depends on the starting material, and the composition of the region of the end product, which can be modified by adding fillers and plasticizers to improve properties or reduce cost.
- The degradation process of biodegradable plastics may involve simultaneous or sequential abiotic and biotic steps, but must include a step of biological mineralization. the biodegradation affect abiotic (cold, humidity ...) and biotic factors (micro-organisms)
- Level 1 – fragmentation (macroscopic decomposition and conversion to oligomers)
- 2nd stage – mineralization (conversion of the organic substances in inorganic, under the influence of microorganisms)
- Chemical mechanisms: hydrolysis, oxidation (Funke et al, 1998).

Biodegrad- and composting products are friendly alternative to protect the environment in order to preserve fossil fuels, and reduce CO_2 emissions. Often there is confusion about the biodegradable, bioizvorne or both. To illustrate the difference, the organization European Bioplastics has proposed a simple two-axis model that includes all kinds of plastic materials and their possible combinations.

Plastics are divided into four characteristic groups. The horizontal axis shows the biodegradability of plastic, and the vertical axis shows the source of raw materials – petrochemicals (fossil) sources or renewable sources. It followed four groups of materials:

- 1st plastic that is not biodegradable and is made from petrochemical sources-this category includes materials that we know as traditional plastics.
- 2nd biodegradable plastics from renewable resources is composite made of biomass and exhibits a biodegradability.
- 3rd biodegradable plastic from fossil sources is plastics that can be biodegradable or made of fossil origin.
- 4th non-biodegradable plastics from renewable sources – plastics produced from biomass but without the status of biodegradability (Križan, 2012).

Biodegradation of PLA (polylactic acid) and PHAs (polyhydroxyalkanoates)

PLA (polylactic acid) decomposes to CO_2, water and biomass in controlled composting conditions in less than 90 days. This decomposition takes place in a controlled environment in large plants where the compost temperature reaches 140 °C (Runjić Sokele, 2007).

PHAs (polyhydroxyalkanoates) are degradable in a biological environment, eg. in the compost. Microorganisms attack PHVB by an enzyme secreted by PHA de-polymerase that breaks the polymer base hydroxybutyrate (HB) and hidoksi-valerate (HV) subunits. HV and HB units later are used for growth. 55 % of tested yeast genus Penicillium degrades PHA. Degradation usually lasts up to 24 weeks but can be quite fast in a controlled environment (45 days) (Zivkovic, 2009).

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Compostable plastics

Compostable plastics are plastics that are biodegradable in the conditions and within the time frame of the cycle of composting. During industrial composting heap kompostirajućoj temperature can reach temperatures up to 70 °C. Composting occurs in humid conditions, the composting process takes place for months. It is important to understand that a biodegradable plastic is not necessarily Compostable (can biodegrade over time or under different conditions), while still compostable plastic biodegradable. Determination of criteria for compostable plastics is important because materials that are not suitable for composting can reduce the final quality of compost (Muscat et al, 2012).

Compostable plastic is defined by various national and international standards (eg. EN13432, ASTM D-6900) relating to industrial composting. EN13432 defines the characteristics of packaging materials must meet to be recognized as kompostabilan and acceptable for recycling of organic solid waste. EN 14995: 2006 extends the scope of plastic that is used for neambalažne application. These standards form the basis for a number of certification systems (Weber et all, 2002).

According to EN 13432 compostable material must have the following characteristics:

- Biodegradable: The ability to convert compostable materials in CO_2 under the action of microorganisms. This property is measured according to EN 14046 (also published as ISO 14855: biodegradability under controlled composting conditions). To demonstrate complete biodegradability, the level of biodegradation of at least 90 % must be achieved in less than 6 months.
- Dissolution (the possibility of disintegration): physical fragmentation and loss of visibility in the final compost, composting measured by testing in laboratory conditions (EN 14045)
- The absence of negative effects on the composting process
- Low levels of heavy metals and the lack of negative impact on the final compost.

Home composting is different than the industry at a lower temperature in the compost heap. Plastics must be specifically tested to demonstrate compostability in home composting conditions (Wiles and Scott, 2006)

Markings for biodegradable/compostable material

According to various international standards such as EN 13432, ASTM D 640 and Green Pla biodegradable/compostable materials are marked.

Technology, biopackaging

Extrusion, thermo-forming, casting, baking, blow molding, injection molding, laminating, coating and many other techniques are the main methods in the processing of plastics currently used for industrial production of plastic packaging fed, but mostly it LDPE (low density polyethylene), HDPE (high density polyethylene), PP (polypropylene), PS (polystyrene), PET (polietilentetraftalat) etc. the good fact is that, renewable at bioosnovi plastics generally show good adaptation to many of the aforementioned methods to be used for plastics processing, and require little or no adjustment. However some species proved to have limitations properties when it comes to processing, so for example, have poor mechanical and thermal properties making the material rigid, dry and stiff, but on the other hand have a poor performance when it comes to gases and moisture. In order to remove shortcomings in their properties need to overcome their own shortcomings before commercial use of packaging on bioosnovi, for example, to overcome the brittleness used biodegradable plasticizers. The plasticizers include glycol and other low molecular weight polyhydroxy component, polyethers and urea.

All in all, as far as the differences in technology and production bioplatike ordinary plastic, the only difference is that during the production of plastic on bioosnovi using various accessories (additive) to enhance its properties during processing. PLA is a hybrid material that has similar properties as synthetic plastics (PET, PP) and very good processing standard equipment used for processing synthetic plastic. In particular PLA films that develop techniques such as injection molding and thermo-forming very good barrier characteristics (section 3.1.). At present, the most represented film bags and containers for organic foods. Services that distribute food are increasingly using cups, pots, containers, laminated or extrusion coated PLA materials on the market more accessible.

The aliphatic polyester copolymer PHBV and PHB (poly-hydroxybutyrate and hydroxyvalerate) are commercially important as bioambalažna / biodegradable plastic and very well quoted when it comes to the food packaging industry. PHB is a very good thermoplastic material with a high degree of crystallization, while PHA with medium chain length longer behaves as an elastic material for which has a low melting point and a low degree of crystallization. But an important feature of PHA material is that it has low water vapor permeability, making it similar to LDPE. PHA is formed technique of blowing, extrusion and injection molding into forms such as films, bottles and containers for food. It is also very used in the biomedical industry (is nontoxic and biocompatible in humans). PCBs are also used for implants, bone plates, sutures and surgical. PHB transparencies above 130 ° C allow a wide range of use and industrial design. It is important to add that the PCB has a low permeability and breaks down without any residual residue. When conditions rashlađuvanja and freezing PHB shows slightly worse performance than the PPA, or at high temperatures its properties are much stronger and more stable than the PPA (Chiellini, 2008).

Advantages and disadvantages of bio packaging

By studying the available literature can be found arguments for both positive and negative characteristics of biopackaging. The good is the fact that all of the research leading to the fact that the disadvantages of bio-packaging and to eliminate its production continues to grow. There are many different opinions, different experts who express their opinions on bio-packaging as something good or as something that will become a reality. Below are separated some of the advantages and disadvantages of bio-packaging (Tables 3 and 4).

Questionnaire

The questionnaire was conducted to find out what is the awareness of the importance and benefits of the use of biodegradable packaging at the student population. The questionnaire was conducted on a sample of 120 respondents, 30 students (15 men and 15 women) with the first

TABLE 3: *Seven advantages and disadvantages of biodegradable packaging.*

Advantages	Disadvantages
renewable	the lack of arable land (future)
good for the environment	compostability
less energy to produce	a single bad properties
easier recycling	the awareness of people
it is not toxic	installations for the production
reduced dependence on oil	processing plants
reduced emissions CO_2	short lived

TABLE 4: *The advantages of biodegradable bags of paper and PE bag.*

Properties	Biodegradable bag	Paper bag	PE bag
Biodegradable	+	+	–
Compostable	+	+	–
Resistant to tearing	+	–	+
Waterproof	+	–	+
Fat resistant	+	–	+
Can be welded	+	–	+
Can be printed	+	+	+
High resistance to melting	+		+

three years of study (undergraduate studies). Included are four faculties at the University of Mostar as follows:

- Faculty of Medicine, University of Mostar (first three years)
- Agriculture and Food Technology, University of Mostar (undergraduate Food Technology)
- Faculty of Mathematics and Science Education, University of Mostar (undergraduate Tourism and Environmental Protection)
- Faculty of Pharmacy, University of Mostar (first three years)

The survey consists of 12 questions listed each separately below graph, a graph in the pictures give the answers to the exam, students in percent.

Graphs 13, 14, 15 and 16 contain a comparison of the Faculty made to four questions, appropriation at its own discretion, the questionnaire considering them the most important demonstration of the entire questionnaire.

Conclusion

Based on research and literature review can be concluded that biodegradable packaging has a bright future in the food industry. A number of factors including policy and legislative changes, as well as world demand for food and energy resources, will undoubtedly influence the development of biodegradable packaging. There is no doubt that the production of and demand for this packaging more to increase partly because of improved properties of biodegradable packaging and partly due to the decrease of its price, which is now unacceptable in relation to the price of other packaging materials.

By increasing the awareness of people, training and, most large retail chains acting as the producers and the consumers can increase the growth and development of biodegradable packaging. In order to overcome this kind of packaging the food industry needs to more research. Most scientists in this field agree that the future of biodegradable packaging depends on a mixture of bio-nanocomposite materials and polymers, which will improve its performance. They agree also that the greatest future of bioambalažnih material has PHA whose competitiveness depends on production, increased production leads to a direct reduction in prices.

The results of the questionnaire have led to the following conclusion:

1. Most students not using biodegradable packaging and does not favor the products included in that package because they do not perceive such products on the shelves of stores, believing that the design of such containers can be done to their perception and attitude change. Do not check the "eco-friendly" labels on products they purchase and are distributed around the thought that such a designation has an impact on people's thinking. Most would buy biodegradable bags in the store if the same price was acceptable, that is the same or not much higher than a regular bag. In her town are barely noticed containers for biodegradable waste but in this rare classified waste prior to its disposal. Opinions are divided about the impact of non-biodegradable packaging on the environment and three quarters of them agree that they see bio-packaging as one of the main ways to preserve the environment. And in the end most of them believe that the education the best way of increasing demand for bio-packaging.
2. Comparing the four faculties on four separate questions, the most positive responses give students of Tourism and Environmental Protection, then students Faculty of Pharmacy, Faculty of Food Technology and at the end of medical school students.

Conflict of interest

I declare that there is no conflict of interest in relation to the publication of this article.

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Graphs based on the results of the questionnaire; 1 – Faculty of Medicine; 2 – Food technology; 3 – Tourism and Environment; 4 – Faculty of Pharmacy

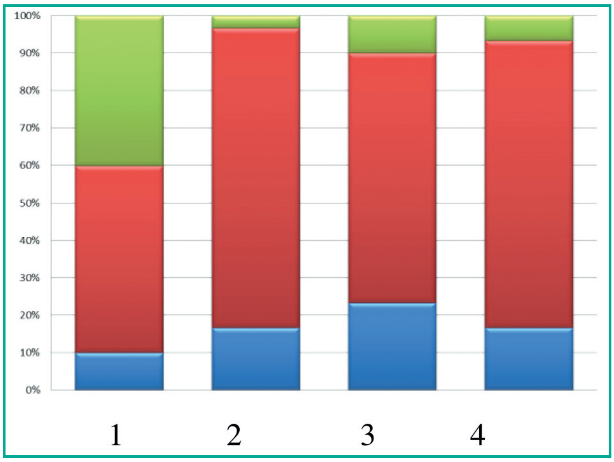

CHART 1: *Question 1 – Do you use biodegradable packaging? ■ I do not care; ■ No; ■ Yes*

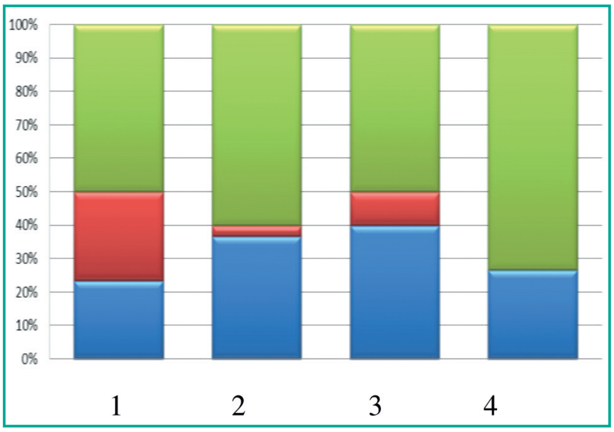

CHART 2: *Question 2 – Do you prefer the products included in the biodegradable packaging? ■ I do not care; ■ No; ■ Yes*

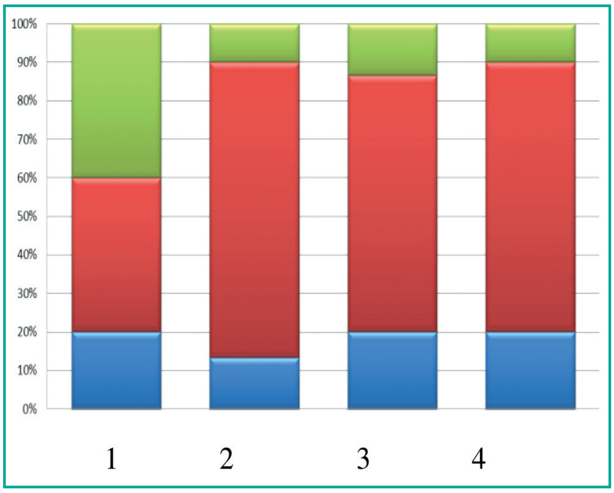

CHART 3: *Question 3 – Have you noticed any products in biodegradable packaging in stores? ■ No; ■ Sometimes; ■ Yes*

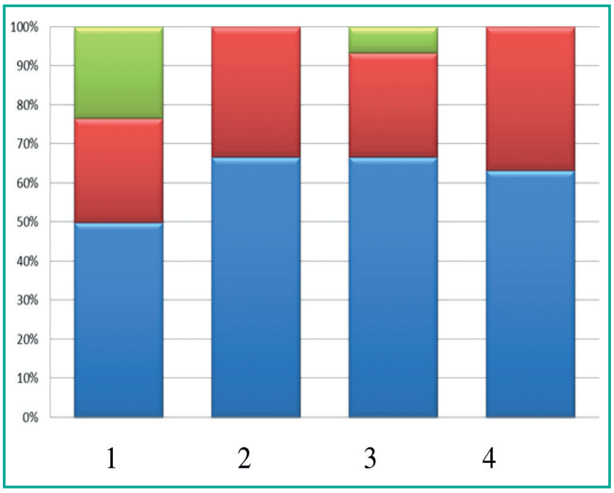

CHART 4: *Question 4 – Do you think the design of biodegradable packaging can make a popular and interesting? ■ No; ■ Sometimes; ■ Yes*

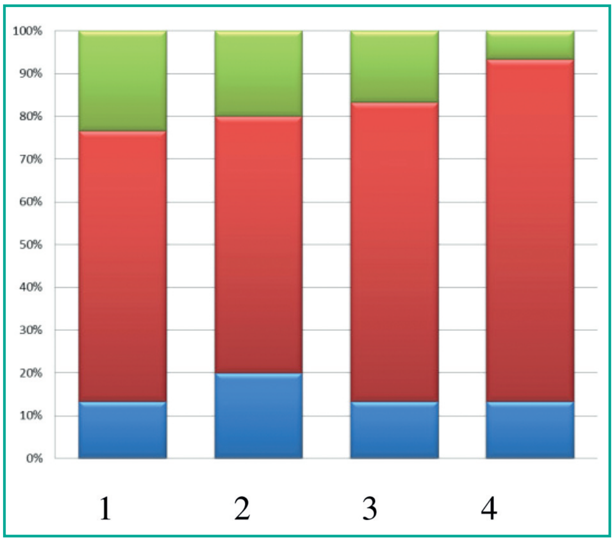

CHART 5: *Question 5 – Would you give more money for biodegradable bag than for ordinary, non-biodegradable plastic bag that costs less? ■ No; ■ Yes, if the price difference is not great; ■ Yes*

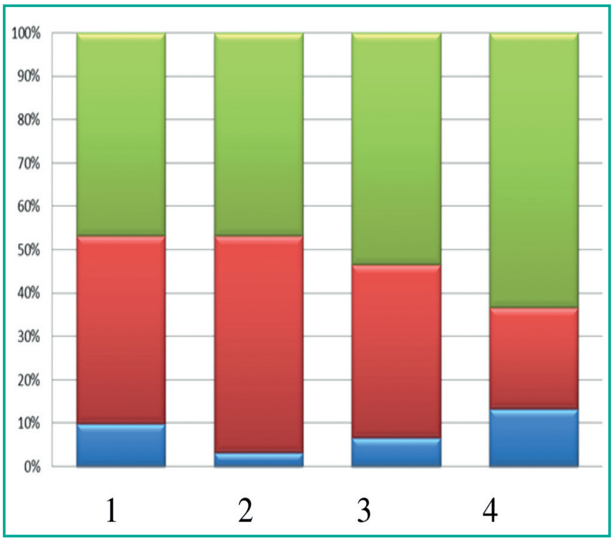

CHART 6: *Question 5 – I check whether "eco-friendly" symbol on the packaging of the products you buy? ■ No; ■ Sometimes; ■ Yes*

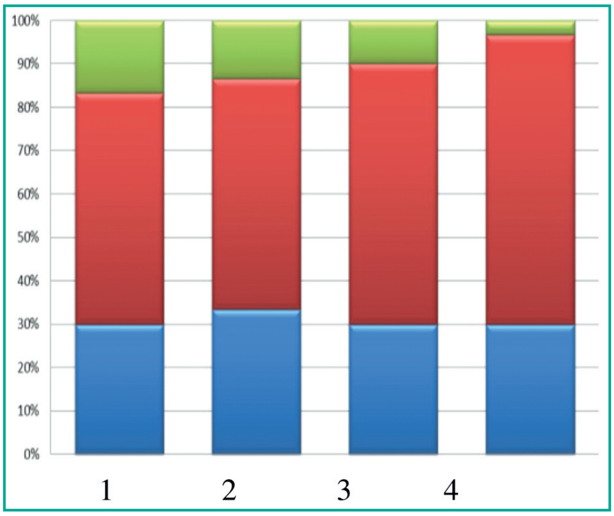

CHART 7: *Question 7 – Do you think that the symbol of "eco-friendly" products to influence the thinking of people?* ■ *No;* ■ *I'm not sure;* ■ *Yes*

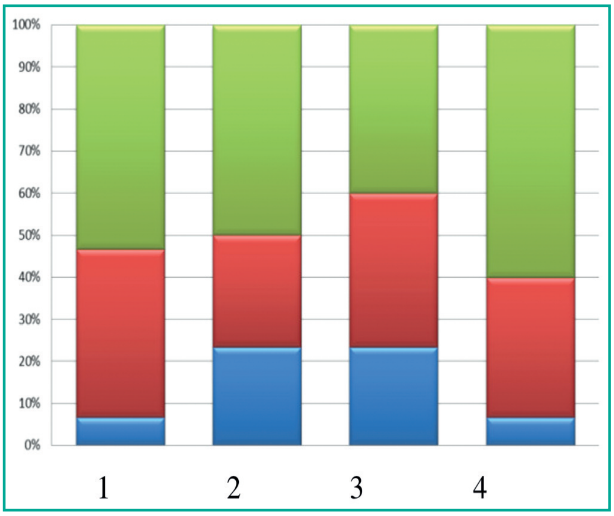

CHART 8: *Question 8 – You meet you in your town facilities / containers for the disposal of biodegradable waste?* ■ *No;* ■ *Sometimes;* ■ *Yes*

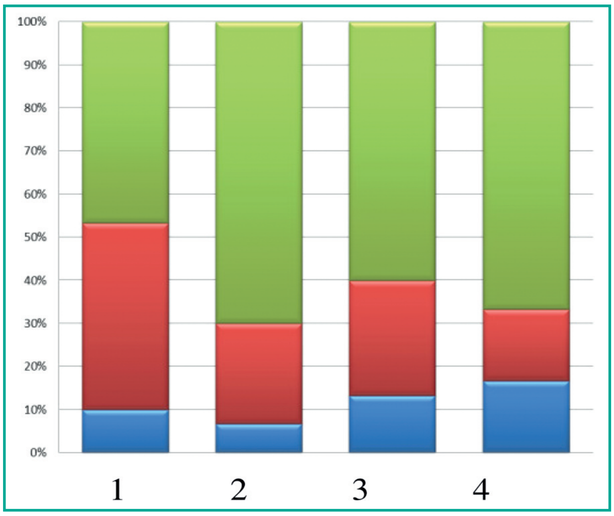

CHART 9: *Question 9 – What do you do with the packaging, which you have already used?* ■ *Throw together with other waste;* ■ *I try to reuse;* ■ *Classified before disposal*

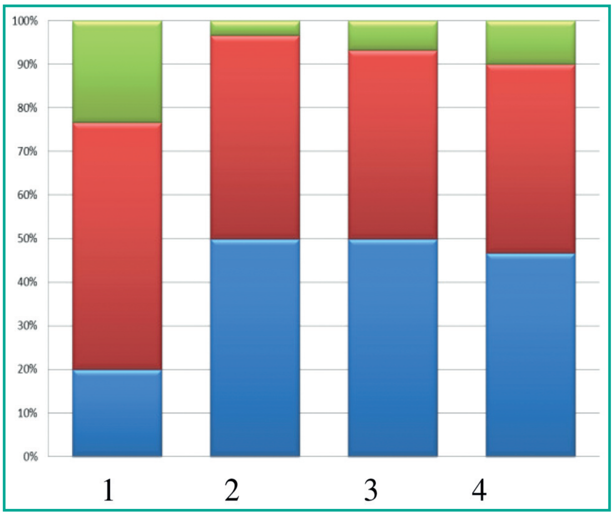

CHART 10: *Question 10 – Are you aware of the impact of degradable packaging on the environment?* ■ *I'm not aware of;* ■ *Yes and no;* ■ *I am aware*

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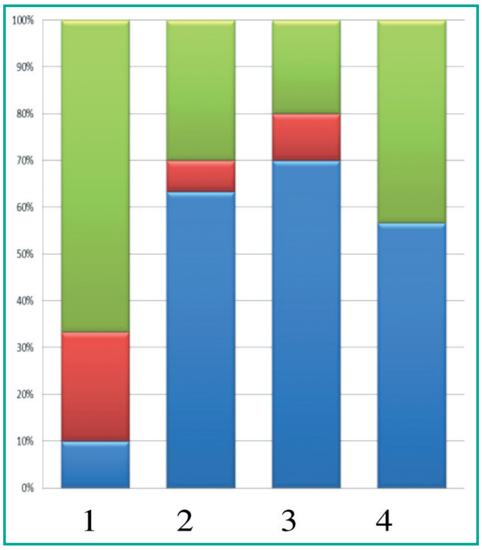

CHART 11: *Question 11 – What is your opinion on bio-packaging? ■ I am not sufficiently informed; ■ Not see how it can help to preserve nature; ■ Main ways to preserve the environment*

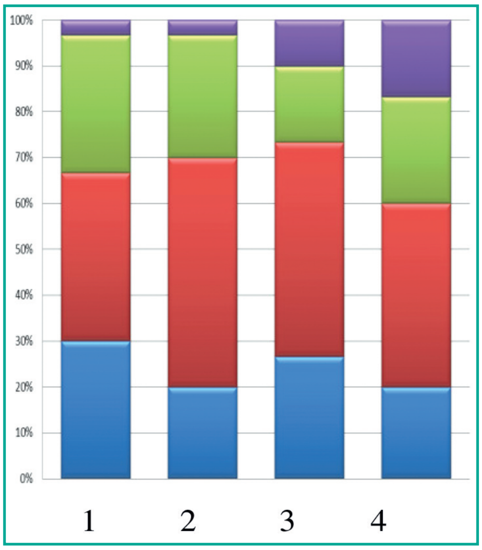

CHART 12: *Question 12 – In what way can increase the demand for bio-packaging? ■ I do not see a solution; ■ Prohibiting the use of biodegradable packaging; ■ Education about its benefits; ■ Decreasing prices*

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Comparison of the Faculty; ■ Faculty of Medicine; ■ Food technology; ■ Tourism and Environment; ■ Faculty of Pharmacy

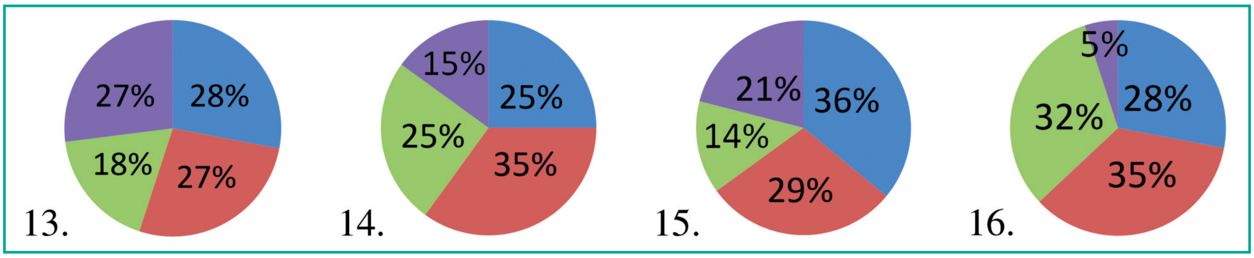

CHART 13: *Comparison of the number of students from different faculties who use biodegradable packaging*

CHART 14: *Comparison of the number of students from different faculties who noticed biodegradable packaging in stores*

CHART 15: *Comparison of the number of students at various colleges that are classified packaging prior to disposal*

CHART 16: *Comparison of the number of students at various colleges that are considered biodegradable packaging one of the basic ways to preserve the environment*

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