Investigating Technological Aspects Used in Active Juice Packing

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Abstract: One of the new concepts in juice packaging industry is active packaging that has been developed in response to ongoing changes in consumer and market demand. The main techniques used in active packaging technology are techniques which absorb oxygen, ethylene, moisture, carbon dioxide, and taste as well as releasing carbon dioxide, anti-bacterial, anti-oxidants, and smell and taste. In this paper, we tried to investigate the technical aspects used in active packaging, such as oxygen absorbers, carbon dioxide absorbers and releasers, ethylene absorbents, moisture absorbents, and smell and taste absorbers and releasers.
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1. Introduction

New technology in juice packaging industry are developed in response to the needs of customers and in line with manufacturing protected food products with softer approaches while remaining fresh, delicious, higher storage life, and controlled quality. Moreover, changes in the distribution (i.e. market globalization as a result of long distance distribution) or life styles of consumers (due to less time for shopping and cooking fresh food) are the most important challenges in the packaging industry. In recent decades, one of the innovations in the field of packaging industry is active and intelligent juice packaging which is established based on the free interaction of juice and its surrounding area. It is estimated that, the total value of global juice packaging industry at 2005 have been worth 1.558 billion dollars and it is forecasted to reach 2.649 billion at 2015 (Anon, 2005). The main concepts in the active juice packaging industry comprises ethylene and oxygen absorber, carbon dioxide agents, moisture regulators, antimicrobial packaging, and absorbents taste and smell absorbers and releasers.

Active juice packaging industry allows juice to have interaction with environment and play a dynamic role in maintaining food (Lahteenmaki and Arvola, 2011).

According to the definition of ACTIPACK project, active juice packaging is defined as following: (Ahvenainen, 2011)

Active juice packaging creates conditions to increase food storage shelf time and improve sensory characteristics and safety of juice while maintaining its (Day, 2011 and 2001).

Active packaging techniques in juice industry are classified into three categories:

- Absorbers
- Releaser systems
- Other systems

Based on the physical form of active systems, absorbers and releasers could be in the form of pads, labels, or films. The pads are freely placed in head space (Aaron L.Brody, Betty Bugusu, Jung H.Han, Claire Koelsch Sand, Tara H. Mchugh, 2008; Raija Ahvenainen, 2011). Labels are placed inside the cap of package. Films or other materials with antimicrobial properties comprised of two groups: immigrant which actively release active ingredients into the package. Nonimmigrant which can effectively prevent the growth of germs without releasing active agents and in this case, the foodstuff should be in direct contact with the active agents (Raija Ahvenainen, 2011).

2. Material and Methods

2.1. Oxygen absorbers

The presence of oxygen in packaged juices can have devastating effects (Joseph Kerry, Paul Butler, 2008) and initiated or speed oxidation reactions (Ahvenainen, 2011). Oxygen absorbers, by removing oxygen (current and incoming O2), can reduce oxidative reactions. Oxygen absorbers effectively prevent the growth of insects, worms or their eggs in cereals such as rice, wheat and soy (Ahvenainen, 2011). Despite the use of MAP technique and vacuum packaging techniques, these methods cannot effectively remove the remaining oxygen and about 0.10 to 2 percent of oxygen will be left inside the pores of juice. Moreover, the oxygen entered while packaging will not be removed by these methods. In the presence of this amount of oxygen, microbial growth still continues. Oxygen absorbers are capable of reducing oxygen levels to less than 0.01 percent (Aaron L.Brody, Eugene R.Strupinsky, Lauri R.Kline, 2001, Joseph Kerry, Paul Butler, 2008) and kept it at this level (Aaron L.Brody, Eugene R.Strupinsky, Lauri R.Kline, 2001). Today, following methods are used to absorb oxygen: iron oxidation, oxidation of ascorbic acid, light sensitive dye oxidation, oxidation enzyme (e.g. glucose oxidase plus catalase), unsaturated fatty acids (such as oleic acid and linoleic acid), and yeasts stabilized in a solid substrate (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). The most common system used for oxygen absorbing is iron oxidation technique (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). It is estimated that, 1 gram of iron can react with 300 cc of oxygen. If the primary oxygen content and the input oxygen content will be specified, you can select a suitable adsorbent to ensure the absence of oxygen during maintenance (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999).

Another oxygen absorber is enzyme that can absorb input oxygen using some substrates (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). The combination of the two enzymes of glucose oxidase and catalase is used to remove oxygen. Glucose oxidase enzyme produces hydrogen peroxide by converting glucose to glucono-delta-lactone. Since H_2O_2 is a remarkable by-product, catalase can break it (Aaron L.Brody, Eugene R. Strupinsky, Lauri R.Kline, 2001, Vermeiren F. Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999) so that G is the substrate of glucose:

Because this enzyme system is very sensitive to PH changes, water activity, salt content, temperature, and other factors, it cannot be effectively used in foods that contain low water (Raija Ahvenainen, 2011). Ascorbic acid is another oxygen absorber, which acts as a reducing agent. An interface metal, preferably copper, is used to catalyze the oxidation reaction (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). Another oxygen absorber technique is using packets of small spirals of an ethyl cellulose films containing a light-sensitive dye and an oxygen acceptor in the head space of transparent packages. Due to the brilliance of the film in the presence of light with appropriate wavelength, the excited dye molecules sensitize oxygen molecules so that, they penetrate into the polymer in single-mode. This single oxygen reacts with molecule acceptor and thus it will be consumed (Vermeiren F.Devlieghere M. van Beest N.de Kruijf J.Debevere, 1999).

2.2. Ethylene absorbents

Ethylene (C_2H_4) is a vegetative hormone that accelerated respiration rate and leads to ripeness, aging, and softening of many fruits, vegetables, and flowers (Joseph Kerry, Paul Butler, 2008). In addition, ethylene accumulation can cause yellowing of green plants and may be responsible the anomalies after harvesting fruits and vegetables (Raija Ahvenainen. 2011, Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). Many of ethylene absorbent (e.g. aluminum oxide, potassium permanganate, activated carbon with metal catalysts, and zeolite) are present (Raija Ahvenainen, 2011). They are placed into pads or films. Potassium permanganate ($KMnO_4$) is the most effective system for absorbing ethylene which produces ethylene oxide, acetate, and ethanol. During this process, the color will changes from purple to brown and it is used to determine the capacity absorbing the residual ethylene (Joseph Kerry, Paul Butler, 2008). $KMnO_4$ cannot be used in direct contact with the juice and must be provided inside pads. Some products of $KMnO_4$, 4 to 6 percent, stabilize on a broad neutral substrate such as perlite, alumina, silica gel, vermiculite, and activated carbon. Other ethylene absorber, based on adsorption and subsequent cracking of ethylene molecule on activated carbon (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999), can effectively remove ethylene with a variety of metal catalysts and is placed inside paper bags and corrugated cardboards (Joseph Kerry, Paul Butler, 2008). Other technologies to absorb ethylene are well-scattered minerals such as zeolites, clays, and Japanese oya in the packaging film (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999).

2.3. Carbon dioxide absorber and releaser

The CO_2, due to its benefits, is added to the juice packages, for example, to suppress microbial growth in products such as meat, chicken, cheese and bakery products. In addition, carbon dioxide is added to fresh products to reduce the amount of respiration and to prevent shrinking due to the vacuum created by oxygen absorbers (Aaron L.Brody, Betty Bugusu, Jung H.Han, Claire Koelsch Sand, Tara H. Mchugh, 2008, Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). The carbon dioxide absorbents are particularly used for fresh, roasted and ground coffee that releases a considerable amount of carbon dioxide (Joseph Kerry, Paul Butler, 2008). Removing oxygen from is the package by absorbing oxygen and releasing carbon dioxide by provided pads is useful (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999) and is used to increase the storage life of fresh meat and fish (Joseph Kerry, Paul Butler, 2008). Such systems are based on iron carbonate or a mixture of ascorbic acid and sodium bicarbonate. When sodium bicarbonate is used with citric acid and soaked with water, it produces CO_2 (Aaron L.Brody, Eugene R.Strupinsky, Lauri R.Kline, 2001, Vermeiren F.Devlieghere M.van Beest N.de

Kruijf J.Debevere, 1999). For the products which, size and appearance of package is important, O2 absorbents and CO2 releasers is being used (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). Although carbon dioxide prevents microbial growth in atmosphere-modified packaging, extra CO2 may have an adverse effect on the product or nullifies the effect of preventive action (Aaron L.Brody, Eugene R.Strupinsky, Lauri R.Kline, 2001). Active compound of Ca (OH)2 in the presence of adequate moisture reacts with CO2 and produces CaCO3 (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). Another technology in CO2 absorbent is packages containing CaO and a hydration factor such as silica gel that is absorbed water. This process removes the extra carbon dioxide produced by the process of fruits and vegetables and hence, the effects of extra carbon dioxide including reduced PH and change of color and the taste will be removed.

2.4. Green Containers

One of the key orientations in packaging industry of food products package is sustainable packaging. Sustainable packaging means designing special mechanism to produce containers in order to preservation of non-renewable resources. Sustainable packaging coalition, a consortium comprised from more than 200 industrial companies, defines the features of sustainable packaging as follows:

- Assurance of health, safety, and usefulness for consumption during consumption
- Enjoyment of efficiency and costs according with market criteria
- Possibility of producing, shipping and, recycling with the use of renewable resources
- Optimized use of renewable and recyclable resources
- Possibility of producing with clean technologies and using best techniques
- Using of raw materials that, in all possible scenario of ending the life of container, have necessary safety
- Designed in a way so that, use raw materials and energy in an optimized manner
- Possibility of effective recycling and use in all industrial and biological cycle compatible with living environment

Sustainability of a packaging system is determined based on the materials used. Therefore, companies and environmental groups work together to reduce the adverse effects of this industry on world's raw materials. In addition, companies, suppliers, and related legislative institutions, have provided guidelines for sustainable packaging industry that highlights the types of raw materials and designs. Regarding the issues related to land, there are numerous laws including regulations pertaining to the packaging, the instructions on packaging waste from European Commission of legislation, evaluation and granting permission to chemical materials, and BSEN 13432 standard.

The green milk container used by the Superior Dairy company, Canton, Ohio is one of them. This container, due to the efficient design that reduces distribution costs and required space for transportation, is completely environment friendly.

3. Results

In the case of moisture-sensitive fruits, excessive moisture in the package can cause lumps in the product, softening of brittle products such as crackers, biscuit and moistening of water-absorbent products like candies. In contrast, removing so much moisture from juice may cause dehydration or creating conditions favorable for oxidation (Aaron L.Brody, Betty Bugusu, Jung H.Han, Claire Koelsch Sand, Tara H. Mchugh, 2008, Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). The main purpose of moisture control is reducing water activity and subsequent growth of molds, yeasts, and bacteria in the juice. Another application is the removal of water from the melting of frozen meat, fish, juice, and blood and tissue fluids. The third reason for moisture control is to prevent condensation of vapor of fresh horticultural products (Vermeiren F.Devlieghere M. van Beest N.de Kruijf J.Debevere, 1999). Desiccants such as silica gel, natural clay, and calcium oxide are used in dried juices (Aaron L.Brody, Betty Bugusu, Jung H.Han, Claire Koelsch Sand, Tara H. Mchugh, 2008). Desiccants are used as porous pads of plastic cartridges and vapor blockers (Aaron L.Brody, Betty Bugusu, Jung H.Han, Claire Koelsch Sand, Tara H. Mchugh, 2008). In addition to the absorber pads in packages of dry juices, several companies produce moisture absorbing pads and films to control moisture in products with high water activities such as, meat, fish, chicken, fruit and vegetables. Essentially, these absorbent consists of two non-woven micro-porous plastic layers such as polyethylene or polypropylene, which there is a super absorbent polymer in between capable of absorbing water 500 times more than its weight. Super absorbent polymers include polyacrylamide salts, carboxymethyl cellulose (CMC) and starch copolymers that have a strong tendency to absorb water (Anon. 2011, Day, B.P.F., 2011, and Robertson, G.L. (ed.), 2006). In general, moisture absorbent pads are being used at the bottom of packages of fresh meats, fish, and chicken to absorb water seeps of tissues that are invisible (Reynolds, G. 2007). In addition, large films are being used to absorb the moisture of melted ice of sea products by air movement (Vermeiren F.Devlieghere M.van Beest N. de Kruijf J.Debevere, 1999).

Absorption of juice taste by polymeric packaging materials may result in the loss of flavor and affect its organoleptic profile (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). Normally, removing taste may have devastating effects on juice quality but it could have positive application in selectively absorbing unwanted odors or flavors (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). From commercial point of view, active juice packaging techniques were rarely used for selective removal of undesirable flavors, but there are also many opportunities (Joseph Kerry, Paul Butler, 2008). Some varieties of orange, such as NAVEL, particularly, are susceptible to bitter taste due to the limonene that is released after pressing and pasteurization of juice. Naringin is a bitter compound that could be found in many citrus juices (Vermeiren F. Devlieghere M.van Beest N.de Kruijf J.Debevere, 1999). A possible solution in active packaging is using limonene absorbents such as cellulose acetate or acetaldehyde paper within the packaging material of orange juice (Reynolds, G. 2007). To deal with this, the cellulose acetate (CA) layer containing naringinase enzymes with fungal origin including α-l-rhamnosidase and β-glycosidase that hydrolyzes naringin to naringenin and prunine that both compounds are non-bitter. Approved cellulose acetate films for contact in the juice industry, which include stabilized naringinase have been shown that, can hydrolyze 60 percent of naringin in grapefruit juice within two weeks at 7°C and reduce the content of limonene due to its absorption in cellulose acetate film (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). Two types of bad smells which could be removed by active juice packaging industry are amines, which are formed by decomposition of fish muscle proteins and aldehydes that comes from auto-oxidation of fats and oils. Unpleasant odors that are volatile amines such as trimethylamine associated with decomposition of fish protein are alkaline and can be neutralized by various acidic compounds (Vermeiren F.Devlieghere M.van Beest N.de Kruijf J. Debevere, 1999). Commercial items are bags of films containing iron salts and an organic acid such as citrate or ascorbate. These bags oxidize amines so that, they can be absorbed by polymer film (Reynolds, G. 2007). Removal of aldehydes such as Hexanal and heptanal from head space can be performed by taste and odor control technology DUPONT (OTC) which is based on molecular sieve with pore size of about 5 nm. This technology can be used for snacks, cereals, dairy products, fish, and chicken. Similar technology to eliminate aldehydes is the use of a range of synthetic aluminosilicate zeolites which absorbs odors in their super porous structure. The powders of this material can be used inside packaging materials, especially paper- based packages (Day, B.P.F., 2011).

4. Discussions

Active packaging in juice industry is one of the exciting emerging technologies in the field of food technology that have numerous benefits in maintaining wide range of juice products. Active packaging is technology that grants new fields of trust due to the recent advances in the fields of packaging, materials science, biotechnology and new demands of the consumers (Ahvenainen, R. and Hurme, E., 1997). It aims to preserve sensory quality and enhance the storage shelf time of the juice while maintaining the nutritional value and microbiological safety (Consumer Goods).

Oxygen and moisture absorbers are among the very important commercial subsets of active packaging in juice industry and their market were growing in the past decade and it is predicted to continue after 2015 (Anon, 2005). Absorbers remove unwanted compounds such as oxygen, carbon dioxide, ethylene, additional water, and smell. Releaser systems, actively, release some ingredients into the pack. Other systems may have various duties like auto-cooling and auto-heating (Raija Ahvenainen, 2011). The use of active packaging increasingly gets popular and many new opportunities in the food and non- industries will be opened in order to use this technology in the future (Joseph Kerry, Paul Butler, 2008).

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