UAlg
UNIVERSIDADE DO ALGARVE

Universidade do Algarve

Use of innovative active packaging in storage and postharvest quality of fresh strawberries and dehydrated kiwifruit snacks

Cristino Sousa Dores

Dissertação para obtenção do Grau de Mestre em:
Hortofruticultura

Trabalho efetuado sob a orientação de:

Professora Doutora Maria Dulce Carlos Antunes

Doutora Custódia Maria Luís Gago

2017

UAlg
UNIVERSIDADE DO ALGARVE

Universidade do Algarve

Use of innovative active packaging in storage and postharvest quality of fresh strawberries and dehydrated kiwifruit snacks

Cristino Sousa Dores

Dissertação para obtenção do Grau de Mestre em:
Hortofruticultura

Trabalho efetuado sob a orientação de:

Professora Doutora Maria Dulce Carlos Antunes

Doutora Custódia Maria Luís Gago

2017

Título: Use of innovative active packaging in storage and postharvest quality of fresh strawberries and dehydrated kiwifruit snacks.

Aluno: 47503

Declaração de autoria

Declaro ser o autor deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Cristino Sousa Dores

Agradecimentos/Acknowledgements

À professora Doutora Maria Dulce Carlos Antunes, Orientadora, pela confiança, aposta e disponibilidade depositadas em mim. Pela liderança, exigência e rigor que a distinguem. Por me proporcionar momentos pessoais e académicos inesquecíveis que levarei para sempre comigo.

À Doutora Custódia Maria Luís Gago, Coorientadora, pelo seu tempo, conhecimento, amizade e simpatia. Pelo foco no que realmente importa, pela experiência e orientação e por tornar tudo muito mais fácil.

À Doutora Adriana Cavaco Guerreiro, por se dividir em mil, por tornar possível o impossível, pelo pragmatismo, pela praticabilidade, pela paciência e compreensão, pela amizade, partilha e atenção. Por tudo.

To Anouk Dantuma, for such a good reception, for making me feel like home in that wonderful country which is The Netherlands. For the friendship, teachings, patience and time. Dank u wel.

Resumo

Uma maior consciencialização ambiental e alimentar tem vindo a assolar populações um pouco por todo o mundo. A crescente procura por alimentos frescos e saudáveis, livres de conservantes sintéticos e que ao mesmo tempo que não prejudiquem o meio ambiente, tem sido palavra de ordem dos consumidores.

A extrema perecibilidade de produtos frescos, nomeadamente de fruta, leva a que medidas de prevenção sejam tomadas para que a sua qualidade possa ser mantida e prolongada. A correta utilização de técnicas de pós-colheita assume um papel preponderante nesta prevenção, atuando de forma direta na redução da deterioração frutícola.

Neste sentido, o tipo de embalagem utilizada na conservação de frutos, é indispensável para um ótimo armazenamento, proteção e distribuição dos mesmos. No entanto, apenas proteção contra choques físicos não é, por si só, suficiente para a manutenção da qualidade da fruta, que poderá sofrer danos relacionados com más técnicas de pós-colheita ou com a ineficácia das embalagens, que deveriam a todo o custo proteger o produto desde o campo até ao consumidor. Como tal, para fazer face a um problema cujo prejuízo pode levar a perdas entre produtor e consumidor na ordem dos 20%, um conceito inovador promete reduzir estas perdas, prolongando o tempo de armazenamento e vida de prateleira ao mesmo tempo que mantém a qualidade dos frutos, o que permite uma maior e melhor disponibilidade do produto.

Este conceito dá-se o nome de Embalagens Ativas. Estas embalagens caracterizam-se por, através de aditivos na sua composição, interagirem com o produto no seu interior, aditivos esses que, visam ser *food-safe* e biodegradáveis, sendo, portanto, uma alternativa viável aos aditivos químicos usualmente utilizados na conservação de frutos.

De acordo com estudos anteriores, os óleos essenciais conhecidos pelas suas propriedades antimicrobianas, assim como os alginatos, sais extraídos de algas da classe Phaeophyceae, cujas propriedades de encapsulação, revestimento e absorção da humidade são de elevado interesse, são dois dos aditivos que demonstraram ter sucesso na preservação de pequenos frutos.

Assim sendo, a conceção das embalagens ativas utilizadas neste estudo tiveram como base os aditivos anteriormente descritos em concentrações superiores à concentração mínima inibitória (MIC) estabelecidos em trabalhos anteriores.

O morango (*Fragaria x ananassa*), é um dos frutos mais consumidos no mundo inteiro, sendo, portanto, um fruto com grande importância económica. Uma vez que este é um fruto

altamente perecível, com graves problemas de conservação, onde se registam perdas graves, processos alternativos de preservação da qualidade em pós-colheita poderão ser de grande interesse na manutenção da qualidade destes frutos.

A procura por produtos alimentares saudáveis diferenciados tem vindo a aumentar, nesse sentido, produtos alternativos vão aos poucos surgindo no mercado.

A utilização de snacks de fruta desidratada neste trabalho visa estudar a conservação destes produtos inovadores, tentando tornar o método de preservação por embalagens ativas um método eficaz não só para produtos convencionais assim como para produtos inovadores que sofram de problemas semelhantes de preservação da qualidade em armazenamento.

O objetivo deste estudo foi avaliar o efeito de embalagens ativas na preservação da qualidade em pós-colheita de morangos frescos e snacks desidratados de kiwi, tentando perceber qual a concentração mais eficaz de entre as estudadas e perspetivar melhorias na conceção e preservação de frutos utilizando embalagens ativas.

Foram realizados 3 ensaios diferentes, utilizando embalagens ativas de diferentes composições. Dos 3 ensaios, um foi feito em snacks desidratados de kiwi (Capítulo III) e os outros dois foram realizados utilizando morangos em fresco (Capítulos IV e V).

Este estudo teve início em Arnhem, Holanda, onde em parceria com a empresa Kenniscentrum Papier en Karton (KCPK), foram fabricadas embalagens ativas com o intuito de serem utilizadas num dos ensaios com morangos (Capítulo IV) e noutro com os snacks (Capítulo III). Posteriormente, para além destas, um outro tipo de embalagens, feitas por uma empresa externa foram ainda testadas num terceiro ensaio utilizando morangos (Capítulo V). As embalagens continham na sua composição Alginato (1 e 2%); Alginato (1 e 2%) combinado com compostos de óleos essenciais, Citral e Eugenol (em concentrações correspondentes ao dobro e quadruplo da MIC, que é 0.15 e 0.1% respetivamente); Alginato (1 e 2%) combinado com Glycix (70%) e extratos vegetais.

Os ensaios realizados com morangos (Chapter IV e V) foram levados a cabo ao longo de 14 dias, com medições dos parâmetros de qualidade no tempo inicial (0 dias) e ao longo de todo o período de armazenamento, enquanto o ensaio relativo aos snacks de kiwi (Chapter III) durou 4 meses, com medições periódicas mensais.

Os parâmetros de qualidade analisados nos ensaios dos morangos foram a cor (L*, a*, b*), firmeza, teor de sólidos solúveis (ºBrix), perda de peso, determinação da carga microbiana (microrganismos aeróbios mesófilos, psicrófilos e fungos e leveduras), antocianinas e avaliação do painel de provadores. No ensaio dos snacks de kiwi, foram medidos a cor (L*, hº, C*), firmeza, determinação da carga microbiana (microrganismos aeróbios mesófilos,

Enterobacteriaceae e fungos e leveduras), atividade da água (aw) e avaliação por painel de provadores.

De um modo geral, não se registaram diferenças significativas entre os vários tipos de tratamentos nas embalagens ativas. No entanto é possível verificar que no caso dos morangos, onde a carga microbiana é um dos parâmetros mais críticos, as embalagens que contêm na sua composição óleos essenciais, apresentam restrições no desenvolvimento de microrganismos, a par de que na fruta desidratada, no último mês de armazenamento o mesmo se verificou para as embalagens testadas em comparação aos tratamentos controlo.

No caso dos snacks de kiwi, as embalagens cujas composições continham Alginato 1% demonstraram ser as responsáveis pelos snacks com melhor aparência ao longo dos 4 meses de armazenamento.

Este estudo comtempla alguns processos inovadores no que diz respeito ao armazenamento e fabrico de embalagens ativas, e uma vez que o armazenamento e conservação de alimentos é um problema transversal a todos os setores, será de bom senso que no futuro se possam, a partir destes pressupostos, aperfeiçoar estes ou outros processos, no sentido de melhorar a preservação de frutícolas e outros alimentos utilizando embalagens ativas.

Palavras chave: fruta, pós-colheita, embalagens ativas, *food-safe*, morango, snacks de fruta.

Abstract

The consumers demand for quality is growing, and the only way that the market as to keep up and respond to that demand is to ensure that the consumers get their needs fulfilled.

For that, Active packaging(AP) is a concept that could change the paradigm of food preservation. With this work, it was pretended to test the effect of several types of AP, with different formulations, on fresh strawberry fruit (*Fragaria x ananassa*. cv. Festival) and dehydrated kiwifruit snacks (*Actinidia deliciosa* cv. Hayward) post-harvest quality. Alginate, essential oils and vegetal extracts were some of the compounds used on the AP composition.

Quality parameters analysis were performed by measuring color CIE ($L^*h^oC^*$) and ($L^*a^ob^*$), firmness/hardness, soluble solids content(°Brix), weight loss, total anthocyanin content, microbial growth and taste panels.

For the dehydrated kiwifruit snacks experiment, through storage, there were no significant differences among active packaging for the most quality parameters studied. Nevertheless, Alginate 1% performed better in terms of appearance as compared to control, and control samples showed slightly higher microbial spoilage after 4 months and appearance decreased from 3 to 4 months. For the strawberries experiments, through storage, there were no significant differences among active packaging for the most quality parameters studied. Nevertheless, the packages with alginate and essential oils combined showed interesting results on restraining the microbiological content and reducing spoilage as compared to control. Further studies are needed to improve these packages.

Keywords: Active packaging, strawberry, kiwifruit, quality, *Fragaria x ananassa.*, *Actinidia deliciosa*, snacks.

Aim and chapters

The aim of this work was to evaluate the effect of active packages with different formulations on fresh strawberries and Kiwifruit snacks quality through storage. Regarding previous works, were chosen 3 major compounds that could serve the biggest purpose of post-harvest quality procedures, keep the freshness and fruit quality for longer periods, improving the shelf-life period. These compounds were the essential oils components known for their antimicrobial effects, Eugenol and Citral, and Sodium Alginate known for his water barrier and moister absorbent properties. Minimum inhibitory concentrations (MIC) for Eugenol and Citral were established in previous works by Guerreiro et al. (2015) as well as the most suitable Alginate concentrations for this kind of experiments. Therefore, the active packages were made by adding to a non-treated paper several combinations of these 3 compounds. Quality parameters analysis were performed by measuring color CIE (L*h^{o} C*) or (L*a* b*), firmness, soluble solids content(°Brix), weight loss, total anthocyanin content, microbial growth and taste panels.

Six chapters form this work.

Chapter I is focused on some introductory notes through a state-of-art including the mainly themes of this work.

Chapter II regards the short term scientific mission (STSM) report resulting from the work done on the production of active packaging that took place on Arnhem, Netherlands, under Kenniscentrum Papier en Karton (KCPK) supervision.

On Chapter III, a report about the effect of active packaging on the storage of kiwifruit snacks is presented, showing how an active packaging could influence a dehydrated product quality which are the healthy food new trend.

Chapters IV and V report the effect of active packaging on the storage of strawberry fruits, which are among the most consumed fruits worldwide. There is a clear difference between those two chapters that led to their division. The measurements of quality evaluation were the same, however different types of active packages were tested.

To finish, Chapter VI ends with a conclusion that synthesized the previous work and future perspectives that could motivate the continuation and the appearing of new related studies.

Contents

List of Figures

List of Tables

Chapter I - *Introduction*

1. Packaging

Packaging is defined as enclosing food to protect it from tampering or contamination from physical, chemical and biological sources. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their origin point and still be wholesome at the time of consumption. The primary purpose of food packaging is to protect the food against physical damage, oxygen, water vapor, ultraviolet light, and both chemical and microbiological contamination (Prasad and Kochhar, 2014).

Conventional polymers made of petroleum-based raw materials are a widely used packaging for foods. Nowadays, bio-based packaging for foodstuffs becomes increasingly popular, and it is being used as a replacement for conventional polymers (Dukalska et al., 2013). Plastic waste is considered a serious social problem. The market for plastics has increased exponentially to an estimated annual production of 280 million tons in 2011, of which approximated 18.5 million tons, i.e. 39% of the European plastics demand, is used for packaging in Europe (Plastics, 2011).

Increased environmental concerns over the use of certain synthetic packaging and coatings in combination with consumer demands for both higher quality and longer shelf life have led to increased interest in alternative packaging materials research (Khwaldia, 2010).

Despite in some assays of the present study were used plastic packages exclusively as fruit containers, it is supposed that the active biodegradable paper tested used could replace the plastic containers in the future (Figures 1.1 and 1.2).

Figure 1.1 – Standard strawberry package (Sambrailo Packaging, 2017)

Figure 1.2 – Alternative strawberry paper-board package (Dantuma and Tiesktra, 2016).

2. Active Packaging

In response to the dynamic changes in current consumer demand and market trends, the area of Active Packaging is increasing significantly. Unlike traditional packaging, which must be totally inert, active packaging is designed to interact with the contents and/or the surrounding environment. Active packaging refers to the incorporation of additives into packaging systems with the aim of maintaining or extending product quality and shelf-life to meet consumer demands in terms of providing high-quality products that are also fresh and safe. Now, active packaging is mainly used in Asia or the United States, whereas in Europe its use is not widespread yet (Prasad, 2014).

Active food-packaging concepts provide some additional functions in comparison with traditional passive packaging materials that are limited to protection of the packaged food product against external influences (Vermeiren et al., 2002).

A variety of active packaging techniques are concerned with substances that absorb oxygen, ethylene, moisture, carbon dioxide, flavors/odors and those which release carbon dioxide, antimicrobial agents, antioxidants and flavors (Vermeiren et al., 1999).

Examples of active packaging applications are presented in table 1.1.

Table 1.1 - Examples of active packaging applications for use within the food industry(Kerry et al., 2006)

Absorbing/scavenging properties	Oxygen, carbon dioxide, moisture, ethylene, flavors, taints, UV light
Releasing/emitting properties	Ethanol, carbon dioxide, antioxidants, preservatives, Sulphur dioxide, flavors, pesticides
Removing properties	Catalyzing food component removal: lactose, cholesterol
Temperature control	Insulating materials, self-heating and self-cooling packaging, microwave susceptors and modifiers, temperature-sensitive packaging
Microbial and quality control	UV and surface-treated packaging materials

Oxidative reactions and contamination by pathogenic microorganisms are among the main factors reducing the shelf life of perishable foods (Portes et al., 2009).

Therefore, a search for antimicrobial and antioxidant agents for the prevention and maintenance of food product quality is a major concerning.

A promising type of active packaging is the incorporation of antimicrobial substances in food-packaging materials to control undesirable growth of microorganisms on the surface of foods (Vermeiren et al., 2002).

The phenome of antimicrobial agent migration from the package into the food is essential to inhibit the growth of microorganisms on the food surface where this growth is critical. The gaseous (volatile) agents can evaporate into the headspace of the packaging system reaching the food. Of course, the release rate of antimicrobial agents should be controlled to match the growth kinetics of the microorganisms. Antimicrobial agents can be incorporated into a packaging system through simple blending with packaging materials, immobilization or coating depending on the characteristics of package system, antimicrobial agent or food product. The blended antimicrobial agents as well as the ones incorporated as coating can migrate into the foods during storage and distribution (Han,2003).

Incorporating these agents on the packaging instead of applying them on food (i.e. as edible coatings) has the advantage of these compounds not being in direct contact with the consumed products, resulting on a decrease of additives ingestion by the consumers, who tendentially choose products free of any kind of preservatives.

The compounds incorporated in the packaging of this work (Figure. 1.3), are a cross of the blending and coating processes, once the compounds penetrate the paper used on the packaging, interacting with it, at the same time that a layer of antimicrobial agents is formed and stays on the paper structure as an antimicrobial barrier.

This process can produce an antimicrobial packaging system, by incorporating the compounds on the ready paper without interfering with the paper producing process itself. This is useful when working with factories and paper mills, using the available resources without affecting their daily production, archiving an important balancing point between research and production, instead of changing their production methods in order to get the desired product, leading sometimes to huge production losses.

Figure 1.3 – Examples of active packaging used on the present study

3. Use of *food-safe* and biodegradable compounds

Nowadays, a healthy lifestyle is becoming highly adopted by people all around the world. The consumers look for products less processed and even the concept of *fast-food* is changing, in an attempt of keeping up with these requests.

Usually, to maintain their quality, a wide range of food products take chemical preservatives on their composition. If in a way, the consumer requires that the products they consume have lesser amounts of chemical preservatives, on the other hand it requires a freshness as they had been prepared at the time (Martins, 2015).

As so, it is necessary to find alternate solutions that could preserve the products being food-safe and environmentally-friendly. The active compounds utilized in this work are known for being food-safe and not affecting the nutritional quality parameters (Guerreiro et al., 2016).

3.1 Sodium Alginate

Alginates are natural polysaccharides extracted from brown sea algae (Phaeophyceae), composed of two uronic acids (b-Dmannuronic acid and a-L-guluronic acid) and located in the intracellular matrix as a gel containing sodium, calcium, magnesium, strontium and barium ions (Fig. 1.4). Alginates are known as hydrophilic biopolymers that have a coating function due to its colloidal properties, being resistant to solvents, oil, and grease. They are used for thickening, suspension, gel forming, emulsion stabilizing, and in sizing and/or coating paper to produce surface uniformity (Guerreiro et al., 2016 ; Khwaldia et al., 2010).

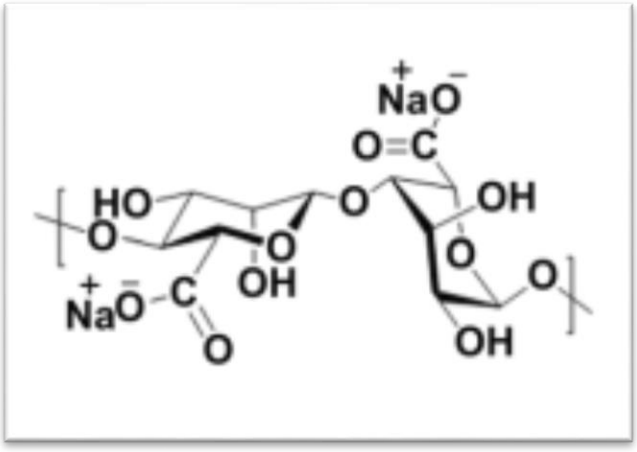


Figure 1.4 – Sodium alginate chemical structure (Pawar and Edgar, 2012)

According to Rhim (2006), paperboard coated with alginate reduce the contact angle of water which indicates an increase in hydrophilicity of the paper and resulting in an increased affinity of the paperboards to water (Fig. 1.5).

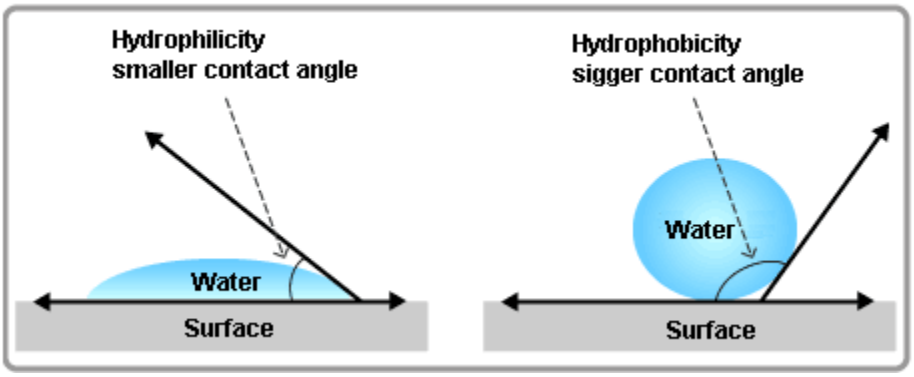


Figure 1.5 – Water contact angle with a surface(ARC-FLASH, 2001).

3.2 Essential Oils and their compounds

Essential oils (EOs) and their components, which are naturally occurring antimicrobial agents, are well known for their potencial against pathogenic microorganisms. Many species and herbs exert antimicrobial activity due to their essential oil fractions. EOs are variable mixtures of essential terpenoids, specially monoterpenes (C_{10}) and sesquiterpenes (C_{15}), although diterpenes (C_{20}) may also occur, and of a variety a low molecular-weight aliphatic hydrocarbons, acids, alcohol, aldehydes, phenolic compounds, acyclic esters, or lactones (Khwaldia et al., 2010; Celikel and Kavas, 2008; Guerreiro, 2015).

Despite the good results achieved with the incorporation of essential oils compounds into coating formulations, high concentrations of EOs are generally needed to achieve effective antimicrobial activity in direct food applications, which might have a negative impact on flavors and odors of food. Even so, most of the EOs are classified as Generally Recognized as Safe (GRAS) and their use as food preservatives is often limited to flavoring considerations, once the effective antimicrobial doses of EOs compounds may exceed organoleptic acceptable levels (Khwaldia et al., 2010; Celikel and Kavas, 2008; Guerreiro, 2015).

Since the chemical composition of plant-derived products, such as EOs, is highly variable, the utilization of the active compound instead of the EOs is a better approach to obtain the desired effects (Guerreiro et al., 2015).

3.2.1 Citral

Citral ($C_{10}H_{16}O$) is a mixture of two isomeric acyclic monoterpene aldehydes: geranial (*trans*-citral) and neral (*cis*-citral) (Fig. 1.6). Citral is usually isolated from the essential oil of lemongrass (Katsukawa et al., 2010; Shen et al., 2015), but can also be extracted from citrus fruits and leaves (Apolónio et al., 2014 ; Wuryatmo et al., 2003) and his effects had been widely demonstrated against mould, yeast and bacteria proliferation. The European Commission (Regulation (EC) No 872/2012) also approved citral as flavoring agent in food industry.

Although Citral is a widely studied EO compound, the antimicrobial mechanism of action is not completely understood. It is known that, in general, the plasma membrane is the primary site of toxic action of terpenes, but the ultimate mechanisms of growth inhibition, cell injury and inactivation are not totally defined (Somolinos et al., 2010).

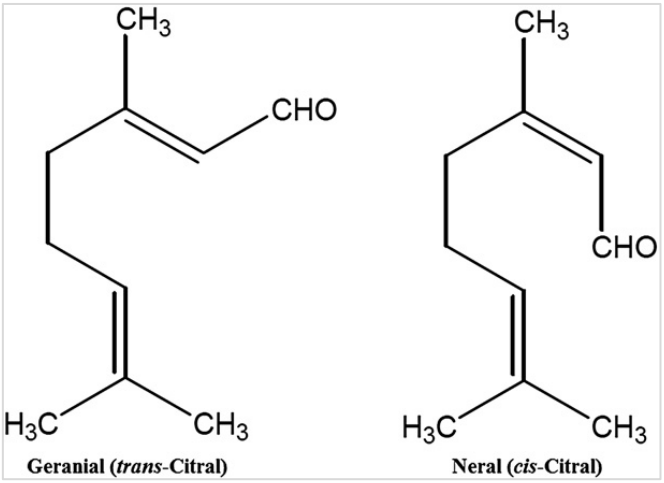


Figure 1.6 - Chemical structures of geranial (*trans*-citral) and neral (*cis*-citral).

3.2.2 Eugenol

Eugenol ($C_{10}H_{12}O_2$) is a naturally-occurring phenol extracted from buds and leaves of clove and is also the main compound in cinnamon leaf EOs (75-95%) (Fig. 1.7) (Ribes et al., 2016). Previous studies show that eugenol exhibits an excellent fungicidal as well as bactericidal activity against organisms like *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Listeria monocytogenes*. It is suggested that the mode of antimicrobial action of eugenol is through disruption of cytoplasmic membrane, which increases its non-specific permeability (Devi et al., 2010).

Eugenol has a very characteristic and intense aroma, and has been long known for its analgesic, local anesthetic and anti-inflammatory effects (Guerreiro, 2015).

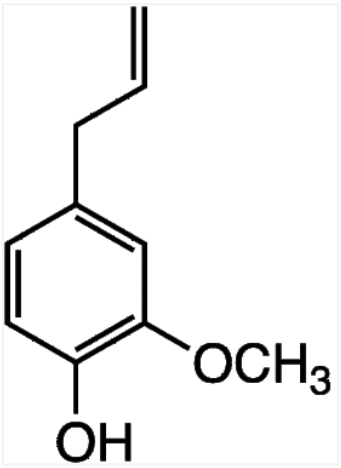


Figure 1.7 - Chemical structures of eugenol.

3.3 Glycix

Glycix is a biobased and biodegradable thermoset plastic. Researchers Gadi Rothenberg and Albert Alberts discovered "Glycix" bioplastic by chance while looking for a biofuel. The basic compounds of the polymer are glycerol and citric acid, two substances that are in abundant supply in nature and can be produced from biomass. To obtain the plasticizer properties, the hardness, brittleness, and toughness of Glycix, it is necessary to submit it to moderate temperatures in order to start a cross-linking reaction between glycerol and citric acid (Alberts and Rothenberg, 2017; Materia, 2015).

4. 'Strawberry cv. Strawberry Festival

The strawberry (*Fragaria x ananassa.*) is the fruit of the strawberry plant belonging to the Rosacea family. Considered as a "small fruit", it has intense color and distinctive taste, and has always been used for fresh consumption, candy confection, jam, beverages, liqueurs, yogurt, ice cream and even in flavorings and pharmaceuticals. This fruit, fresh or processed, occupies a prominent place in the diet and the traditional cuisine of various countries all over the world (OMAIAA,2011).

The world biggest strawberry producer are the United States of America, which annually produce around 30.5% of the world production while in all the European countries is produced around 33.3% (GPP, 2013).

'Strawberry Festival' (cultivar used on this study) origin comes from a cross between 'Rosa Linda' and 'Oso Grande' cultivars. It was selected in 1995 from a field nursery at GCREC-Dover, Florida. 'Rosa Linda', a Univ. of Florida cultivar was used as a parent due to

its high early season yield potential and its desirable fruit shape. 'Oso Grande', a Univ. of California cultivar, was used as a parent because of its ability to produce large, firm fruit. 'Strawberry Festival' is a short-day cultivar. The average petiole has a length of 120 mm. Average length and breadth of leaflets is 78 and 73 mm for terminal leaflets, respectively, and 69 and 72 mm, respectively, for secondary leaflets. Leaflet margins are crenate and average 21 serrations per terminal leaflet, and 26 per secondary leaflet. The fruit is attached to long pedicels, those of mature primary fruit are 188 to 240 mm long, with branching of the inflorescence usually occurring close to the crown. 'Strawberry Festival' fruits are mostly conic shaped. The external color of fully mature fruit is deep red and glossy and internal color is bright red. Currently 'Strawberry Festival' is one of the major cultivars grown in west central Florida (Chandler et al., 2000).

'Strawberry Festival' is a grower favorite because it has a sturdy bush that is easy to harvest, doesn't yield huge quantities of fruit on any one date and produces very few cull fruits. It is a supermarket favorite because its fruit are attractive, fit well in standard packages and have a long shelf life (Fig. 1.8). This clone was named 'Strawberry Festival' in recognition of the Florida Strawberry Festival, an annual festival in Plant City that celebrates the abundant crop of berries harvested in eastern Hillsborough County during late February and early March (FFSP, Inc.,2013).

Figure 1.8 – 'Strawberry Festival' Strawberry U.S. Patent PP14,739 (FFSP, Inc.,2013).

5. 'Hayward' Kiwifruit

Kiwifruit are native to the southeast Asia. There are more than 50 species in the genus *Actinidia*. The most common kiwifruit species grown commercially is *Actinidia deliciosa*.

'Hayward', discovered in 1920's and introduced into cultivation in early 1930's, selected by Hayward Wright. 'Hayward' kiwifruits are found in supermarkets all around the world (Strik, 2005;Morton, 1987).

The kiwifruit plant is a vigorous, woody, twining vine reaching up to 9 m. Its alternate, long-petioled, deciduous leaves are oval to nearly circular, cordate at the base, approximately 7.5-12 of.5 cm long. Young leaves and shoots are coated with red hairs, while mature leaves are dark-green and hairless on the upper surface and downy-white with prominent light-colored veins beneath. 'Hayward' cultivar fruits are exceptionally large, broad-oval, with slightly flattened sides with approximately 80-90 grams a fruit (Fig. 1.9). The skin is light greenish-brown with dense, fine, silky hairs while the flesh is light green. The sweet flavor stands out, showing also a good storing quality. The vine is moderately vigorous, usually blooms late and flowers borne singly or, rarely, in pairs. The petals are broad, overlapping, cupped, and the styles more erect than those of other cultivars though they vary from horizontal to vertical (Strik, 2005;Morton, 1987).

Kiwi buds enter endodormancy during winter, and a required minimum number of chilling hours for maximum bud break and bloom is needed. Despite 'Hayward' cultivar has chilling requirement of over 950 hours for vegetative buds and 1150 hours for optimum flowering, a growing season of about 225 to 240 frost free days is also a special need. Most kiwifruit species should tolerate temperatures down to -12°C but some plants may be damaged at slightly higher temperatures, being temperature the most limiting factor for kiwifruit production (Strik, 2005;Morton, 1987;Wall et al., 2008).

Figure 1.9 – 'Hayward' Kiwifruit (Spreafico, 2017)

6. Dehydrated Fruit Snacks

Dehydration is probably the oldest form of preserving food. The use of dehydrated foods leads to some loss of quality, however, this method allows an extension of the products shelf-life with a considerable quality. A dried food product offers the advantage of decreased weight, reducing transportations costs. However, there is often a decrease in the quality of the dried products due to the usual dehydration techniques which require high temperatures during the drying process (Cohen and Yang, 1995).

Exposing dehydrated fruits to room temperature conditions causes deterioration of these kind of products, having the package an important role on maintaining quality.

The dehydrated kiwifruit snacks have differentiating characteristics that give them a good acceptance by consumers. The confection of the snacks in this study were made according to previous trials where synthetic additives were avoided, being the snacks the most natural as possible (Fig. 1.10). It is expected that through the fruit dehydration process, the snacks to have a crispy and crunchy texture and a more appealing form due to the circular moulding given. These snacks can also be used in the confection of ice creams, yogurts, desserts, cereals and drinks.

Figure 1.10 – Kiwifruit dehydrated snacks

7. Fruit Quality and Postharvest Techniques

The fruit market depends largely on the quality presented of his products. Quality is defined as any of the features that classify the degree of excellence or superiority of a product. The quality of fresh horticultural products is a combination of characteristics, attributes, and properties that give value for food and may vary according to the purpose of who sells or buys. Producers are concerned that their commodities have good appearance and few visual defects, but for them a useful cultivar must score high on yield, disease resistance, ease of harvest, and shipping quality. To receivers and market distributors, appearance quality is most important as well as firmness and long storage life. Consumers consider good quality fruits and vegetables to be those that look good, are firm, and offer good flavor and nutritive value (Kader, 2002).

Horticultural fresh products quality is influenced by several factors, starting on the handling of fruits and vegetables from harvest till their storage at home. To please all the elements on supply chain, certain post-harvest techniques could be adopted to reduce losses and guarantee that the products reach the final consumer with the desired quality.

7.1 Harvest

The way to harvest fruit can be a differentiating factor between a durable and quality product and a rather desired product. The type of harvest varies in case that fruits are intended for fresh consumption or industrial processing. For fresh consumption, the fruits must be harvested carefully to avoid injury and fruit contamination, if the fruit is intended for industrial processing, must be picked those fruits with small defects and a less desirable appearance (Sousa and Curado, 2005).

The physiological maturity of a fruit occurs when it reaches his maximum development and the ability to reach full maturity in the plant or out of it. However, in commercial terms, the harvest may not always be able to be accomplished according to physiological maturity which must be taken into account the market and the time until consumption. As such, commercially, the harvest is performed according to the so-called commercial maturity, instead of physiological maturity (Sousa and Curado, 2005).

7.2 Strawberry Harvest

Strawberries are non-climacteric fruits and are among the most perishable produced items. They are harvested at a point where they are ready to be consumed unlike many other fruits, like kiwifruits, that are harvested at a less sensitive unripen stage and then ripen later.

The maturation index for the harvest most used is based on color surface of strawberry and harvest should be done when the fruit has acquired the characteristic color of the cultivar in $2/3$ or $3/4$ of the surface if the product is intended for distant markets. If the product is intended for local markets the harvest can be performed when the strawberry provide its characteristic color in the whole fruit. Immediately after harvest, the fruits must be conditioned on the package that will reach the consumer in a way to minimize the handling of strawberries avoiding a decrease in quality (Sousa and Curado, 2005).

Once harvested and cut off from its source of water and nutrients, the process of degradation begins, and cooling as soon as possible is imperative to minimize the rate of degradation and maximize strawberry quality and shelf life (CSC,2011).

The strawberry harvest should be staggered, in hours of lower heat and with the fruits in the proper state of maturity to meet the market requirements (Sousa, 2005).

7.3 Kiwifruit Harvest

Kiwifruit are climacteric fruits, as so, they could be harvested at a less sensitive unripen stage and then ripened later. When the fruit appears to be firm and showing around 6.5 percent (6.5 °Brix) of Total Soluble solids (TSS) are ready to be harvested. The fruits must be removed quickly from the field due to heat right after harvest, because the fruit can lose water very quickly. After 3 to 4 percent of water loss, fruit may appear shriveled, especially at the stem end. Keep fruit in the shade while awaiting transport, and cool them as quickly as possible must be done to maximize storage life. The harvest must be executed with caution once kiwifruit are easily damaged by rough handling even though they seem quite hard at this stage of maturity (Atkinson et al., 2011; Strik, 2005).

7.4 Storage

Temperature management is the most effective tool for maintaining quality and safety, extending the postharvest- life of fresh horticultural products. It begins with the rapid removal of field heat by initial cooling and continues throughout the cold chain (refrigerated transportation, cold storage at wholesale distribution centers, refrigerated retail display/*shelf-life* and cold storage at home). Management of relative humidity along with temperature is essential in reducing water losses and maintaining quality (Kader, 2013).

Exposure of fresh fruit to low O2 and/or elevated CO2 atmospheres within the range tolerated by each commodity reduces their respiration and ethylene production rates what leads

to a retardation of senescence. However, the use of some inadequate CA, may be responsible for some physiological disorders on the fruit (Yahia, 2009).

Fruits distribution could also be a problem with severe repercussions. The distance between the place of production and the place of consumption could be considerable. Transports with controlled temperature must be used. Some basic precautions must be taken, as pre-cool the transportation cold chambers or limit the amount of products on the chambers to not overload their capacity, as well as maintain the transport clean and drive through the fastest route should be taken into account (Poças, 2001).

Strawberries have a relatively high rate of respiration and are highly susceptible to water loss and mechanical damage. They are also susceptible to decay from fungus, specially *Botrytis sp.* and *Rhizopus sp.* This all means that strawberries require special attention to all aspects of postharvest handling. The cooling of fruits should be made immediately after harvest. Delays in this process lead to a reduction in the percentage of marketable fruit (CSC, 2011). According to Poças (2001), the ideal conditions of strawberries cold storage are 0±0.5ºC at 90-95% of relative humidity. At these conditions strawberries could be stored up to 7 days.

'Hayward' kiwifruit has an atypical climacteric behaviour. It has an autocatalytic ethylene production during ripening at room temperature but not at temperatures below 10°C(Antunes, 2008). This characteristic allows to take adequate measures for long term storage prolonged, making it possible to commercialize fruits through time, exposing the fruits to ethylene to start the ripening process before shipping to stores. Normally kiwifruits are stored at 0ºC with 90 to 95% of relative humidity in not controlled atmosphere or at same temperature and humidity conditions, but with a controlled atmosphere of 2%O_2+5%CO_2. On these conditions, kiwifruits could be stored for at least 6 months for not controlled atmosphere and up to 9 months for controlled atmosphere environments, if the atmosphere is ethylene-free (Antunes, 2008).

8. Quality parameters

Quality is not a linear definition, depending in most cases of consumers or markets. However, there is a consensus that factors such as visual appearance, texture, flavor, absence of defects and microbiological contamination are part of a set of attributes, which allows to classify the quality of a product (Guerreiro, 2015).

8.1 Color

Measuring the surface color of a fruit give an indication of the ripening stage as well an appearance perception. CIE Lab(L^*, a^*, b*) scale was settled. The a* parameters is responsible for readings from green (-a*) to red (+a*), b* parameter shows values between blue (-b*) and yellow (+b*) color. L* represents color lightness, going from white (L*=100) to black (L*=0). The calculation of hue angle (h°) and Chroma (C*) can also give a more accurate measure of color. Hue and color saturation (Chroma) values were obtained using the following formulas (Guerreiro, 2015; Martins, 2015; McGuire, 1992):

$$Hue\ (h^*) = SE\left(a^* > 0; \arctan\left(\frac{b^*}{a^*}\right) x\ \frac{180}{3{,}1416}; \arctan\left(\frac{b^*}{a^*}\right) x\ \frac{180}{3.1416} + 180\right)$$

$$*)(=)SE\left(a^* < 0; \arctan\left(\frac{b^*}{a^*}\right) x\ \frac{180}{3{,}1416}; \arctan\left(\frac{b^*}{a^*}\right) x\ \frac{180}{3.1416}\right) + 180$$

$$Chroma(C*) = \sqrt{(a^*)^2 + (b^*)^2}$$

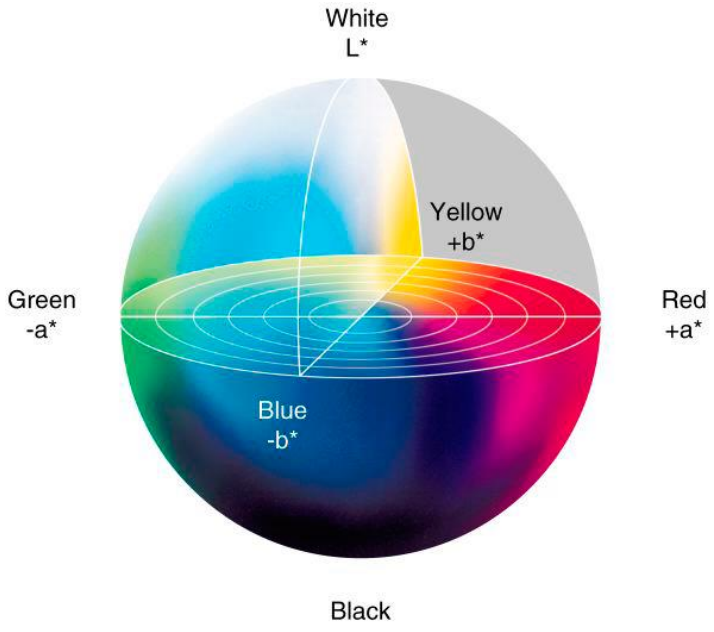


Figure 1.11 - CIE Lab(L^*, a^*, b*) color scale (Williams, 2002)

8.2 Weight loss

Water loss is the main reason for weight loss and it is an indicator of fruit desiccation. As so, weight lost was calculated as percentage of initial weight just for the fresh fruit trials, and using the following formula:

$$Weight\ loss = \frac{Weight_{initial} - Weight_{final}}{Weight_{initial}} x100$$

8.3 Firmness/Crispness

Firmness, along with the color, is the first quality parameter checked by consumers. Firmness is a parameter that is based in the strength needed to penetrate the fruit pulp. For non-fresh products, crispness is the texture parameter measured, defined as the necessary strength to break a product.

The values are given in Newton(N) and measured using a penetrometer(Martins, 2015).

8.4 Total Soluble Solids

The Total Soluble Solids(TSS) are measured in ºBrix values using a refractometer. TSS is used to obtain the soluble solids content of an aqueous solution (fruit juice), which is an indirect measurement of the sugars content and sweetness of a fruit (Martins, 2015).

8.5 Microbiology

The deterioration of food is mainly caused by microbial agents and oxidative reactions, affecting the products quality. An urgency to find antimicrobial agents and antioxidants for the prevention and maintenance of quality is a current concerning (Barros, 2013). To understand the limits of food acceptance and safety, microbiological analysis are performed, measuring the amount of microbial content in a product expressed by Log10 CFU/g (Colony Forming Unit).

8.6 Water activity(a_w)

The free water of a food product is an indicator of quality mainly in dehydrated food products. Free water in products is responsible for the growth of undesirable organisms such as bacteria or fungi. The water activity (a_w) provides information regarding the possibility of microbiological growth, giving indications of the stability and durability of a sample and it is a measure of how efficiently the free water present in a product can take part in a reaction. a_w is

the ratio of the vapor pressure of the water in the substrate (p) to that of pure water at the same temperature (p_o), calculated by the following formula (Sandulachi, 2010):

$$a_w = \frac{p}{p_o}$$

8.7 Anthocyanins

Fruit color is a major determinant of quality in red berry fruits and is due to the presence of anthocyanins, a group of water-soluble pigments with antioxidant properties (Patras et al., 2009). Anthocyanin pigments are important to food quality because of their contribution to color and appearance. There is increasing interest in the anthocyanin content of foods once they are related with possible health benefits. Anthocyanin pigment content can also be a useful criterion in quality control and purchase specifications of fruit (Lee et al., 2005).

Anthocyanin pigment concentration, expressed as Cyanidin-3-glucoside equivalents, as follows(Guerreiro et al., 2013;Lee et al., 2005):

$$\frac{A \times MW \times DF \times 10^3}{\varepsilon \times l}$$

A = (A520 nm − A700 nm) pH 1.0 − (A520 nm − A700 nm)pH 4.5

MW = 449.2 g/mol = value of the molecular weight of Cyanidin-3-glucoside

DF = dilution factor

ε = 26,900 molar extinction coefficient for Cyanidin-3-glucoside, in $\mathrm{L} \times \mathrm{mol} - 1 \times \mathrm{cm} - 1$

103= factor for conversion from g to mg

l = path length in cm.

8.8 Sensory panel

Sensory panel is a very important indicator of consumer acceptance. Different treatments and storage time could cause an alteration on fruit flavor. Panel members are usually asked to evaluate the appearance, crunchiness, aroma, texture, sweetness, acidity and overall flavor on the base of a 7 point hedonic scale: 1-dislike definitely; 2-dislike; 3-dislike mildly; 4-neither like nor dislike; 5-like mildly; 6-like; 7-like definitely. Panel members usually consist of University students and staff members who were trained at the beginning of the experiment

to become familiar with the characteristics of the fruit (Guerreiro, 2015; Rojas-Graü et al., 2009).

9. References

Alberts, A.H., and Rothenberg, G. (2017). Plantics-GX: a biodegradable and cost-effective thermoset plastic that is 100% plant-based. Faraday Discuss. 202, 111–120.

Antunes, M.D. (2008). Colheita e conservação. In Kiwi. Da Produção À Comercialização, pp. 192–203.

Apolónio, J., Faleiro, M.L., Miguel, M.G., and Neto, L. (2014). No induction of antimicrobial resistance in Staphylococcus aureus and Listeria monocytogenes during continuous exposure to eugenol and citral. FEMS Microbiol. Lett. 354, 92–101.

ARC-FLASH (2001). Thin-film Coating Techinque. http://www.arc-flash.com.tw/our_tec2-5-en.htm [Date Accessed: 2017-10-03]

Atkinson, R.G., Gunaseelan, K., Wang, M.Y., Luo, L., Wang, T., Norling, C.L., Johnston, S.L., Maddumage, R., Schröder, R., and Schaffer, R.J. (2011). Dissecting the role of climacteric ethylene in kiwifruit (Actinidia chinensis) ripening using a 1-aminocyclopropane-1-carboxylic acid oxidase knockdown line. In Journal of Experimental Botany, pp. 3821–3835.

Barros, A.C. (2013). Aplicação de embalagens ativas com agentes naturais na preservação de alimentos Aplicação de embalagens ativas com agentes naturais na preservação de alimentos. Universidade do Algarve.

CSC - California Strawberry Commission (2011). Maintainig Quality of Fresh Strawberry.

Celikel, N., and Kavas, G. (2008). Antimicrobial Properties of Some Essential Oils against Some Pathogenic Microorganisms. Czech J. Food Sci. 26, 174–181.

Chandler, C.K., Legard, D.E., and Dunigan, D.D. (2000). " Strawberry Festival " Strawberry. Hortscience - Am. Soc. Hortic. Sci. 35, 1366–1367.

Cohen, J.S., and Yang, T.C.S. (1995). Progress in food dehydration. Trends Food Sci. Technol. 6, 20–25.

Dantuma, A., and Tiesktra, S. (2016). Trends en behoeften in verschillende markten en de papierketen. In Vakblad Voedingsindustrie, p.

Devi, K.P., Nisha, S.A., Sakthivel, R., and Pandian, S.K. (2010). Eugenol (an essential oil of clove) acts as an antibacterial agent against Salmonella typhi by disrupting the cellular membrane. J. Ethnopharmacol. 130, 107–115.

Dukalska, L., Ungure, E., Augspole, I., Muizniece-Brasava, S., Levkane, V., Tatjana, R., and Krasnova, I. (2013). Evaluation of the Influence of Various Biodegradable Packaging Materials on the Quality and Shelf Life of Different Food Products. Proc. Latv. Univ. Agric. 30, 20–34.

FFSP - Florida Foundation Seed Producers Inc. (2013). "Strawberry Festival." http://www.ffsp.net/varieties/strawberry/strawberry-festival/ [Date Accessed: 2017-10-09]

GPP - Gabinete de Planeamento e Políticas (2014). Anuário Agrícola (Enigma Previsível).

Guerreiro, A.C. (2015). Innovative edible coatings to improve storage of small fruits and fresh-cut Innovative edible coatings to improve storage of small fruits and fresh-cut. Universidade do Algarve.

Guerreiro, A.C., Gago, C.M.L., Miguel, M.G.C., and Antunes, M.D.C. (2013). The effect of temperature and film covers on the storage ability of Arbutus unedo L. fresh fruit. Sci. Hortic. (Amsterdam). 159, 96–102.

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on Arbutus unedo L. fresh fruit storage. Postharvest Biol. Technol. 100, 226–233.

Guerreiro, A.C., Gago, C.M.L., Miguel, M.G.C., Faleiro, M.L., and Antunes, M.D.C. (2016). The influence of edible coatings enriched with citral and eugenol on the raspberry storage ability, nutritional and sensory quality. Food Packag. Shelf Life 9, 20–28.

Kader, A.A. (2013). Postharvest Technology of Horticultural Crops - An Overview from Farm to Fork. J. Appl. Sci. Technol. 1, 1–8.

Kader, A. a (2002). Quality and Safety Factors : Definition and Evaluation for Fresh Horticultural Crops. In Postharvest Technology of Horticultural Crops, pp. 279–285.

Kerry, J.P., O'Grady, M.N., and Hogan, S.A. (2006). Past, current and potential utilisation of active and intelligent packaging systems for meat and muscle-based products: A review. Meat Sci. 74, 113–130.

Khwaldia, K., Arab-Tehrany, E., and Desobry, S. (2010). Biopolymer Coatings on Paper Packaging Materials. Compr. Rev. Food Sci. Food Saf. 9, 82–91.

Lee, J., Durst, R.W., and Wrolstad, R.E. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. J. AOAC Int. 88, 1269–1278.

Materia (2015). Glycix • Materia. https://materia.nl/material/glycix/ [Date Accessed: 2017-09-24]

Martins, A. (2015). Innovative edible films to improve storage ability of fresh-cut apple cv. Bravo de Esmolfe. Universidade do Algarve.

McGuire, R.G. (1992). Reporting of objective color measurements. HortScience 27, 1254–1255.

Morton, J.F. (1987). Kiwifruit. In Fruits of Warm Climates, pp. 293–300.

OMAIAA - Observatório dos Mercados Agrícolas e das Importações Agro-Alimentares (2011). A Produção e Comercialização do Morango em Portugal. http://www.observatorioagricola.pt/item.asp?id_item=104 [Date Accessed: 2017-10-09]

Patras, A., Brunton, N.P., Da Pieve, S., and Butler, F. (2009). Impact of high pressure

processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purées. Innov. Food Sci. Emerg. Technol. 10, 308–313.

Pawar, S.N., and Edgar, K.J. (2012). Alginate derivatization: A review of chemistry, properties and applications. Biomaterials 33, 3279–3305.

Poças, M. de F.F. (2001). Disqual - Manual de Boas Práticas - Morango (Disqual).

Portes, E., Gardrat, C., Castellan, A., and Coma, V. (2009). Environmentally friendly films based on chitosan and tetrahydrocurcuminoid derivatives exhibiting antibacterial and antioxidative properties. Carbohydr. Polym. 76, 578–584.

Prasad, P., and Kochhar, A. (2014). Active Packaging in Food Industry : A Review. IOSR J. Environ. Sci. Toxicol. Food Technol. 8, 1–7.

Rhim, J.. (2006). Water resistance and mechanical properties of biopolymer (alginate and soy protein) coated paperboards. LWT- Food Sci. Technol. 39, 806–813.

Rojas-Graü, M.A., Oms-Oliu, G., Soliva-Fortuny, R., and Martín-Belloso, O. (2009). The use of packaging techniques to maintain freshness in fresh-cut fruits and vegetables: A review. Int. J. Food Sci. Technol. 44, 875–889.

Sambrailo Packaging (2017). Strawberry Packaging | Sambrailo Packaging. http://www.sambrailo.com/products/berries/strawberry-packaging/ [Access in: 2017-10-23]

Sandulachi, E. (2010). Water Activity Concept and Its Role in Food Preservation. Water Act. Concept Its Role Food Preserv. 40–48.

Somolinos, M., García, D., Condón, S., MacKey, B., and Pagán, R. (2010). Inactivation of Escherichia coli by citral. J. Appl. Microbiol. 108, 1928–1939.

Sousa, M.B.S. e, and Curado, T. de F. (2005). Colheita, Pós-colheita, Conservação e Qualidade. In Manual Do Morangueiro, pp. 107–119.

Spreafico (2017). Kiwi Hayward. http://www.spreafico.net/Products/Kiwi/Kiwi-Haiward/ [Date Accessed: 2017-10-11]

Strik, B. (2005). Growing Kiwifruit (A Pacific Northwest Extension).

Vermeiren, L., Devlieghere, F., Van Beest, M., De Kruijf, N., and Debevere, J. (1999). Developments in the active packaging of foods. Trends Food Sci. Technol. 10, 77–86.

Vermeiren, L., Devlieghere, F., and Debevere, J. (2002). Effectiveness of some recent antimicrobial packaging concepts. Food Addit. Contam. 19, 163–171.

Wall, C., Dozier, W., Ebel, R.C., Wilkins, B., Woods, F., and Foshee, W. (2008). Vegetative and floral chilling requirements of four new kiwi cultivars of Actinidia chinensis and A. deliciosa. HortScience 43, 644–647.

Williams, A. (2002). Graybalance: A key element in color reproduction. http://www.newsandtecharchives.com/issues/2002/02-02/ifra/02-02_greybalance.htm. [Date Accessed: 2017-10-24]

Yahia, E.M. (2009). Preface. In Modified and Controlled Atmospheres for the Storage, Transportation, and Packaging of Horticultural Commodities, E.M. Yahia, ed. (CRC press Tailor & Francis Group), pp. IX–XIII.

Chapter II– Training Report

New Product Development – Active packaging development

Supervisors: Dantuma, A.[1] &Antunes, M.D.C.[2]

[1]KCPK, IJsselburcht 3, 6825 BS Arnhem, The Netherlands.
[2]Faculdade de Ciências e Tecnologia, Edf. 8, Campus Gambelas, 8005-139 Faro, Portugal,

Contents

1. INTRODUCTION

The perishability of the fresh horticultural products leads to losses that may reach important and worrying levels. These losses, quantitative and/or qualitative, could involve serious losses for the producer, the merchant and the consumer.

Strawberries, fresh or processed, occupy a prominent place in the diet and the traditional cuisine of various countries all over the world. These fruits are among the most perishable produce items, they have a relatively high rate of respiration and are highly susceptible to water loss and mechanical damage. They are also susceptible to decay from fungi and bacteria. This all means that strawberries require special attention to all aspects of postharvest handling. The main reasons for strawberry rejection at the entry of the warehouses were rot, excessive ripeness and logistics -related problems. At stores, rots are the main reasons for rejection and consecutive product returns.

At same time, increased environmental concerns over the use of certain synthetic packaging and coatings in combination with consumer demands for both higher quality and longer shelf life have led to increased interest in alternative packaging materials research. Incorporation of antimicrobial agents in coatings to produce active paper packaging materials provides an attractive option for protecting food from microorganism development and spread.

The use of biopolymers such as Alginates, Essential oils and Bioplastics known for their water barrier and antimicrobial properties, has been exploited in the preparation of active packaging in order to prolong the storage time and quality of fresh and dehydrated fruits.

The work described on this report aim to attend to these important quality and market issues, trying to find a feasible and an economically interesting way to improve fruit storage and shelf-life by creating and testing the effect active packaging on post-harvest fruit quality.

1.1 Alginate, Essential oils and Glycix

Alginates, which are extracted from brown seaweeds of the Phaephyceae class, are the salts of alginic acid. Alginates are resistant to solvents, oil, and grease and exhibit interesting film-forming properties (Khwaldia et al., 2010).

Mechanical and water barrier properties of paperboards can be modified by biopolymer coatings, and alginate-based films can increase water barrier properties. This barrier is important to preventing the proliferation of microorganisms and the fruit softening by losing water (Rhim, 2004). Alginates show also a good capacity of encapsulation and holding together other compounds what can be an advantage when there is a need to add other compounds to an Alginate solution. Alginates, as opposed to essential oils, can tolerate temperatures up to

approximately 240ºC (Soares et al., 2004) and combine very easily with water being also able to be dissolved in it.

Essential oils and their components, which are naturally occurring antimicrobial agents, are well known for their potency against pathogenic and spoilage microorganisms. The antimicrobial activity of essential oils such as thyme, cinnamon, clove, oregano, and their major components are mainly related to their high small terpenoid and phenolic contents. Despite the good results achieved with the incorporation of essential oils into coating formulations, the major drawback is their strong flavor and odor, which could change the original taste of foods. The implications on sensory characteristics of food products are of great merit for future research (Khwaldia, 2010).

Since the chemical composition of plant-derived products, such as essential oils, is highly variable and may involve many compounds, the utilization of single compounds, such as citral and eugenol, instead of essential oils is a better approach to obtain an edible coating with constant characteristics as requested by the market (Guerreiro et al., 2015).

Another product, named Glycix, was also used on the active packages manufacturing, this product is a bioplastic that can also improve the water-barrier proprieties of the paper made of glycerol and citric acid, two substances that are in abundant supply and can be produced from biomass, being 100% biodegradable (Materia, 2015). These two types of products are derived from natural sources, food safe and biodegradable, what can be an advantage for using them on food products or be used on all kind food packaging applications. Beside the Alginate and the Essential oils compounds being very easily to obtain in the market, they can be expensive. Depending on the type of Alginates and Essential oils compounds, the prices could vary. 1kg of Alginate can cost around 90€, 100ml of Citral can cost around 32€ and 100ml of Eugenol around 25€ (costumer values in 2016).

2. MATERIAL AND METHODS

2.1 Size press trials

During the October month were done 44 treatments adding Alginate, Essential oils compounds and Glycix to three different types of paper. The paper used on those trials were nontreated regular paper weighting 90g/m^2 and 120g/m^2 and an oil filter treated paper weighting 165g/m^2.

2.1.1. Alginate and Alginate with Essential oils solution preparation

To prepare the solutions containing Alginate that were later added to the paper, it was mixed (using a blender at the speed of 2000 rpm) Sodium Alginate from Panreac Applichem (See Appendix: IIIII -Alginate Producer Specifications) with distilled water. The solutions contained Alginate in concentrations of 0.25%, 0.5%, 1%, 2%, 3% and 4%.

Another type of solutions containing alginate and essential oils components were done adding citral and eugenol to an alginate solution. The concentration of Citral and Eugenol in this kind of solutions were 0.3% and 0.2% and 0.6% and 0.4% respectively, corresponding to the double and quadruple of MIC (minimum inhibitory concentration) established by Guerreiro et al. (2015). These solutions were also formulated, based on previous studies (Guerreiro et al.,2015). Before selecting which paper would be the ideal to use on the active packaging manufacturing, at the initial trials the only lowest concentrations of Essential oils compounds (0.3% and 0.2%) were used, in order to reduce waste and save material.

To verify if the solution stuck to the paper, on the first trials were added a small quantity of red coloring to the solution, what may have slightly change the Alginate and Essential oils concentrations in the first trial, but that were properly corrected for the rest of the experiment (Treatment A).

After the Alginate solutions preparation, it was tested their viscosity using the Brookfield DV-E Viscometer (Table 1). Depending on the viscosities of the solutions it was necessary to use different kinds of spindles as well as different rotations per minute to ensure a correct measurement. To do that, it was necessary to find which spindle was more accurate by measuring the viscosity. This accuracy is shown by the % of precision (which should be stable and the highest value possible) on the equipment. This % of precision changed according to the viscosity indicating that other spindle, that could give us a higher precision, should be used. The amount of essential oils added to the solution was so small that was not observed any significant viscosity change**.**

Table 2.1 – Solutions Viscosities

Solutions	**Viscosity(mPas)**	**Rpm**	**Spindle**
Alginate 0.25%	48	100	Rv2
Alginate 0.5%	87	100	Rv2
Alginate 1%	280	100	Rv2
Alginate 2%	2100	50	Rv5
Alginate 3%	10520	20	Rv5
Alginate 4%	23500	30	Rv6

2.1.2. Incorporation of the solutions into the paper

One solution at time was placed in a Size press (Ernst Benz;Model: KLFH-K). Then the paper rolled through the press and the solution were incorporated into it (Fig. 2.1). The size press applied a pressure of 15kg/cm^2. The speed can also be adjustable to unsure a homogeneous solution addition. The size press was set at speed 3 which corresponds to 3 meters/minute for all the trials.

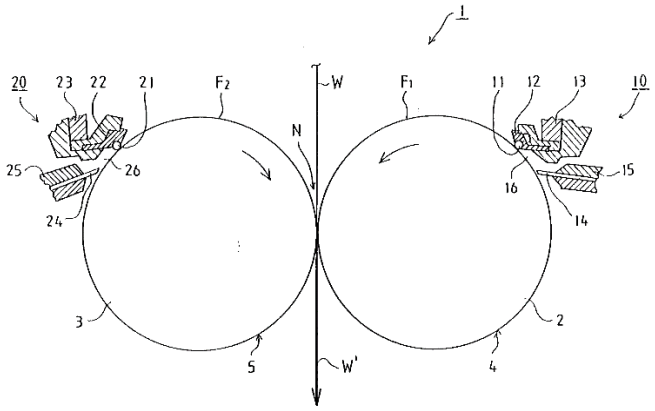


Figure 2.1 - Coating device for coating of a size-press roll, paper or board EP 0674047 A2 (Rantanen, 1991).

Following, the paper was dried on two different ways, air dried for 24h and heat dried using a hot press at 100ºC (after which the papers were left at room conditions for the remainder of the 24 hours). The papers containing essential oils were only air dried, once the maximum temperature that they can tolerate is around 30-35ºC; higher than this temperature the compounds would denature and volatilize.

To know the paper capacity to absorb the previous solutions, it were measured the paper sheet weights before and 24 hours after the solutions incorporation. The paper sheets were weighted using a digital scale Mettler Toledo Ms1003s /03 Newclassic Mf.

Past 24h, the papers that were heat-dried after the addition of the alginate solution showed a decrease of weight compared to their initial weight. This decreasing was related with the process of heat drying, where before the Alginate solution being added to these papers, they had moisture absorbed from air, and once they were not heat-dried before the solution incorporation, their weight was their own weight plus the moisture on it, once they were stored at room temperature.

So, after being incorporated the Alginate, and being heat dried, the papers lost all the moisture that absorbed from the air, and the water from the Alginate solutions, which led to a

lower weight compared to their initial one. To prevent this fact and to be sure of the real amount of solution absorption of the papers sheets, it was decided to pre-dry all the papers before adding any type of solution.

Some treatments included adding more than one layer of the same Alginate solutions to the paper, in this case the paper was first rolled through the size press and then manually, by rod coating, was applied another layer of Alginate in just one size of the sheets. These sheets, on trials, were 5x smaller than regular A4 sheets to facilitate the addition of the solution. The goal of these experiments was to evaluate if the paper could take more solutions that took on the first experiments.

There was other type of treatment that included Glycix on one size of the paper sheet. This additive was incorporated first in a concentration of 50% on trials, and for the final fruits experiments with a concentration of 70%. This additive was incorporated in the paper by using a manual size press (Treatment N_1) (Fig. 2.2).

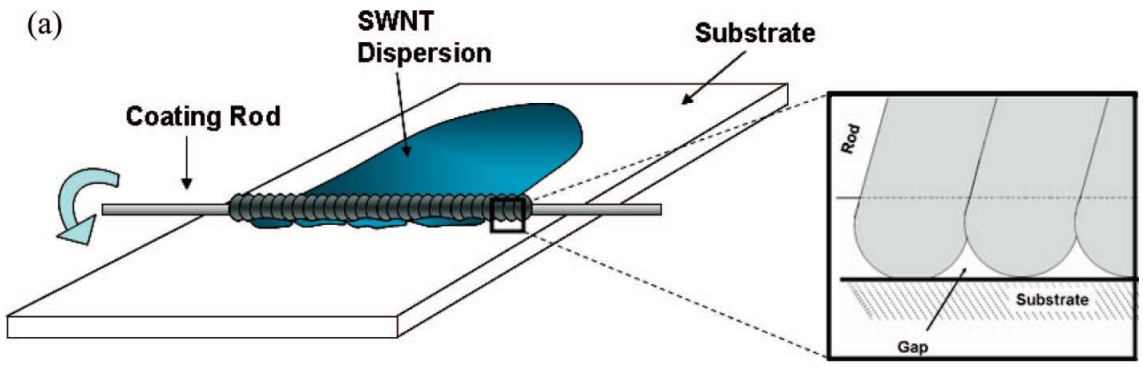


Figure 2.2 – Rod coating method (Dan et al., 2009)

All the treatments are shown in Table 2:

Table 2.2 – Paper Treatments

Treatment	**Type of solution**	**Pre-dried**	**Heat dried**	**Air dried**	**Type of paper**
A	Alginate 2%			X	90g/m^2
B	Alginate 2%		X		90g/m^2
C	Alginate 1%			X	90g/m^2
D	Alginate 1%		X		90g/m^2
E	Alginate 0.5%			X	90g/m^2
F	Alginate 0.5%		X		90g/m^2
G	Alginate 3%			X	90g/m^2

Treatment	**Type of solution**	**Pre-dried**	**Heat dried**	**Air dried**	**Type of paper**
H	Alginate 3%		X		90g/m^2
I	Alginate 4%			X	90g/m^2
J	Alginate 4%		X		90g/m^2
K	Alginate0.25%			X	90g/m^2
L	Alginate0.25%		X		90g/m^2
M	Alginate 0.5%	X	X		90g/m^2
N	Alginate 0.5%	X		X	90g/m^2
O	Alginate 1%	X	X		90g/m^2
P	Alginate 1%	X		X	90g/m^2
Q	Alginate 2%	X	X		90g/m^2
R	Alginate 2%	X		X	90g/m^2
S	Alginate 3%	X	X		90g/m^2
T	Alginate 3%	X		X	90g/m^2
U	Alginate 1%+ Citral 0.3%+ Eugenol 0.2%	X		X	90g/m^2
V	Alginate 1%+ Citral 0.3%+ Eugenol 0.2%	X		X	165g/m^2
W	Alginate 1%	X		X	165g/m^2
C_1	Alginate 1%	X	X		165g/m^2
Y	Alginate 2%	X	X		165g/m^2
Z	Alginate 2%	X		X	165g/m^2
A_1	Alginate 3%	X	X		165g/m^2
A_2	Alginate 3%	X		X	165g/m^2
B_1	Alginate 0.5%	X	X		165g/m^2
B_2	Alginate 0.5%	X		X	165g/m^2
2nd layer of Alginate[1]	Alginate 1%	X	X		165g/m^2
2nd layer of Alginate[1]	Alginate 1%	X	X		80g/m^2
C_2	Without solution	X	X		90g/m^2 120g/m^2 165g/m^2
D_1	Alginate0.5%+ Citral 0.3%+ Eugenol 0.2%	X		X	90g/m^2 120g/m^2 165g/m^2
E_1	Alginate 2%+ Citral 0.3%+ Eugenol 0.2%	X		X	90g/m^2 120g/m^2 165g/m^2
F_1	Alginate 1%+ Citral 0.3%+ Eugenol 0.2%	X		X	120g/m^2
G_1[2]	Alginate 0.5%	X	X	X	120g/m^2 (90g/m$^{2;}$ 165g/m^2)
H_1[2]	Alginate 3%	X	X	X	120g/m^2 (90g/m$^{2;}$ 165g/m^2)

Treatment	Type of solution	Pre-dried	Heat dried	Air dried	Type of paper
I_1[2]	Alginate 2%	X	X	X	120g/m^2 (90g/m$^{2;}$ 165g/m^2)
J_1[2]	Alginate 1%	X	X	X	120g/m^2 (90g/m$^{2;}$ 165g/m^2)
K_1[3]	(Alginate0.5% Alginate 1% Alginate2%) + Glycix	X		X	90g/m^2 120g/m^2
L_1[4]	Alginate 1% Glycix	X		X	90g/m^2 120g/m^2
M_1[4]	Alginate 1% + Essential oils	X		X	90g/m^2 120g/m^2
N_1 [5]	Glycix 70%	X	X		90g/m^2 120g/m^2

[1] First attempts of adding more than one layer (not used in the results analysis). The concentrations of the 2nd layers were equal to the 1st that was added as well using the size press.

[2] These treatments consisted on adding the Alginate solutions on A4 size paper sheets of 120g/m^2 and 2 and 3 layers of the Alginate solutions on 90g/m^2, 120g/m^2 and 165g/m2 small paper sheets.

[3] The Alginate solutions were added using the size press and one layer of Glycix was added manually with an appropriate roll in one of the sides of the sheets.

[4] The Alginate solutions were added using the size press and the Glycix and the Essential oils were added using an Ink Jet Printer Canon iP7200.

After the solutions incorporation the paper sheets were wrapped up in aluminum foil and plastic to prevent degradation.

The resulting data (paper weights) of the previous treatments was analyzed on KCPK office (Appendix).

The graphics are grouped on % of weight gain, representing the weight gain in relation to the paper initial weight. They are also grouped on grams (g) of weight gain, what shows the real weight gain. Notice that different types of papers were used so a bigger weight gain in grams do not always means necessarily a bigger pick up, being that a thicker paper will always absorb more grams of moisture or water than a thinner paper.

3. INKJET PRINTING

Ink jet printing is the most common type of printing that works by spraying fine droplets of ink into a paper. It was intended to apply a surface treatment to the paper using an ink jet printer, by replacing the cartridges filled with regular ink for new cartridges refilled with the

pretended solutions. But once this is a completely new method, there are some issues that must be considered.

The printer, a Canon iP7250, works with a CMYK colors model as opposed to the computer software that uses a RGB colors model. So, in order to know, and choose the cartridge that we intent to use, when printing is necessary to find the right RGB colors codes that correspond to each type of CMKY colors and consequently to each cartridge. Only by finding these codes we can ensure that only the pretended cartridge with the pretended solution is being used.

Table 2.3 – Colors codes

Colors	R	G	B	50-90% Transparency[5]
100% Cyaan	0	255	255	
50% Cyaan	0	255	255	
20% Cyaan	0	255	255	
10% Cyaan	0	255	255	
100% Magenta	255	0	255	
50% Magenta	255	0	255	
20% Magenta	255	0	255	
10% Magenta	255	0	255	
100% Yellow	255	255	0	
50% Yellow	255	255	0	
20% Yellow	255	255	0	
10% Yellow	255	255	0	
100%Key(black)	0	0	0	
50% Key (black)	0	0	0	
20% Key (black)	0	0	0	
10% Key (black)	0	0	0	

[5] To get the different % of colors, change the transparency.

3.1 Incorporation of the solutions into the paper

The first trials consisted on adding Glycix to office paper sheets (Cannon Black Label Office A4 80g/m2). First it was diluted a solution of 70% of Glycix in 1:2,1:10,1:20 and 1:50 proportions, to understand how much viscosity could the printer handle. The printer, could print all the dilutions, so a few samples of the 1:2 dilution (less diluted solution) were printed. Five layers of the Glycix solution were added, once this kind of printers add small amounts of ink/solutions to the paper, and it was necessary to add more than one layer (at least 5) to be able to observe that the solution was successfully incorporated into the paper. After the addition of the Glycix solutions, it is necessary to heat the paper sheets at approximately 180ºC for about

4 minutes (more than 4 minutes, the paper will stay very stiff and break easily) in order to begin the polymerization of the solution that will confer the bioplastic/water-barrier proprieties (inherent to Glycix) to the paper.

It was possible to add successfully the Glycix (1:2) to the 90g/m2 and 120g/m2 paper, but at some point, the printer stopped working, possibly clogged by this solution, so at that moment it was impossible to test the incorporation of Alginates or Essential oils compounds using the ink jet printer.

4. RESULTS & DISCUSSION

All papers sheets could successfully incorporate Alginate, Essential oils compounds and Glycix into their composition. But there were some differences among papers and solutions despite these ones being not significant.

While doing the Alginate solutions it was possible to check that the solutions at 3% and 4% exhibited high viscosity (what was confirmed by the viscosity measurement and when used on the size press). This was a problem because beyond being very difficult to obtain a homogeneous solution, it was also a very tricky to add these solutions to the paper using a size press. For that it was decided not to use these two Alginate solutions on further trials.

The 0.25% Alginate solution showed to be very liquid which was also a problem regarding his addition to the paper, once was very difficult to keep such liquid solution on the Size press (without dropping out) enough time to roll the paper through it. Also, the amount of Alginate on this kind of solution was so small that possibly was not going to have any of the desired effects.

For that reason, it was decided to exclude this type of solution on the Size press trials, and try to use it only on the Ink Jet printer, which less viscous solutions are supposed to work better. This led to three possible solutions to incorporate into the papers, the Alginate at 0.5%, 1% and 2% with Essential oils compounds, using the Size press.Chapter II- Appendix).

The moisture pick-ups of the papers submitted to an Alginate treatment can improve up to 2% more when compared to papers without any treatment.

The air-dried treatments always showed a higher moisture content (up to 24 hours) when compared to the heat-dried treatments, what can be due to the heating process, once this process led to an evaporation of all the water in the papers and after 24 hours they still lighter than the air-dried treatment papers. This is an expect result once the air-dried papers air spaces were already occupied by moisture and alginate solutions unlike the heat-dried treatment papers air spaces, which were just occupied by alginate without any kind of water. Taking into account

that the rate of moisture absorption is the same on the two treatments (once the type of paper is the same), it will take more time to the heat-dried papers to get the same amount of moisture than the air dried papers. So, after 24 hours, the moisture content on the heat-dried papers will be lower than the air-dried papers.

In the heat-dried treatments, it is also possible to realize that the immediate weight gain (weigh gain right after adding the Alginate solutions or the additional layers and heat-drying the paper) of 90g/m^2 paper is, in most of the cases, higher than the 120g/m^2 paper, despite of 24 hours later the weight gain be the opposite. These results can be due to the easiness of the 90g/m^2 to absorb the solution, possibly, for being thinner than the 120g/m^2 paper.

The addition of 2 and 3 layers showed very interesting results, especially on the texture of the paper, implementing sometimes some gloss into it. But the manually method to add these additional layers, led to some counterproductive results, what can be improved choosing a more accurate process of adding those layers.

Regarding the 2 layers treatment, the 90g/m^2 paper shown the best results, except when Alginate at 3% was used, in this case (and only in this one) the 120g/m^2 paper showed a higher solution pick-up. On 3 layers treatment, the 120g/m^2 paper had the higher solution pick-ups, always higher than the 90g/m^2 paper. These last relations are based on the % of weight gain after 24 hours, compared to initial weight.

The Essential oils addition to the paper confer a characteristic smell to paper, what is perceptible but not exaggerated, and can be added to all solutions independently of the Alginate concentration.

The treatments that were aimed to add Glycix to the paper result in a small change on the texture of the sheets as well as an extra stiffness.

Generally, the 165g/m^2 paper presented higher pick up rates of Alginate and moisture in all the trials. This paper is an oil filter treated paper so it feels much more oily and humid than the others. Although his pick up and water content capacity was bigger than the other papers, the humidity of this paper gives an idea of the water contained in it being very “available” and that may be a disadvantage, once it could possibly increase microbiological growth and consecutively led to a higher spoilage percentage. Maybe by being an oil filter treated paper, his composition could also interfere with the components of the solutions especially with Essential oils.

For the lowest concentrations of Alginate (0.5%) it’s possible to see that the 90g/m^2 paper showed Alginate and moisture pick-ups very similar to the other two papers.

This could be due to the low viscosity of these solutions, which were still very liquid, easy to penetrate and be absorbed by this thinnest paper. It was so easy to absorb that it was impossible to add a second layer of Alginate at 0.5% (by rod coating) to the 165g/m^2 paper, due to the absorption ability of this kind of paper, which is very high, resulting that before a homogeneous layer was formed, the paper sheet already had completely absorbed the solution dropped on the top of the sheet.

The samples of 120g/m^2 paper (same fiber that the 90g/m^2) showed in the most cases, a higher Alginate and moisture pick-up than the 90g/m^2 paper, but lower than 165g/m^2. This paper also showed an interesting water content (around 70%) without being very humid. The water content gives an idea of how much moisture the paper can hold. In all the heat-dried treatments, the 120g/m^2 as shown the best results, always surpassing the 90g/m^2 paper moisture pick-ups.

5. CONCLUSIONS & RECOMMENDATIONS FOR FURTHER TRIALS

Depending on the treatment, there is an ideal paper to use. However, the 120g/m^2 seem to be an easier paper to manipulate and to incorporate the solutions once it was necessary, more than once, to stop the size press and clean it, since the 90g/m^2 paper get stuck, repeating from beginning all the incorporation process. Also, the solution addition was not so easy to incorporate on this paper showing sometimes non-homogeneous coating, which could be reduced by slowing the speed of the size press.

The realistic and feasible way to add Alginate to paper must consider a heat dry treatment and a previous non treated paper.

The manually rod coating method is a good method to do some experiments, but a non-homogeneous coating as well as the unknown applied pressure to the paper, led to many uncertainties about the incorporation of the solutions into the paper.

The best solutions to incorporate into the paper were Alginate 1 and 2%, being less difficult to make by showing the right viscosity.

The way to add essential oils to the paper should be reviewed as well, once these compounds cannot tolerate a heat drying process. But once the papers destination are to being turned into active packaging for fresh fruits, the incorporation of these compounds are of extreme importance.

For further trials, it is also necessary to find more accurate methods that can guarantee that the solution application is equally added to all the samples, which sometimes was difficult to achieve due to the manually methods or the small capacity of the equipment. It is also

necessary to find a method to incorporate the essential oils into a sample made by realistic ways, like for example, adding them after the drying process.

Considering all the trials done on this work and the results obtained, it was concluded that the treatments of Alginate at 1% and 2 % using the 120g/m^2 paper demonstrate to be the best ones, regarding not only the paper pick-ups but also the facility of the samples preparation.

Beside that the addition of essential oils require to be air dried (what is not very realistic), they could be very interesting in the prevention of spoilage and for that it was decided to test a paper treated with Alginate and these compounds as well.

About the dehydrated fruit, it was decided as well to do a treatment not only using the Alginate at 1% and 2%, but also adding a layer of 70% Glycix(using a manual size press) on the exterior surface of the paper that is not in contact with the fruit, improving the water barrier proprieties.

For those reasons the ideal treatments would be the heat-dried, 120g/m^2 papers treatments with Alginate 1 and 2% and Glycix for the dehydrated fruit tests, as well as air-dried 120g/m^2 papers treatments with Alginate 1 and 2% and Essential oils compounds for the fresh fruit tests.

On the dehydrated fruit snacks trials the paper sheets were shaped into an enveloped form and glued with a biodegradable glue made from vegetable sources (Axton, AKI), being transformed into a package.

On the fresh fruit trials, the paper sheets were cut and placed into standard strawberry trays (Polypropylene plastic trays (8cm*10cm*4cm)), covering all the bottom and the sides of the trays.

In the end what really matters is to choose a treatment that can better be applied on fruits for quality maintenance purposes, at the same time being feasible and realistic into an industrial scale. The Figure 2.3 summarize all the treatments that were tested.

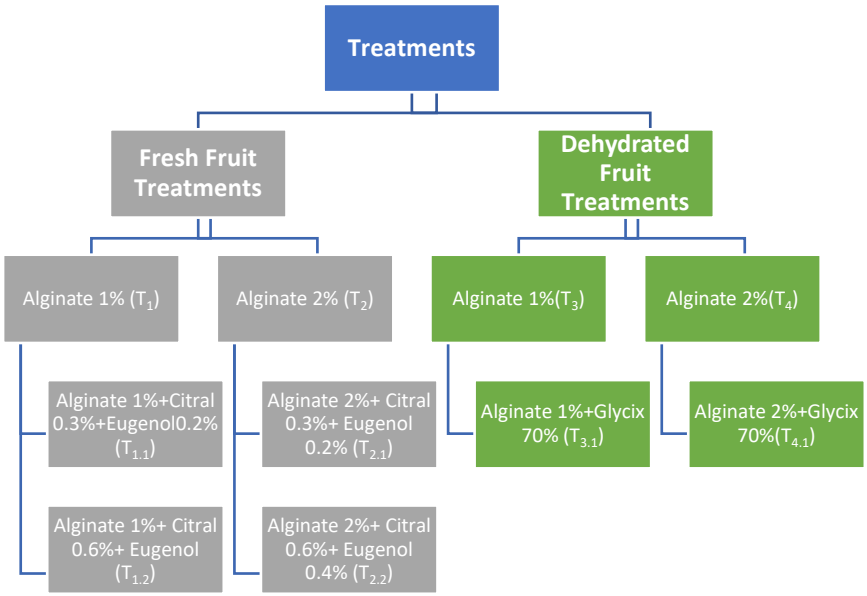


Figure 2.3 – Treatments of 120g/m^2 that were tested on fruit.

6. REFERENCES

Dan, B., Irvin, G.C., and Pasquali, M. (2009). Continuous and scalable fabrication of transparent conducting carbon nanotube films. ACS Nano *3*, 835–843.

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on Arbutus unedo L. fresh fruit storage. Postharvest Biol. Technol. *100*, 226–233.

Khwaldia, K., Arab-Tehrany, E., and Desobry, S. (2010). Biopolymer Coatings on Paper Packaging Materials. Compr. Rev. Food Sci. Food Saf. *9*, 82–91.

Materia (2015). Glycix • Materia. https://materia.nl/material/glycix/ [Date Accessed: 2017-09-24]

Rantanen, R. (1991). Coating device for coating of a size-press roll, paper or board. http://www.google.st/patents/EP0674047A2?cl=en&hl=pt-PT#forward-citations [Date Accessed: 2017-09-19]

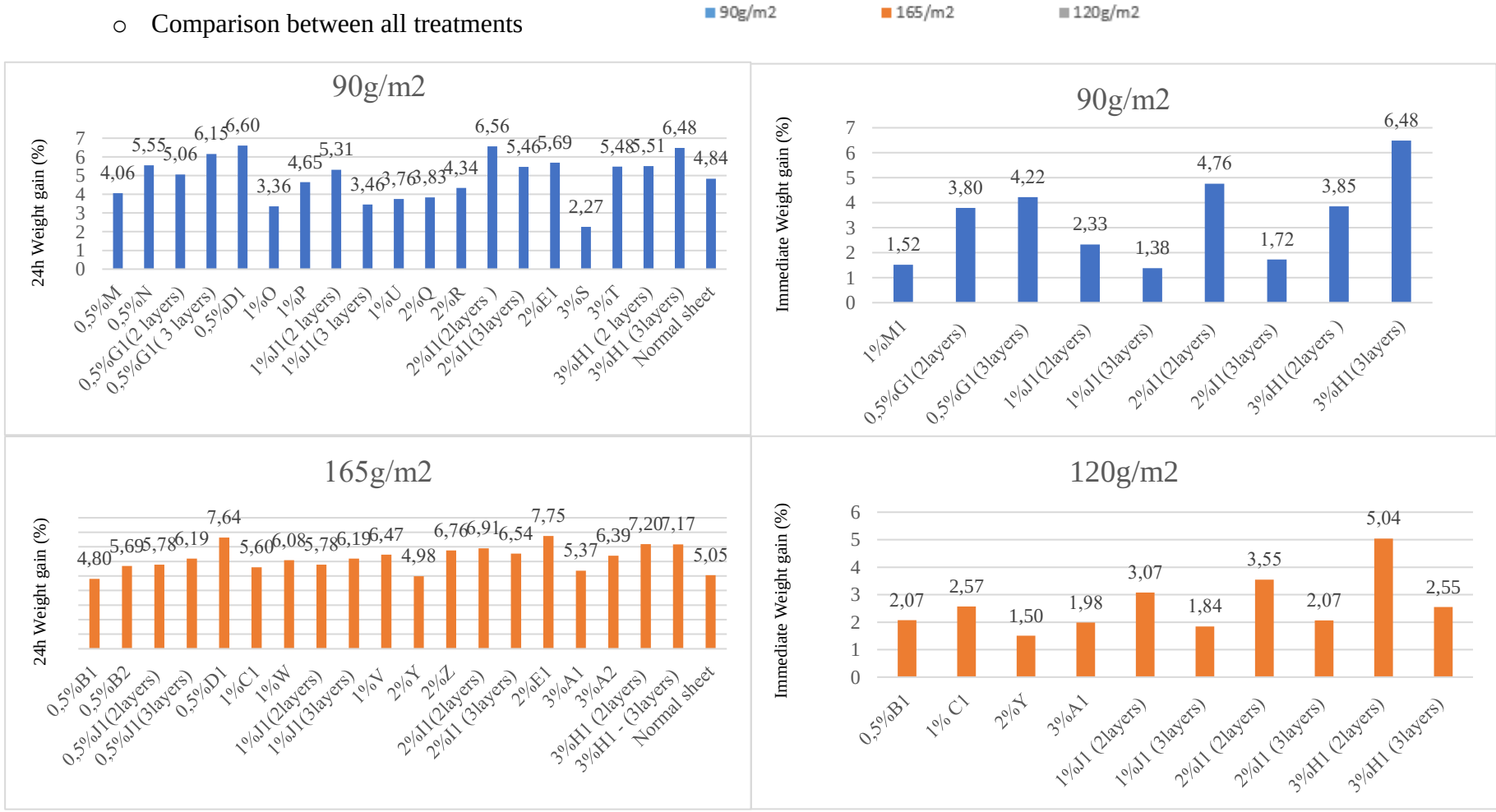
Rhim, J. (2004). Physical and mechanical properties of water resistant sodium alginate films. LWT - Food Sci. Technol. *37*, 323–330.

Soares, J.P., Santos, J.E., Chierice, G.O., and Cavalheiro, E.T.G. (2004). Thermal behavior of alginic acid and its sodium salt. *29*, 53–56.

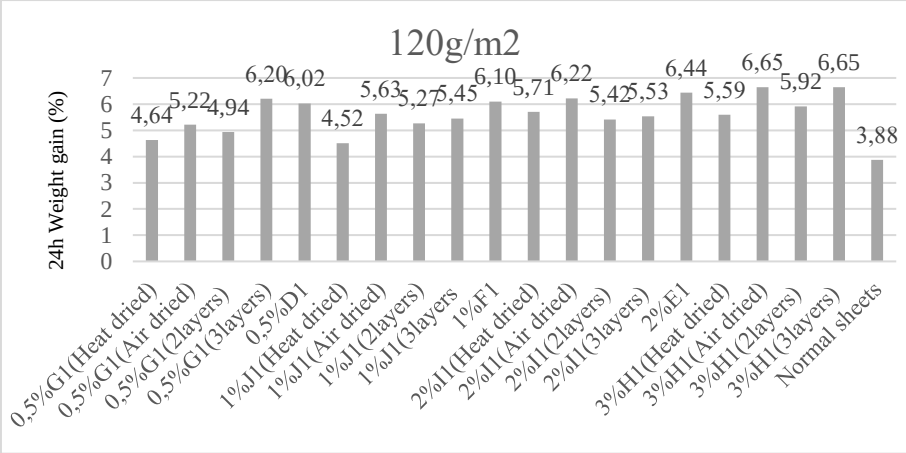
7. APPENDIX

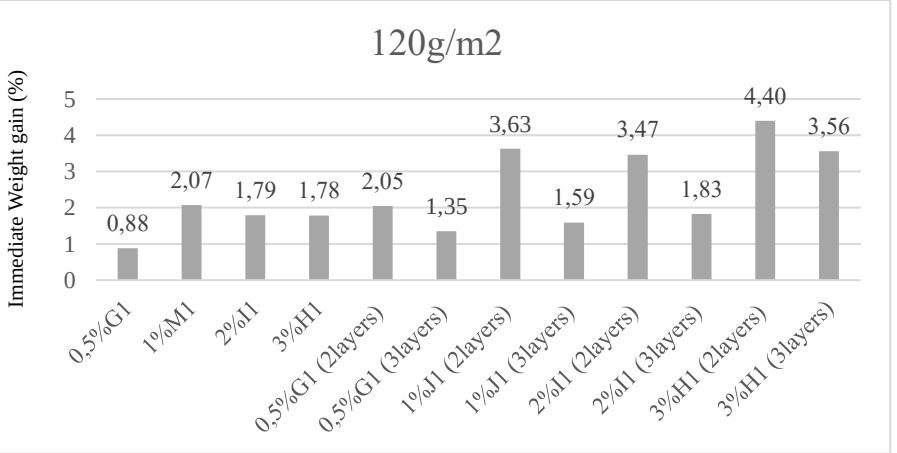
I -Weight gain (%) graphics

- Comparison between all treatments



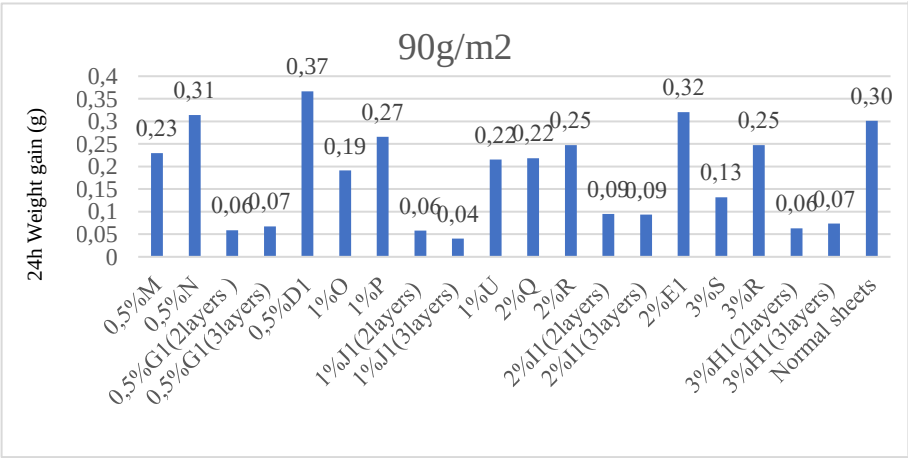
*Normal sheet: paper sheets without any type of treatments

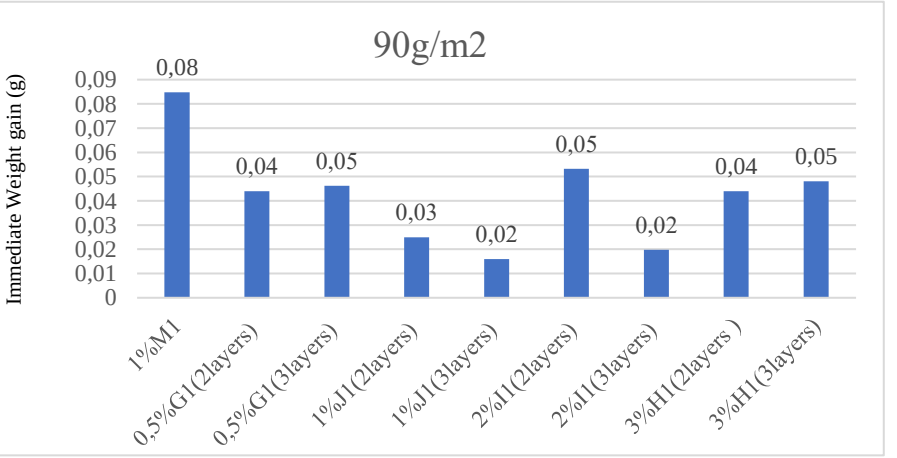




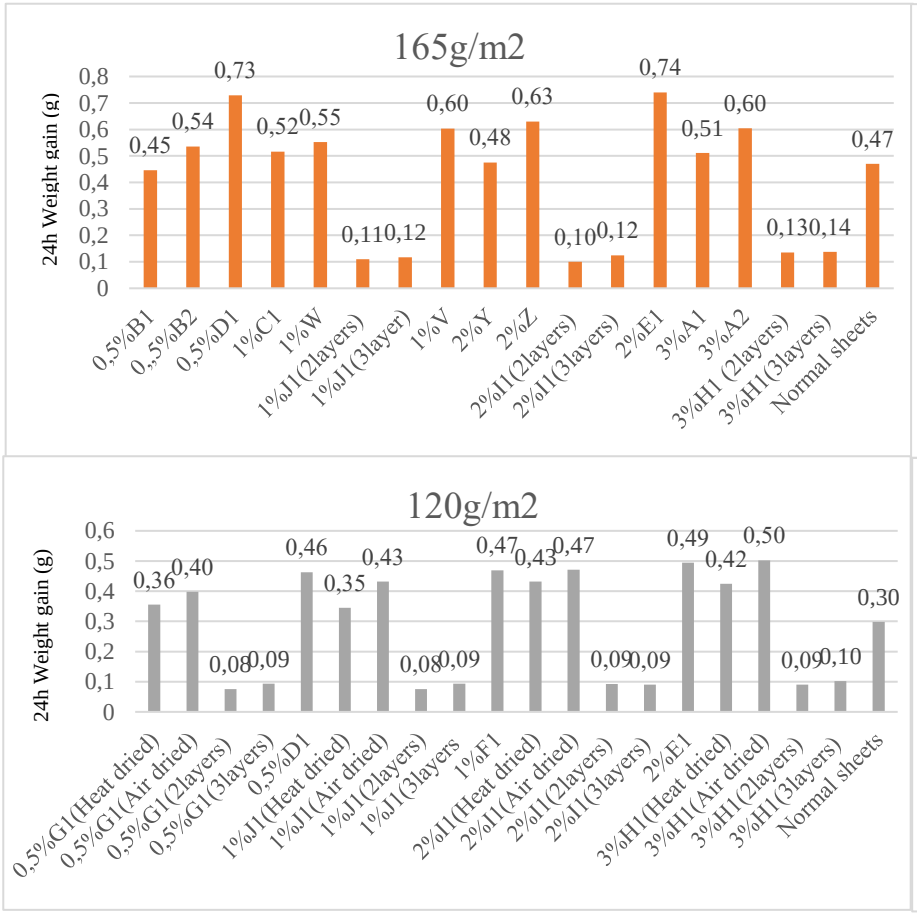
II -Weight gain (g) graphics

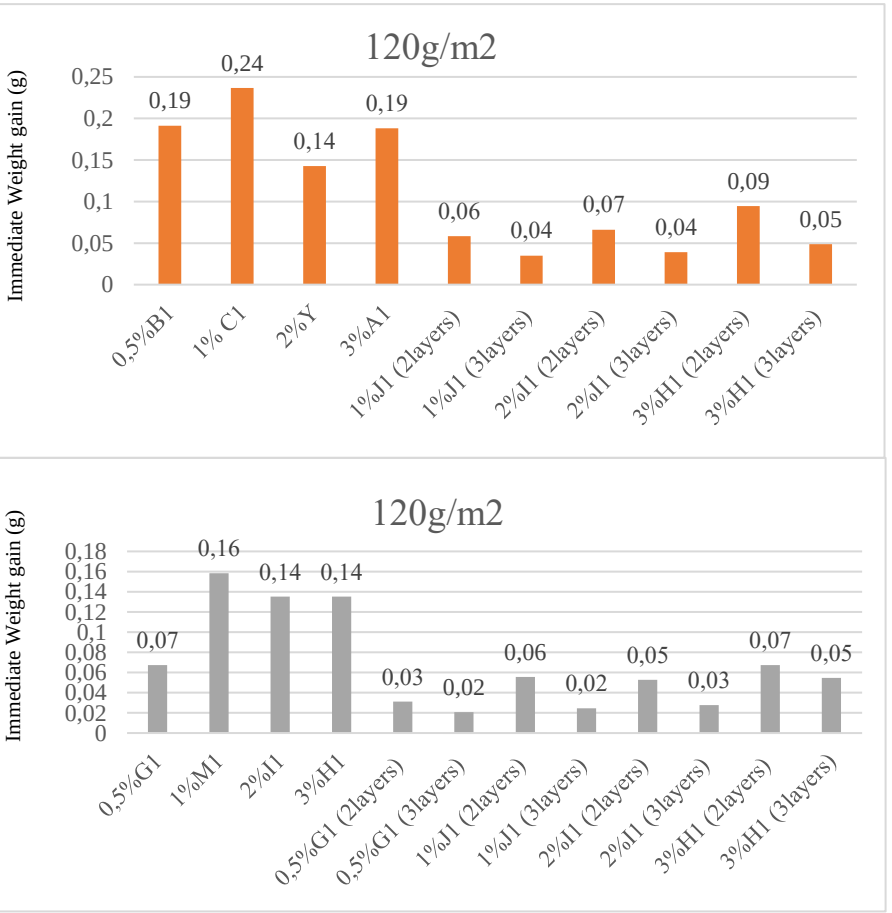
- Comparison between all treatments





*Normal sheet: paper sheets without any type of treatments





*Normal sheet: paper sheets without any type of treatments

III - Alginate Producer Specifications

PanReac AppliChem
ITW Reagents

Certificate of Analysis

Description	Alginic Acid Sodium Salt *BioChemica*
Product number	A3249
CAS number	9005-38-3
Molecular weight	
Formula	
Lot number	5R010496
QC-release date	11.02.2015
Retest date	02.2020

Parameter	Specification	Analysis
Appearance	white to pale tawny powder	pale yellow powder
pH (1 %; H_2O)	5.5 - 8.0	6.90
Heavy metals (as Pb)	max. 0.002 %	< 0.002 %
Sulfated ash	18 - 27 %	25.0 %
Loss on drying	max. 15 %	11.0 %
Viscosity (1 %; 20°C)	350 - 550 mPas	450 mPas
As	max. 0.0003 %	< 0.0003 %
Pb	max. 0.0005 %	< 0.0005 %

We hereby guarantee that this product was manufactured by a synthetic method, the raw material is not of animal origin and during the manufacturing process no material of animal origin is used.

This document has been produced electronically and is valid without a signature

AppliChem GmbH
Ottoweg 4
D-64291 Darmstadt
Phone +49 6151 9357 0 • Fax +49 6151 9357 11
www.applichem.com • service@dc.applichem.com

i.A. Tanja Platz
Quality Control

The manufacture of this product is carried out with greatest care. We guarantee the above details secured by our QM system. The suitability for special applications is not guaranteed. The certificate of analysis does not release you from performing the standard control upon receipt of incoming goods.

Chapter III - *The effect of active packaging on the storage of kiwifruit snacks*

Accepted on Acta Horticulturae

Appendix I – Poster present at IX International Symposium on Kiwifruit

The effect of active packaging on the storage of Kiwifruit snacks

Cristino Dores[1,2], Ana I. Vieira[1,2], Adriana C. Guerreiro[1,2,3], Custódia L. Gago[1,2,3], M. Graça Miguel[2], M. Leonor Faleiro[3], A. Dantuma[4], & M. Dulce Antunes[1,2]

[1]CEOT, [2]MeditBio, [3]CBMR, Faculdade de Ciências e Tecnologia, Edf. 8, Campus Gambelas, 8005-139 Faro, Portugal, [4]KCPK, IJsselburcht 3, 6825 BS Arnhem, The Netherlands.

Abstract

The consumption of snacks based on fruit has increased in the last years due to consumers concern to health issues and the knowledge of nutritional benefits of fruit. The aim of this work was to develop a snack with high fruit content based on kiwifruit (*Actinidia deliciosa* 'Hayward') and evaluate the effect of different active packages on its quality through storage. It was developed a snack made of kiwifruit pulp mixed, at equal proportions, with pectin solution (4% pectin+ 1% ascorbic acid), then with natural yogurt at a proportion of 3:1 to which was added stevia powder at 5%. The final mixture was poured on a baking foil, in ≈ 2 mL portions, and dried at 40 ºC, for 48 h. After drying, snacks were stored in active packaging paper bags (120 g/m^2) of the following composition: Paper enriched with alginate 1% or 2%; paper enriched with alginate 1% plus glycix 70% or 2% plus glycix 70%; control (non-treated paper). Measurements of microbial content, color (L*C*h°), crispness, water activity and sensory panels were performed. Results showed that the snacks were of good nutritional quality and were appreciated by the sensory panel. Through storage, there were no significant differences among active packaging for the most quality parameters studied. Nevertheless, Alginate 1% performed better in terms of appearance, control samples showed slightly higher microbial spoilage after 4 months and appearance decreased from 3 to 4 months. Further studies are needed to improve these packages.

Keywords: *Actinidia deliciosa*, snacks, fruit, quality, health, alginate.

INTRODUCTION

The consumption of healthier and convenient foods has increased throughout the last years. However, fresh fruits are highly perishable. Dehydration is probably the oldest form of preserving food. A dried food product offers the advantage of decreased weight, which has the potential for savings costs of transportation.

Fruit snacks are becoming very popular because all the fresh fruit nutrients are concentrated maintaining the fruit benefits. Kiwifruit (*Actinidia deliciosa)* is a subtropical fruit and belongs to the family Actinidiaceae. It is considered as one of the best fruits due to its high nutritive value (Rashidi and Seyfi, 2007). The predominant cultivar up to now is Hayward (Drzewiecki et al., 2016).

The competitive dried fruit market requires a package that will preserve the product inside and stand out on the store shelf (PMC, 2016). The type of package in which fruits are kept has influence on their characteristics. In response to the dynamic changes in current consumer demand and market trends, the area of active packaging is becoming increasingly significant.

Research and development of antimicrobial materials for food applications, such as packaging and other food contact surfaces is expected to grow in the next decade with the advent of new polymer materials and antimicrobials (Appendini and Hotchkiss, 2002). Mechanical and water barrier properties of paperboards can be modified by biopolymer coatings, and alginate-based films can increase water barrier properties. Alginates, which are extracted from brown

seaweeds of the *Phaephyceae* class, are the salts of alginic acid; they are resistant to solvents, oil, grease and exhibit interesting film-forming properties (Khwaldia et al., 2010; Guerreiro et al., 2015), so can be used to improve active packaging.

The aim of this work was to develop paper based active packaging enriched with alginate and a bioplastic coating based on glycerin and citric acid, and evaluate their effect on the storage ability of kiwifruit snacks.

MATERIAL AND METHODS

Kiwifruit (*Actinidia deliciosa*) cv. Hayward, origin from North Portugal, were purchased at the eating ripe stage from a local supermarket and were selected for snacks preparation. The yoghurt used was natural solid yoghurt also purchased in a local supermarket (Auchan, Jumbo).

For the snacks, the base ingredients were kiwifruits, natural yoghurt and pectin +ascorbic acid solution. Pectin solution and fruit were mixed in equal portions. Then, to the mixture was added natural yogurt at a proportion of 75/25 (75% kiwifruit and pectin + 25% yogurt). The pectin solution, added to the fruit, included pectin (4%), ascorbic acid (1%) and distilled water (95%). The mixture was performed using an Ultra- Turrax T18 (IKA, Staufen, Germany) during few minutes. The speed of the Ultra-Turrax was increased as the consistency. By the end of the mixing Stevia at 5% was added. The final paste was immediately poured, in baking foil, in portions (≈2 mL) and then dried at 40 ºC for 48 h. After drying, the snacks were left to cool for ≈ 45 minutes in a desiccator.

The snacks were then placed in 5 different types of active packages, then stored at room temperature (≈23 ºC) for 4 months. The packages used in this experiment were paper based (120g/m^2) enriched with alginate and a bioplastic coating named Glycix (Pantics BV) based on glycerin and citric acid.

The 5 different treatments used in this experiment were: Alginate 1% (Alg1%), Alginate 1% and a layer of Glycix at 70% on the exterior surface of the paper (Alg1%+Biop.), Alginate 2% (Alg2%), Alginate 2% and a layer of Glycix at 70% on the exterior surface of the paper (Alg2%+Biop.), and a control paper package without coating. Alginate 1 and 2 % as well as Glicix 70% solutions were made with distilled water by mixing till get a homogeneous solution.

The active packages were made by adding to a non-treated paper (120 g/m^2) sheet a solution of Alginate (1 ou 2%) formulated according to Guerreiro et al., 2015.

To add the Alginate solution to the paper it was used a size press (Ernst Benz;Model: KLFH-K) at a pressure of 15kg/cm^2. After that, the paper was heat dried using a hot press at 100ºC, and with a manual size press was added a layer of Glycix at 70% to the exterior surface of the paper sheet. The Glycix solution requires heat to polymerize and create a plastic surface, conferring and improving the water barrier properties of the paper. So, in order to polymerize the paper sheets, those were heated using a traditional oven at 180º C for 4 minutes.

The prepared active paper sheets were fold in an envelope shape and glued with a biodegradable glue made from vegetable sources (Axton, AKI). Prepared snacks were stored in the active packages at room temperature (≈15g/package). Just after snacks preparation and monthly, through storage, quality analysis of the snacks were performed.

The microbiological parameters that were determined included aerobic mesophilic microorganisms, *Enterobacteriaceae* and moulds and yeasts. The counts of aerobic mesophilic were done according to the standard Portuguese NP-4405 (2002) using Plate Count Agar medium (Biokar, Paris, France). The counts of *Enterobacteriaceae* were performed according to ISO 21528-2 (2004) using Violet Red Bile Glucose Agar (Biokar, Paris, France). The counts of moulds and yeasts were done according to the ISO 21527-2 (2008) using Dichloran Rose-Bengal Chloramphenicol Agar (Biokar, Paris, France). The color was measured by a Minolta Chroma meter CR-300 (EC Minolta, Japan) using the CIE Lab scale (L*, a* and b*). Hue was calculated as h° = arctan (b*/a*) and color saturation (Chroma) as $C^* = (a^{*2} + b^{*}_{2})^{0.5}$ (Mcguire, 1992).

The crispness was determined by puncture with a Chatillon TCD200 and Digital Force Gauge DFIS 50 (Jonh Chatillon & Sons, Inc., USA) using a spherical piston of 15 mm diameter until the snack breakout.

Water activity (a_w) of the snacks was measured at room temperature using a Rotronic Hydrolab meter (Rotronic AG, Bassersdor, Switzeland).

Sensory panel was performed with 15 semi-trained panelists. Panel members were asked to evaluate the appearance, crunchiness, aroma, texture, sweetness, acidity and overall flavor on the base of a 7 point hedonic scale: 1 – dislike definitely; 2 – dislike; 3 – dislike mildly; 4 – neither like nor dislike; 5 – like mildly; 6 – like; 7 – like definitely. Overall liking was calculated as a mean of the sensory parameters evaluated. This panel was performed at initial time, 3 and 4 months of storage.

RESULTS AND DISCUSSION

Color

The visual impact is the first thing that most of the people take notice in a product. In this case, the evaluation of color parameters is an important step for determining the quality of the fruit snack. For the 1, 3 and 4 months of storage the lightness parameter (L*) shown no statistically significant differences (P>0.05) among treatments (Figure 3.1), showing very similar L* values. There was a slight decrease in L* through the 4 months storage. Nevertheless, values decreased from 54 to 49, which in terms of appearance is not very important.

The hue (h˚) and Chroma (C*) values did not show any statistically significant difference among treatments trough the storage (Figures 3.2 and 3.3), having the h* values a tendency to decrease and the C* values a small increase over storage time. The color parameters results showed that the snacks color tends to get slightly darker trough storage, turning from a yellowish color to an orange color, as the result of oxidative reactions (Burdurlu and Karadeniz,2003).

Crispness and water activity

Crispness of the snacks is measured as the necessary force to break them. In the first month of storage, it was verified a small increase of the crispness values in all treatments (Figure 3.4), and after that, they remained almost constant for all treatments.

Higher force is necessary when the snacks are tender. This tenderness results in a higher force to break them which means higher crispness. The increase verified from just after manufacturing the snacks to the first month of storage, may be due to air exposure of the snacks from manufacturing till package closing. The addition of bioplastic layer to the packages has the objective to increase impermeability of the packages and alginate to adsorb it. However, in the present experiment, all treatments behaved well, without statistically significant differences (P>0.05) in keeping crispness for up to 4 months.

The a_w is an important parameter to check the product condition for microbial growth. The values obtained in our experiment did not show any statistically significant difference (P>0.05) among treatments (Figure 3.5) during the storage period, being below the range for microbial growth right after the first month of storage (Rahman, 2007). There was a slight decrease in a_w values through the 4 months storage. The slightly higher values at the beginning of the experiment may be due to air exposure before measurements as it was verified for the crispness measurements.

Microbial counts

At the beginning of the experiment, it was observed a low number of moulds and yeasts (1.4 ± 0.28 Log_{10} cfu/g), which is not unexpected in fruits and goes in accordance to Carlin and Nguyen-the, 2000; range of yeast and moulds, and are under the yeast and moulds critical limits stablished by Stannard (1997) for dehydrated fruits. No moulds and yeasts counts were observed from the first month of storage for all treatments (Figure 3.6). The counts of *Enterobacteriaceae* were always negative during the four months of storage. Despite the low a_w values, an increase on the counts of mesophilic aerobic bacteria was a common result for all treatments during the 4 months

of storage period (Figure 3.7). These values are in accordance with Carlin and Nguyen-the (2000) microbiological range for aerobic mesophilic bacteria in dehydrated food products. More recent bibliography (Commission Regulation(EC) No 2073/2005; Food Standards Australia New Zealand, 2016; Food Safety Authority of Ireland, 2016) did not establish any limit for mesophilic aerobic bacteria on fruit snacks, once these type of products have an inherently high plate count because of the characteristic microbial load present or as a result of the processing (Food Standards Australia New Zealand, 2016). Carlin and Nguyen-the (2000) reported that in dehydrated food products microbial load can go up to 8 Log_{10} cfu/g, which is above the mesophilic aerobic bacteria measured on this experiment. No statistically significant difference ($P>0.05$) among treatments were observed during the storage period. Nevertheless, at the end of the storage period, control samples showed a slightly higher mesophilic count.

Sensory panel

In order to verify the consumer's preference of the snacks exposed to the different treatments a sensory panel was performed (Figure 3.8 and 3.9). At the initial time, all the parameters were evaluated, showing results between 4 and 5 out of 7, which indicate a good acceptance of the snacks by the panellists.

At the third and fourth month only, the appearance of the snacks was evaluated. There was a significantly better appearance in the snacks after 3 months storage in comparison to 4 months (Figure 9). After 3 months storage, all treatments performed a value of 5 - Like mildly for appearance, except Alg1% which performed 6 - Like, in a scale of 1 to 7, similar to values at the beginning of the experiment.

After 4 months storage, the appearance of all treatments decreased and was in the limit of acceptance 4- neither like nor dislike for all treatments.

CONCLUSION

The results of this study show that kiwifruit (*Actinidia deliciosa* cv. Hayward*)* snacks are of good quality and can be stored for at least 4 months. Since these new kind of innovative food products reached the market recently, microbiological limits should be conceived, once the information about this is very limited. Although all packages performed well till 3 months storage, Alg. 1% performed better in terms of appearance. After 4 months, appearance was reduced to the limits of consumer's acceptance and at that time control samples showed slightly higher microbial counts. Further studies are required to improve the package manufacturing and test their effect in extending the storage period.

Literature cited

Appendini, P., and Hotchkiss, J.H. (2002). Review of antimicrobial food packaging. Innov. Food Sci. Emerg. Technol. *3*, 113–126.

Burdurlu, H. S., and Karadeniz, F. (2003). Effect of storage on nonenzymatic browning of apple juice concentrates. Food Chem. 80, 91–97

Carlin, F., and Nguyen-the, C. (2000). Fresh and Processed Vegetables. In The Microbiological Safety and Quality of Food, Vol. 1, B.M. Lund, T.C. Baird-Parker, G.W. Gould, eds. (Gaithersburg,MD,USA: Aspen Publishers), p. 620-667

Commision Regulation(EC) No 2073/2005 of 15 November 2005. Microbiological criteria for foodstuffs. Off. J. Eur. Union, pp.26.

Drzewiecki, J., Latocha, P., Leontowicz, H., Leontowicz, M., Park, Y.S., Najman, K., Weisz, M., Ezra, A. and Gorinstein, S. (2016). Analytical Methods Applied to Characterization of *Actinidia arguta*, *Actinidia deliciosa*, and *Actinidia eriantha* Kiwi Fruit Cultivars. Food Anal. Methods *9*, 1353-1366.

Food Safety Authority of Ireland (2016) Guidelines for the Interpretation of Results of Microbiological Testing of Ready-to-Eat Foods Placed on the Market (Revision 2), pp.48

Food Standards Australia New Zealand. (2016). Compendium of Microbiological Criteria for Food, October 2016, pp.50

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on *Arbutus unedo L.* fresh fruit storage. Postharvest Biol. Technol. *100*, 226–233.

ISO 21528-2:2004 - Microbiology of food and animal feeding stuffs -Horizontal methods for the detection and enumeration of Enterobacteriaceae - Part 2: Colony-count method. International Standards Organization, Switzerland.

ISO 21527-2:2008. Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for the Enumeration of Yeasts and Moulds – Part 2: Colony Count Technique in Products with Water Activity Less Than or Equal to 0.95. International Standards Organization, Switzerland

Khwaldia, K., Arab-Tehrany, E., and Desobry, S. (2010). Biopolymer Coatings on Paper Packaging Materials. Compr. Rev. Food Sci. Food Saf. *9*, 82–91.

Mcguire, R.G. (1992). Reporting of objective color measurements. HortScience *27*, 1254-1255.

NP-4405:2002. Food Microbiology – General Rules for Microorganism Counts. Colonies Count at 30 ºC. Instituto Português da Qualidade, Lisboa, Portugal (in Portuguese).

PMC – PaperMachineryCorporation. Dried food packaging. (2016) http://www.papermc.com/cups-and-containers/paper-cups-containers/dried-fruit-packaging/

Rahman, M.S. (2007). Food preservation: overview. In Handbook of food preservation, 2nd edn, M.S. Rahman, eds. (Boca Raton, FL: CRC Press), p. 3-17.

Rashidi, M., and Seyfi, K. (2007). Classification of fruit shape in kiwifruit applying the analysis of outer dimensions. Int. J. Agric. Biol. 1560-8530, 759–762.

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on Arbutus unedo L. fresh fruit storage. Postharvest Biol. Technol. *100*, 226–233.

Rashidi, M., and Seyfi, K. (2007). Classification of fruit shape in kiwifruit applying the analysis of outer dimensions. Int J Agric Biol 759–762.

Stannard, C. (1997). Development and use of microbiological criteria for foods. Food Sci. Technol. Today *11*, 137–176.

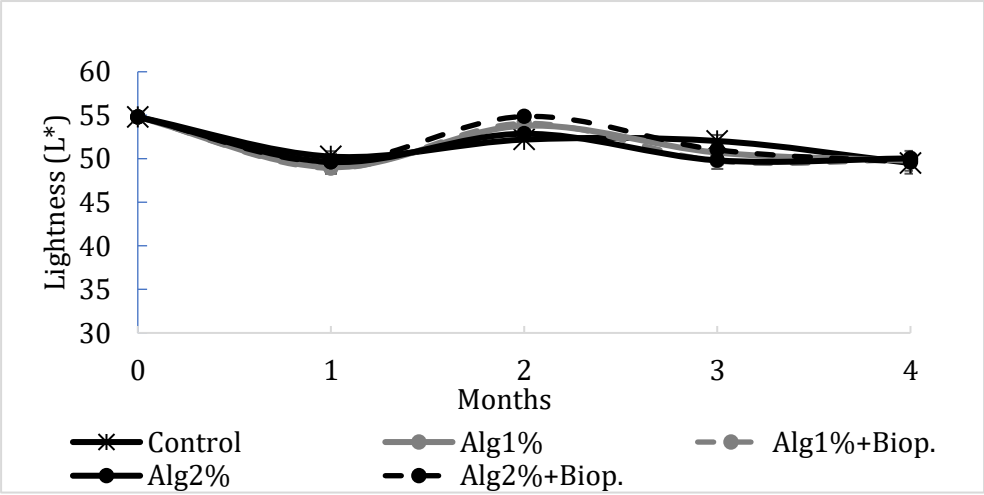


Figure 3.1. Lightness (L*) color parameter of kiwifruit snacks through 4 months of storage at room temperature (≈23 ºC).

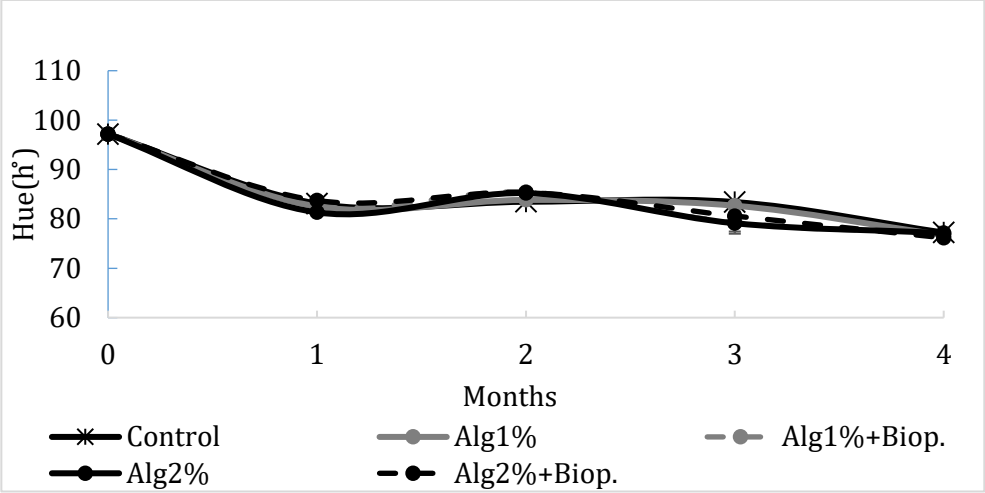


Figure 3.2. Hue (h°) color parameter of kiwifruit snacks through 4 months of storage at room temperature (≈23 ºC).

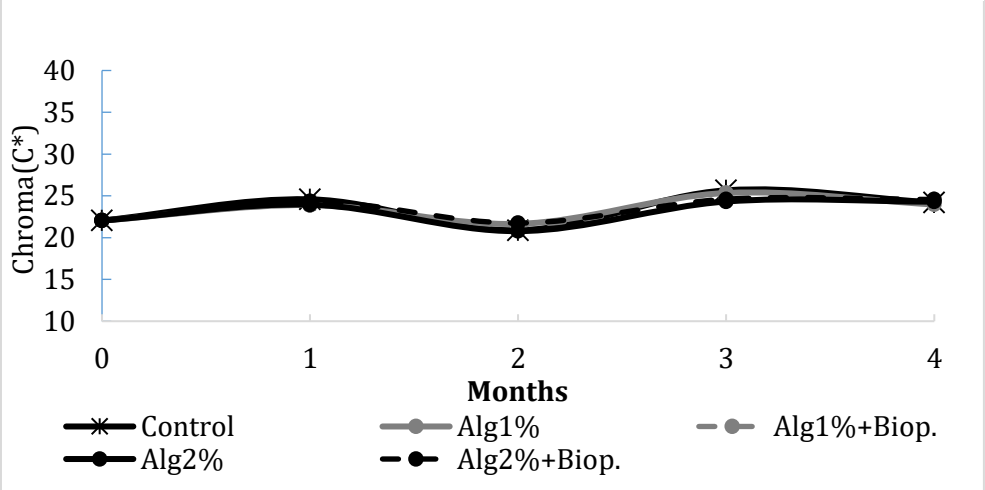


Figure 3.3. Chroma (C*) color parameter of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC).

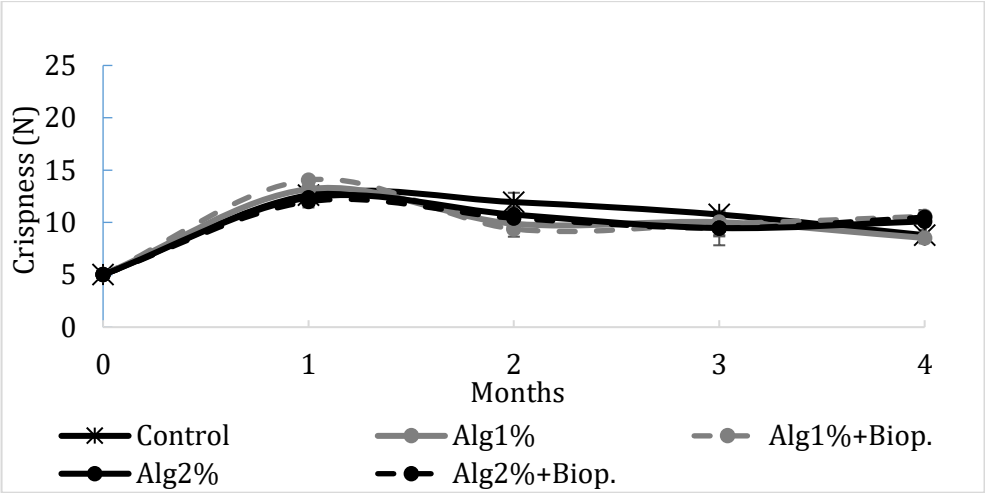


Figure 3.4. Crispness (N) of kiwifruit snacks snacks through 4 months of storage at room temperature (≈23ºC).

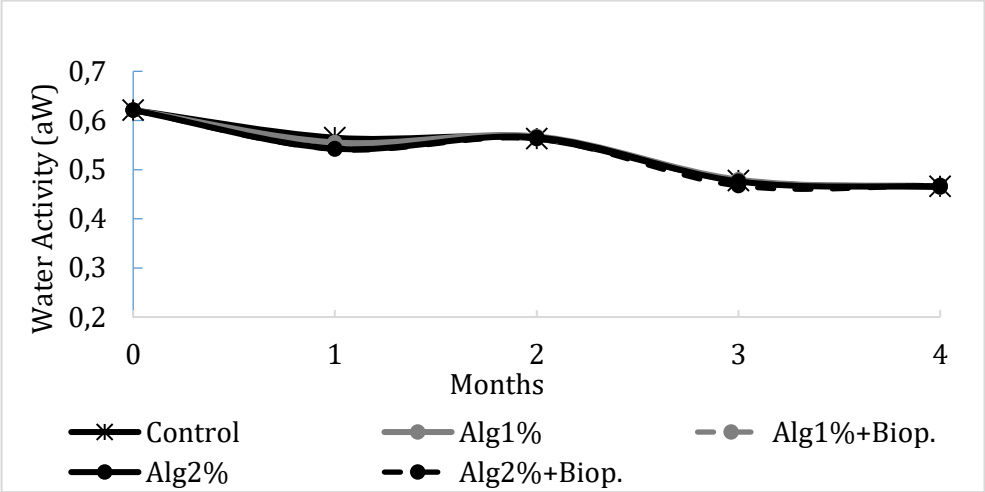


Figure 3.5. Water activity (a_w) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC).

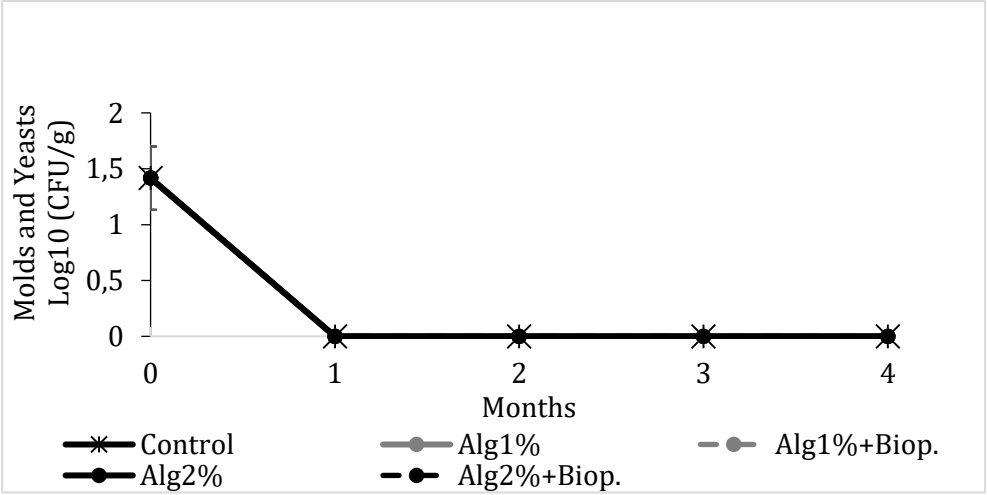


Figure 3.6. Molds and Yeasts (Log_{10} CFU/g) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC).

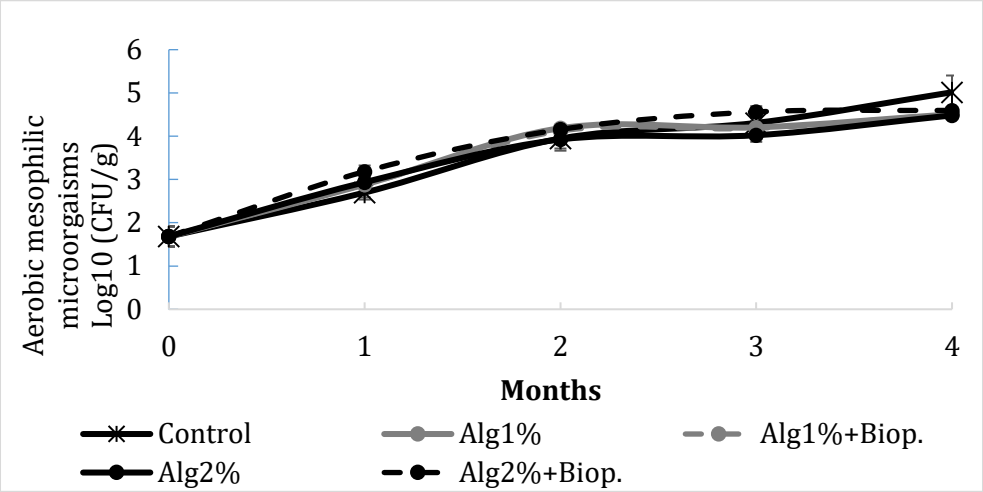


Figure 3.7.Aerobic mesophilic microorganisms Log_{10} (CFU/g) of kiwifruit snacks

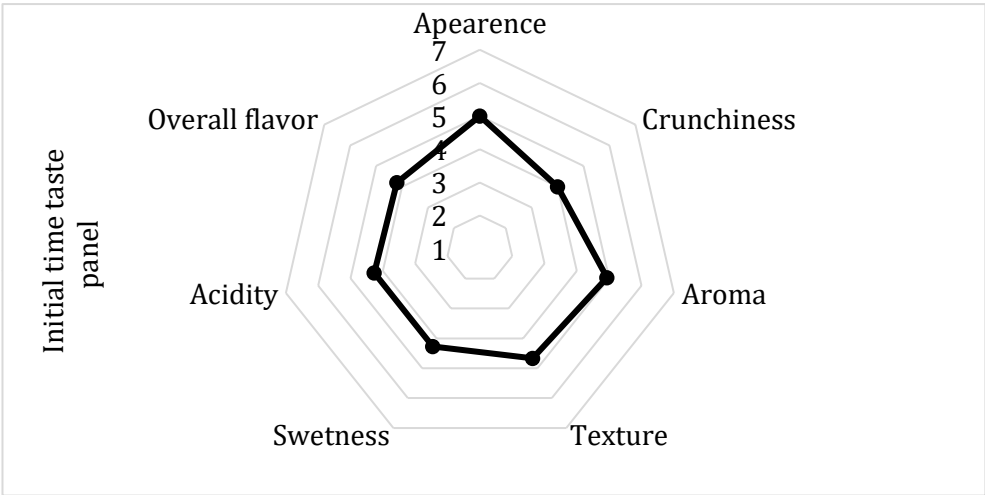


Figure 3.8. Initial time taste panel of kiwifruit snacks.

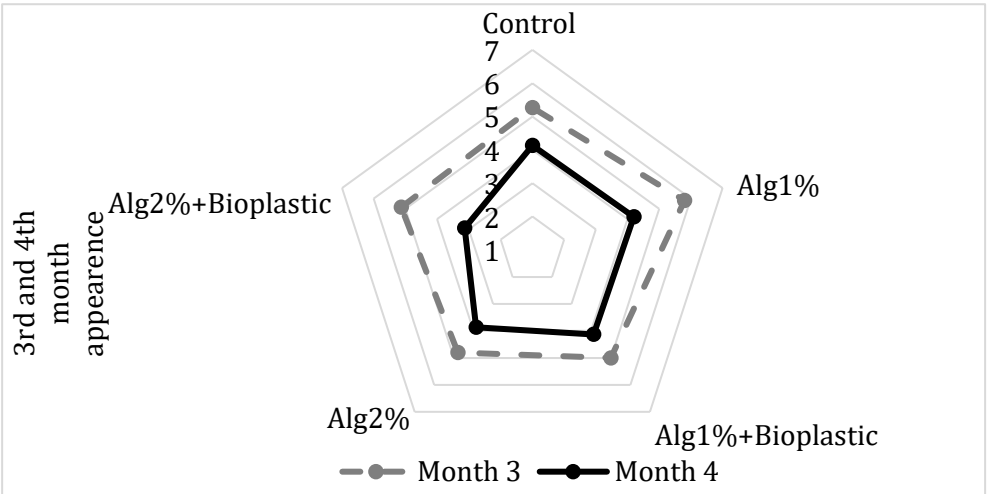


Figure 3.9. Appearence of kiwifruti snacks on third and fourth month of storage.

Chapter IV - *The effect of active packaging enriched with Citral, Eugenol and Alginate on the storage of 'Strawberry Festival' strawberry fruits*

The effect of active packaging enriched with citral, eugenol and alginate on the storage of 'Strawberry Festival' strawberry fruits

Cristino Dores[1,2], Ana I. Vieira[1,2], Adriana C. Guerreiro[1,2,3], Custódia L. Gago[1,2,3], M. Graça Miguel[2], M. Leonor Faleiro[3], A. Dantuma[4], & M. Dulce Antunes[1,2]

[1]CEOT, [2]MeditBio, [3]CBMR, Faculdade de Ciências e Tecnologia, Edf. 8, Campus Gambelas, 8005-139 Faro, Portugal, [4]KCPK, IJsselburcht 3, 6825 BS Arnhem, The Netherlands.

Abstract

Strawberries are largely consumed around the world and are among the most perishable fruits. Packaging and storage conditions must be taken in serious account. The aim of this work was to evaluate the fresh strawberry quality through storage in different active packaging. The strawberry (*Fragaria x ananassa* 'Strawberry Festival') fruits were harvest from a local farm in South Portugal and stored at 4 ˚C ±0.5 in active packaging of the following composition: Paper enriched with alginate 1% or 2%; paper enriched with Alginate 1 or 2% plus 0.3% Citral and 0.2% Eugenol ; paper enriched with Alginate 1 or 2% plus 0.6% Citral and 0.4% Eugenol; Standard strawberry package control (Polypropylene plastic trays (8cm*10cm*4cm)) and a Standard strawberry package control with non-enriched paper. Measurements of color (L*a*b*), firmness,˚Brix, weight loss, microbial content, anthocyanins and sensory panels were performed. Through storage, there were no significant differences among active packaging for the most quality parameters studied. Nevertheless, the packages with alginate and essential oils combined showed interesting results on restraining the microbiological content and reducing spoilage. Further studies are needed to improve these packages.

Keywords: *Fragaria x ananassa.*, fruit, storage, quality, alginate, essential oils.

INTRODUCTION

Strawberry (*Fragaria x ananassa*) is a very popular species cultivated in numerous countries for its fruits (culinary term) which are frequently consumed either fresh, frozen or as an additive to dairy products. Regular consumption of strawberries can have potential health promoting effect(Prymont-Przyminska et al., 2014). The strawberry is a delicate and perishable fruit, susceptible to mechanical injury, physiological deterioration, water loss and decay (Sanz et al., 1999).

Losses of fresh fruits and vegetables in developed countries are estimated to range from 2 to 23 percent, with an overall average of 12 percent losses between production and consumption sites (Kader and Rolle, 2004). To achieve good marketability, the highest quality possible must be maintained during a short period of time, just the time necessary to reach the consumer (Nadas et al., 2003).

The type of package in which fruits are kept has influence on their characteristics. In response to the dynamic changes in current consumer demand and market trends, the area of active packaging is becoming increasingly significant. Research and development of antimicrobial materials for food applications such as packaging and other food contact surfaces is expected to grow in the next decade with the advent of new polymer materials and antimicrobials (Appendini and Hotchkiss, 2002). Mechanical and water barrier properties of paperboards can be modified by biopolymer coatings, and alginate-based films can increase water barrier properties. Alginates, which are extracted from brown seaweeds of the Phaephyceae class, are the salts of alginic acid.

They are resistant to solvents, oil, grease and exhibit interesting film-forming properties (Khwaldia et al., 2010).

Essential oils constituents have proven to have antimicrobial effects (Guerreiro et al., 2015), so can be added to improve active packaging.

The aim of this work was to develop paper based active packaging enriched with alginate and essential oils, and evaluate their effect on the storage ability of strawberry fruit.

MATERIAL AND METHODS

The strawberry fruits (*Fragaria x ananassa*) 'Strawberry Festival', origin from a farm in Faro, South Portugal, were purchased at the eating ripe stage from a local producer.

The active packages were made by adding to a non-treated paper (120 g/m^2) sheet a solution of Alginate (1 or 2%) plus Citral (0.3 or 0.6%) and Eugenol (0.2 or 0.4%) formulated according to (Guerreiro et al., 2015).

To add the Alginate and the essential oils compounds solution to the paper it was used a size press (Ernst Benz;Model: KLFH-K) at a pressure of 15kg/cm^2. After that, the paper was air dried at room temperature (≈ 20 ºC).

Eight different treatments were used in this experiment: Alginate 1% (Alg1%), Alginate 1% plus Citral 0.3% and Eugenol 0.2% (Alg1%+Ci0.3%+Eu0.2%), Alginate 1% plus Citral 0.6% and Eugenol 0.4% (Alg1%+Ci0.6%+Eu0.4%), Alginate 2% (Alg2%), Alginate 2% plus Citral 0.3% and Eugenol 0.2% (Alg2%+Ci0.3%+Eu0.2%), Alginate 2% plus Citral 0.6% and Eugenol 0.4% (Alg2%+Ci0.6%+Eu0.4%), standard strawberry package control (Polypropylene plastic trays (8cm*10cm*4cm)) and a control standard package with non-enriched paper.

The prepared active paper sheets were cut and placed into standard strawberry trays, covering all the bottom and the sides of the trays. After that, 6 strawberry fruits were placed into the packages and then stored at 4 ºC for 14 days. Quality measurements were performed at initial storage time, 7, 10 and 14 days.

The microbiological parameters that were determined included aerobic mesophilic microorganisms, psychrophilic microorganisms and moulds and yeasts. The counts of aerobic mesophilic were done according to the standard Portuguese NP-4405 (2002) using Plate Count Agar medium (Biokar, Paris, France). The counts of psychrophilic were performed according to ISO 21528-2 (2004) using Plate Count Agar medium (Biokar, Paris, France). The counts of moulds and yeasts were done according to the ISO 21527-2 (2008) using Dichloran Rose-Bengal Chloramphenicol Agar (Biokar, Paris, France). The color was measured by a Minolta Chroma meter CR-300 (EC Minolta, Japan) using the CIE Lab scale (L*, a* and b*).

The firmness was determined by puncture with a Chatillon TCD200 and Digital Force Gauge DFIS 50 (Jonh Chatillon & Sons, Inc., USA) using a 4 mm diameter probe at a depth of 7 mm.

For the ◦Brix determination a digital refractometer HI 96801 (Hanna instruments, USA) was used, measuring the fruits juice sugar content.

The weight loss was expressed as a percentage of the initial weight.

The total anthocyanin content was measured using a modified pH differential method (Lee et al., 2005). Absorbance of anthocyanin at 520 nm and 700 nm in different pH buffers (pH 1.0 and 4.5) were measured, respectively. Absorbance readings were converted to total mg of Cyanidin 3-glucoside per 1g of fresh weight of sample using the molar extinction coefficient of 26,900 and absorbance of A.

Anthocyanin pigment concentration was, therefore, expressed as Cyanidin-3-glucoside equivalents, as follows:

$$\frac{A \times MW \times DF \times 10^3}{\varepsilon \times l}$$

A = (A520 nm − A700 nm) pH 1.0 − (A520 nm − A700 nm) pH 4.5
MW = 449.2 g/mol = value of the molecular weight of Cyanidin-3-glucoside
DF = dilution factor
ε = 26,900 molar extinction coefficient for Cyanidin-3-glucoside, in L × mol − 1 × cm − 1

103= factor for conversion from g to mg
l = path length in cm.

Sensory panel was performed with 15 semi-trained panelists. Panel members were asked to evaluate the appearance, texture, aroma, texture, sweetness, acidity and overall flavor on the base of a 7 point hedonic scale: 1 – dislike definitely; 2 – dislike; 3 – dislike mildly; 4 – neither like nor dislike; 5 – like mildly; 6 – like; 7 – like definitely. Overall liking was calculated as a mean of the sensory parameters evaluated. This panel was performed at initial time, 7 and 14 days of storage.

RESULTS AND DISCUSSION

Color

Color grading is a crucial step in the processing of fruits and vegetables that directly affects profitability, because the quality of agricultural products is often associated with their color(Lee et al., 2005). During storage, the L* (lightness, 100= white; 0= black) parameter shown no statistically significant differences (P>0.05) among treatments,showing very similar and decreasing values. The Alg1%+Ci0.6%+Eu0.4% treatment shows lower values after 14 days (Figure 4.1).

Regarding the a* (+, red; -, green) color parameter, all treatments except the standard packaging control, showed an increase till day 10 of storage with very similar values among treatments, being the Alg2%+Ci0.6%+Eu0.4% the treatment with lowest values on the first 7 days showing statistically difference (P<0.05) from the other treatments. On the 10th storage day the standard packaging control exhibit the lowest a* value being statistically different from the other treatments with exception of the Alg2%+Ci0.6%+Eu0.4% which also show the lowest values among the other treatments containing alginate and the package with paper without coating (Figure 4.2).

The b*(+, yellow; -, blue) parameter showed similar and stable values until the 10th day of storage were all treatments values decrease being the Alg1%+Ci0.6%+Eu0.4% the treatment with the highest decrease among treatments, differing statistically (P>0.05) from the other treatments, but not from the standard packaging control after 14 days of storage (Figure 4.3).

Butkhup and Samappito(2000) showed similar results on fruits which are resulting from normal oxidation of phenolic compounds responsible for the browning and ripening of fruits.

Firmness, Total soluble solids (˚Brix) and weight loss

All treatments show very similar weight loss values, increasing during storage. Nevertheless, the Alg2%+Ci0,6%+Eu0,4% and the standard package with non-enriched paper show the lowest weight loss values during the 14 days of storage (Figure 4.4).

The firmness values do not show any statistically difference (P<0.05) among treatments, exhibiting a small increase of firmness on the first 7 days, mostly on Al 1%, and after that add a small decrease until the 14th day of storage (Fig.5).

There was a common decrease in all treatments after 7 days of storage on ˚Brix values, where Alg1%+Ci0.3%+Eu0.2% presented the lowest values and Alg2%+Ci0.3%+Eu0.2% showed the highest ones. On the 10th day of storage it was verified an increase of ˚Brix values in Alg1%+Ci0.3%+Eu0.2% and standard package control treatments unlike the rest of treatments which values decreased and where Alg2%+Ci0.3%+Eu0.2% was the treatment with the lowest values. After 14 days of storage the treatments with higher concentration of essential oils (Alg1%+Ci0.6%+Eu0.4% and Alg2%+Ci0.6%+Eu0.4%) showed a decrease of ˚Brix as well as the standard package control. On the other hand, the rest of the treatments showed an increase of ºBrix values (Figure 4.6). Despite these results is safe to say that all treatments show a decrease tendency of ºBrix values, exhibiting lower values after 14 days than on the initial time, which could

be due to high-postharvest metabolism as reported by Caner and Seckin (2008). Also the fact º Brix is measured always in diferent fruit can explain the differences.

Microbial counts

The yeast and moulds values were very similar and stable during storage showing no significant difference till the 14th day of storage where the Alg1%+Ci0,6%+Eu0,4% prove to be the treatment with the lowest value of yeast and moulds, being statically different($P>0.05$) from the rest of the treatments (Figure 4.7). Except for Alg.2% , Alg2%+Ci0.3%+Eu0.2% and standard package control with non-enriched paper, which are slightly over the limit exceptionally on day 10, the rest of the treatments are always below the limits of 3 Log_{10} cfu/g (Barth et al., 2009) during 14 days of storage.

According to Barth et al.(2009), the limits for aerobic bacteria on minimally fresh processed fruit for safe consumption are 7 Log_{10} cfu/g. Regarding the aerobic mesophilic bacteria, all treatments showed values below those limits, where the Alg1%+Ci0.3%+Eu0.2% showed very interesting results, being the treatment with less mesophilic load until day 10, where Alg.1% appeared to have similar values. By the end of the storage period all treatments exhibited values lower than the standard control and the standard control package with non-enriched paper. The Alg.1%, Alg1%+Ci0,3%+Eu0,2% and the Alg2%+Ci0,3%+Eu0,2% were the treatments with lowest values being statistically similar ($P<0.05$) to Alg1%+Ci0,6%+Eu0,4%, which also presented intermediate values, but statistically different ($P>0.05$) from the rest of the treatments (Figure 4.8).

The psychrophilic counts were null in all treatments, except for the Alg1%+Ci0,3%+Eu0,2% treatment at the end of the experiment (Figure 4.9). Despite that result the limits for psychrophilic bacteria for ready-to-eat food (8 Log_{10} cfu/g) were respected according to Barth et al. (2009).

Anthocyanins

For the anthocyanins values, there were not statistically significant differences ($P<0.05$) among treatments until day 10, were the Alg.1% showed the highest anthocyanins content. By the end of the experiment the Alg2%+Ci0,3%+Eu0,2% and Alg2%+Ci0,6%+Eu0,4% exhibit opposed results, being the treatments statistically significant different ($P>0.05$) and with the lowest and the higher values of anthocyanins, respectively. With the exception of Alg.1% which anthocyanins content decrease on the 14th day of storage, the rest of the treatments presented stable and even increasing with maturity as described by Wang and Lin(2000) (Fig. 4.10).

Sensory panel

To verify the consumer's preference of the fruits exposed to the different treatments a sensory panel was performed (Figure4.11a;4.11b;4.11c). Until day 7, all the parameters were evaluated, showing results between 5 and 6 out of 7 on initial time and 4 and 5 out of 7 after 7 days of storage. All treatments showed very similar scores in all parameters at day 7, but the standard control package performed higher scores on aroma and texture. At the 14th day of storage only the appearance was evaluated due to the microbiological load for yeast and moulds were close to the safe limits (Barth et al., 2009). At his point the scores varied between 4 and 5 with the Alg2%+Ci0.3%+Eu0.2 showing the highest score among treatments. These results indicate a good acceptance of the fruit by the panellists after 14 days of storage(Figure 4.11a;4.11b;4.11c).

CONCLUSION

The results of this study show that strawberries (*Fragaria x ananassa.* 'Strawberry Festival'*)* are of good quality and can be stored for at least 14 days, being only limited by the microbial growth, which limits should be conceived, once the consumers acceptance did not exclude the fruits regardless their microbial load. Although there were no significant differences among active packaging for the most quality parameters studied, the packages with alginate and essential oils combined showed less aerobic mesophilic bacteria growth, as well as for Alg1%+Ci0,6%+Eu0,4% on yeast and molds, which indicates that this combination may be beneficial for decreasing the microbiological growth. Further studies are required to improve the package manufacturing and test their effect in further extending the storage period.

Literature cited

Appendini, P., and Hotchkiss, J.H. (2002). Review of antimicrobial food packaging. Innov. Food Sci. Emerg. Technol. *3*, 113–126.

Barth, M., Hankinson, T.R., Zhuang, H., and Breidt, F. (2009). Microbiological Spoilage of Fruits and Vegetables. In Compendium of the Microbiological Spoilage of Foods and Beverages, pp. 135–183.

Butkhup, L., and Samappito, S. (2011). changes in physico-chemical properties , polyphenol compounds and antiradical activity during development and ripening of maoluang (Antidesma bunius L. Spreng) fruits. J. Fruit Ornam. Plant Res. *19*, 85–99.

Caner, C., and Seckin, Æ.M. (2008). Extending the quality of fresh strawberries by equilibrium modified atmosphere packaging. 1575–1583.

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on Arbutus unedo L. fresh fruit storage. Postharvest Biol. Technol. *100*, 226–233.

ISO 21528-2:2004 - Microbiology of food and animal feeding stuffs -Horizontal methods for the detection and enumeration of Enterobacteriaceae - Part 2: Colony-count method. International Standards Organization, Switzerland.

ISO 21527-2:2008. Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for the Enumeration of Yeasts and Moulds – Part 2: Colony Count Technique in Products with Water Activity Less Than or Equal to 0.95. International Standards Organization, Switzerland

Kader, A.K., and Rolle, R.S. (2004). The role of post-harvest management in assuring the quality and safety of horticultural produce. Fao Agric. Serv. Bull. 1–22.

Khwaldia, K., Arab-Tehrany, E., and Desobry, S. (2010). Biopolymer Coatings on Paper Packaging Materials. Compr. Rev. Food Sci. Food Saf. *9*, 82–91.

Lee, J., Durst, R.W., and Wrolstad, R.E. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. J. AOAC Int. *88*, 1269–1278.

Nadas, A., Olmo, M., and García, J. m. (2003). Growth of Botrytis cinerea and Strawberry Quality in Ozone-enriched Atmospheres. J. Food Sci. *68*, 1798–1802.

NP-4405:2002. Food Microbiology – General Rules for Microorganism Counts. Colonies Count at 30 ºC. Instituto Português da Qualidade, Lisboa, Portugal (in Portuguese).

Prymont-Przyminska, A., Zwolinska, A., Sarniak, A., Wlodarczyk, A., Krol, M., Nowak, M., de Graft-Johnson, J., Padula, G., Bialasiewicz, P., Jaroslaw, M., et al. (2014). The astaxanthin-induced improvement in lipid metabolism during exercise is mediated by PGC-1alfa increase in skeletal muscle. J. Clin. Biochen. Nutr *54*, 86–89.

Sanz, C., Perez, a G., Olias, R., and Olias, J.M. (1999). Quality of strawberries packed with perforated polypropylene. J. Food Sci. *64*, 748–752.

Wang, S.Y., and Lin, H. (2000). Antioxidant Activity in Fruits and Leaves of Blackberry , Raspberry , and Strawberry Varies with Cultivar and Developmental Stage. J. Agric. Food Chem. *48*, 140–146.

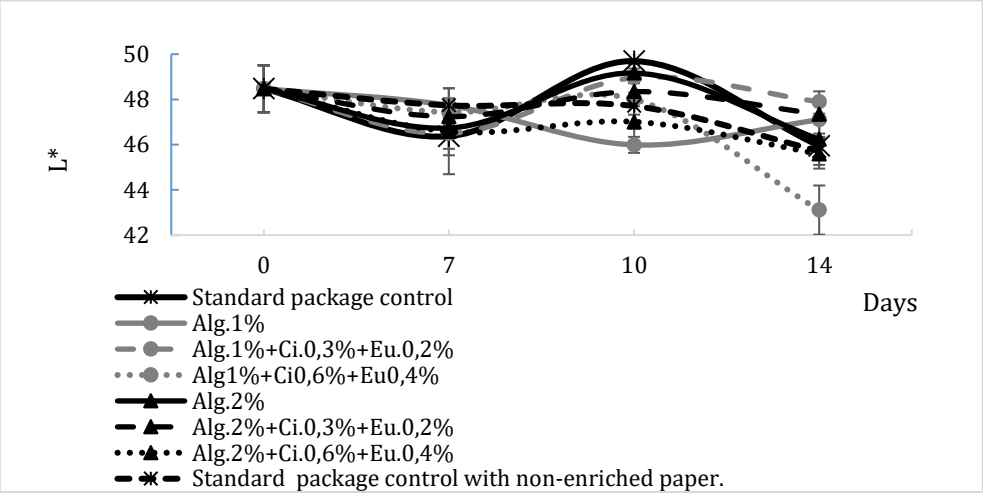


Figure 4.1.Lightness (L*) color parameter of strawberries through 14 days of storage at 4 ºC.

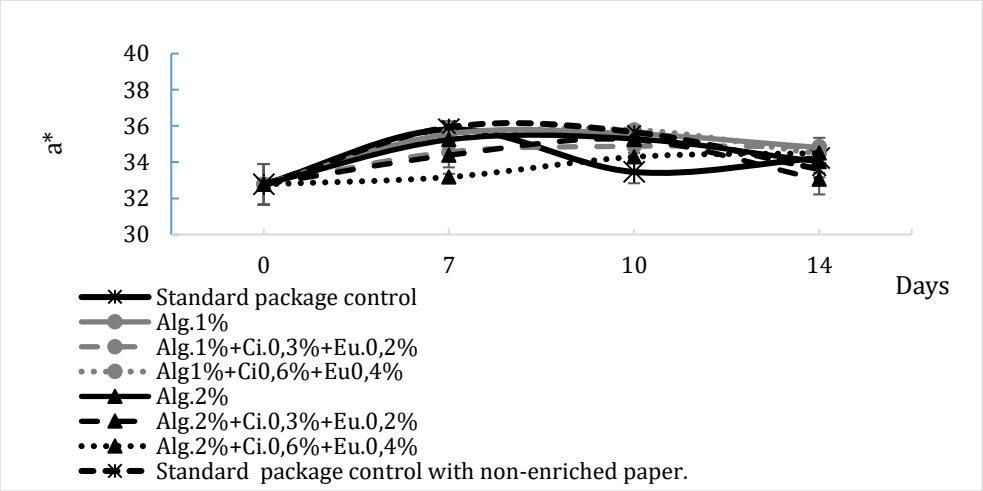


Figure 4.2. a* color parameter of strawberries through 14 days of storage at 4 °C.

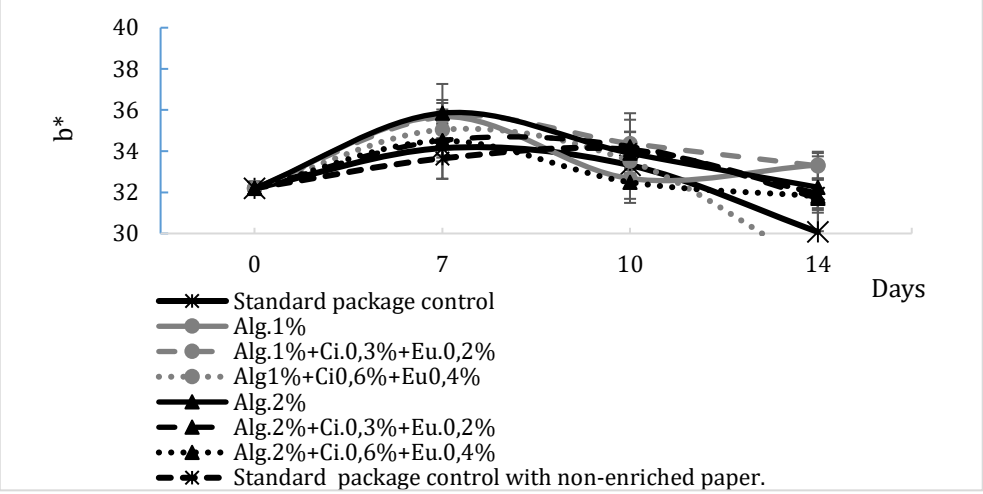


Figure 4.3. b* color parameter of strawberries through 14 days of storage at 4°C.

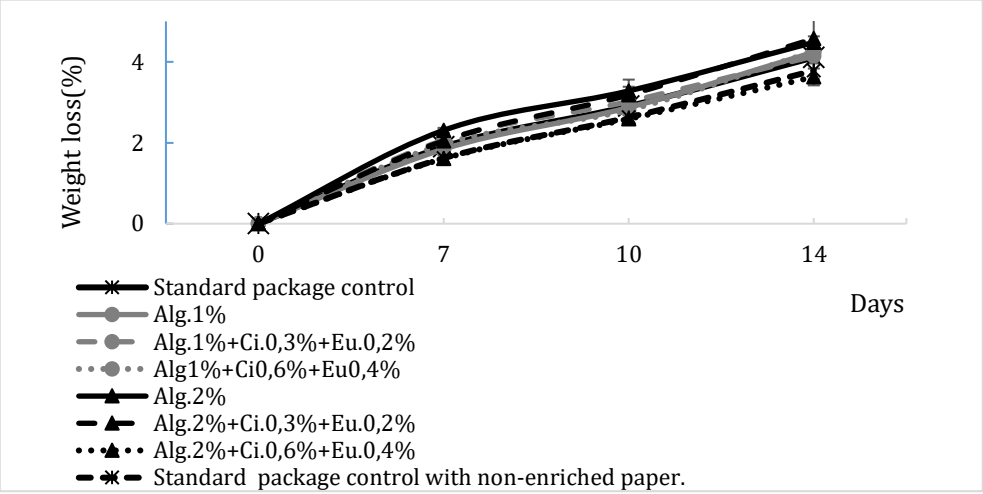


Figure 4.4. Weight loss (%) of strawberries through 14 days of storage at 4 ºC.

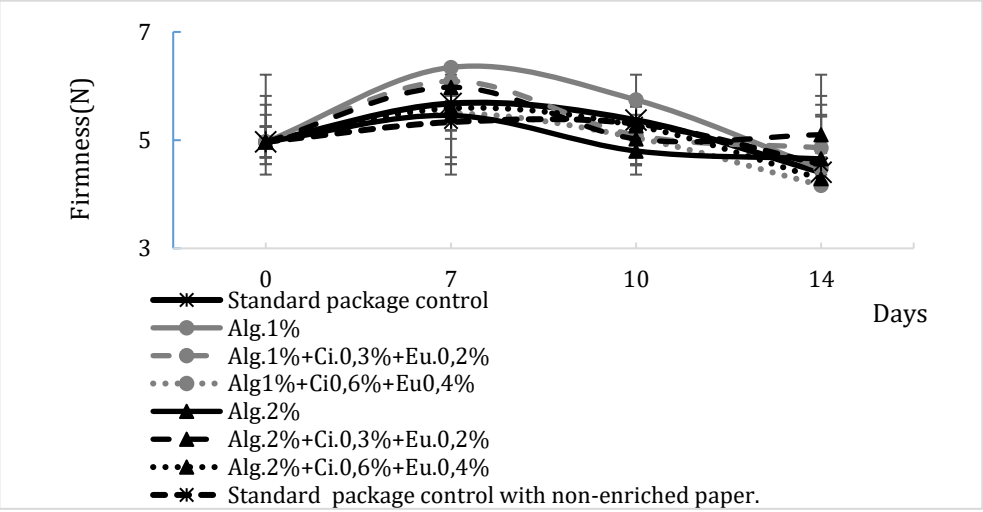


Figure 4.5. Firmness(N) of strawberries through 14 days of storage at 4 ºC.

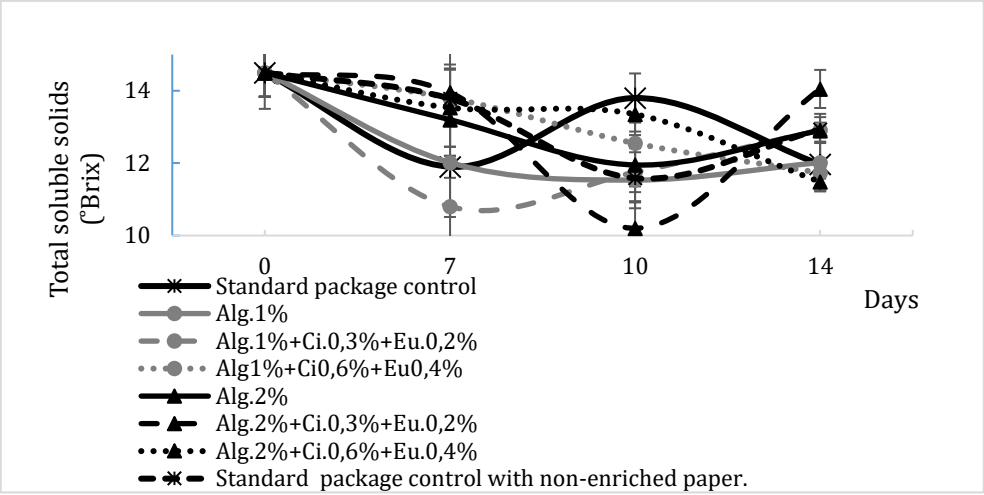


Figure 4.6 – Total soluble solids (°Brix) of strawberries through 14 days of storage at 4 ºC.

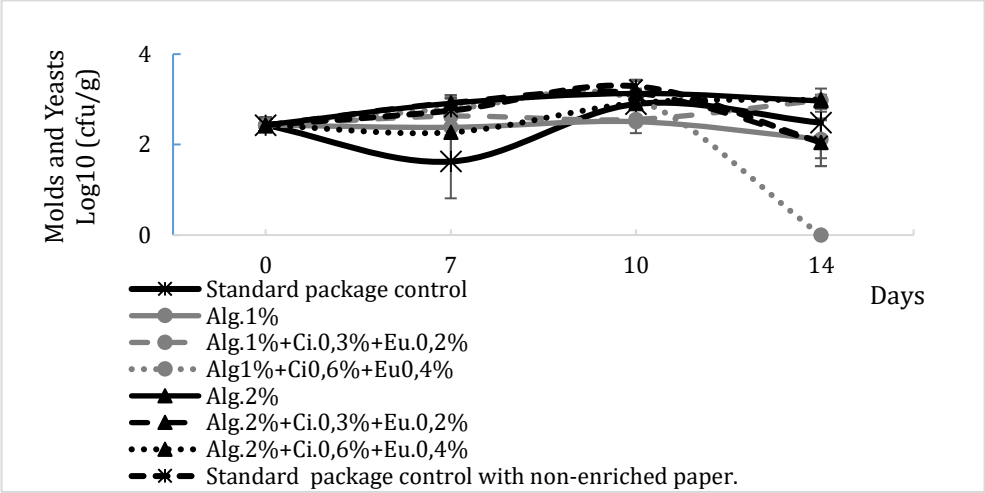


Figure 4.7. Molds and Yeasts Log_{10} (cfu/g) of strawberries through 14 days of storage at 4 ºC.

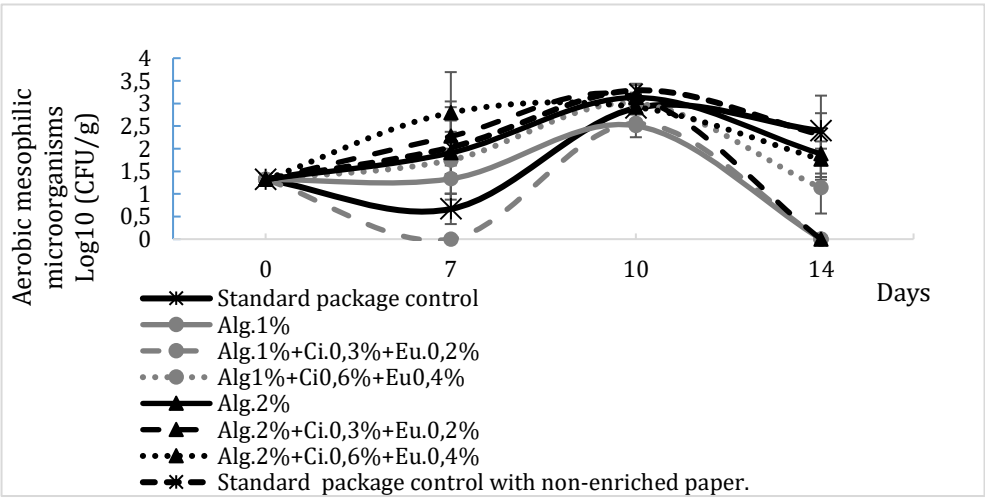


Figure 4.8. Aerobic mesophilic microorganisms Log_{10}(cfu/g) of strawberries through 14 days of storage at 4 ºC.

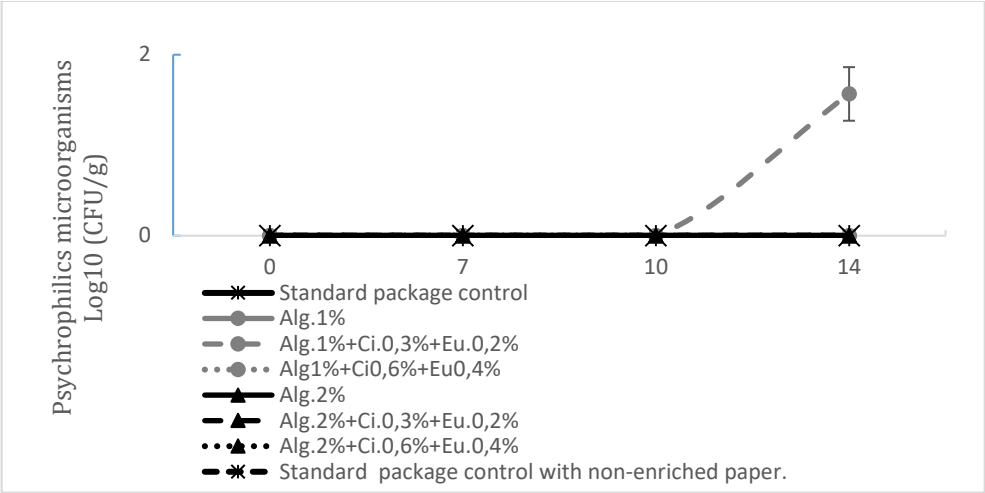


Figure 4.9. Psychrophilic microorganisms Log_{10}(cfu/g) of strawberries through 14 days of storage at 4 ºC.

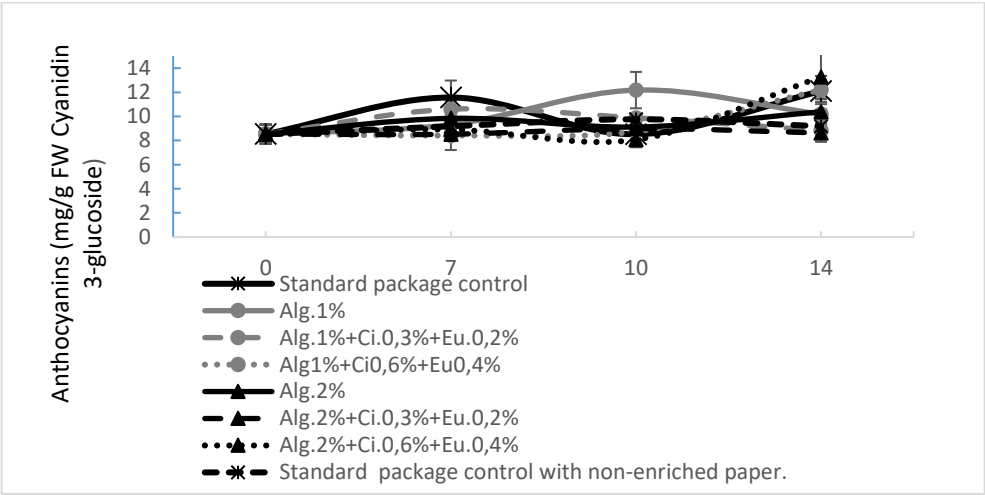


Figure 4.10. Anthocyanins (mg/g FW Cyanidin 3-glucoside) of strawberries through 14 days of storage at 4 ºC.

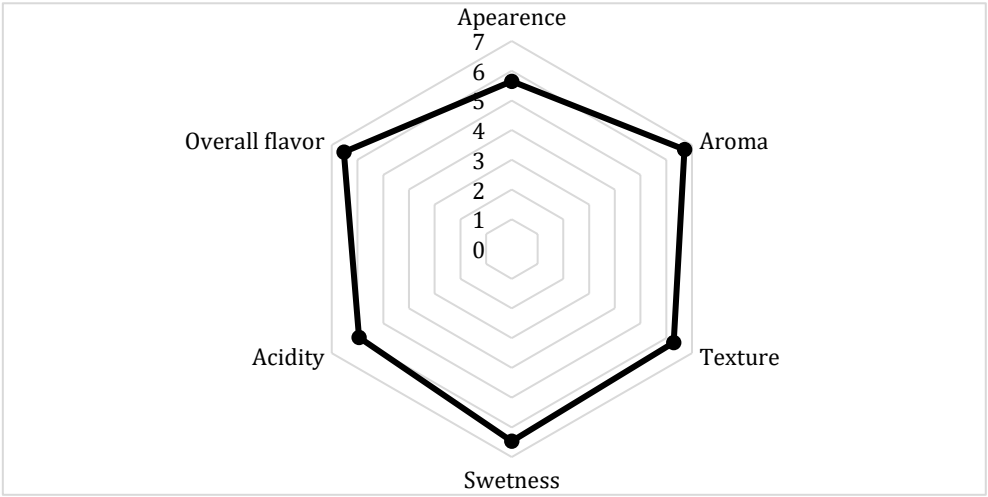


Figure 4.11a. Sensory panel at initial time.

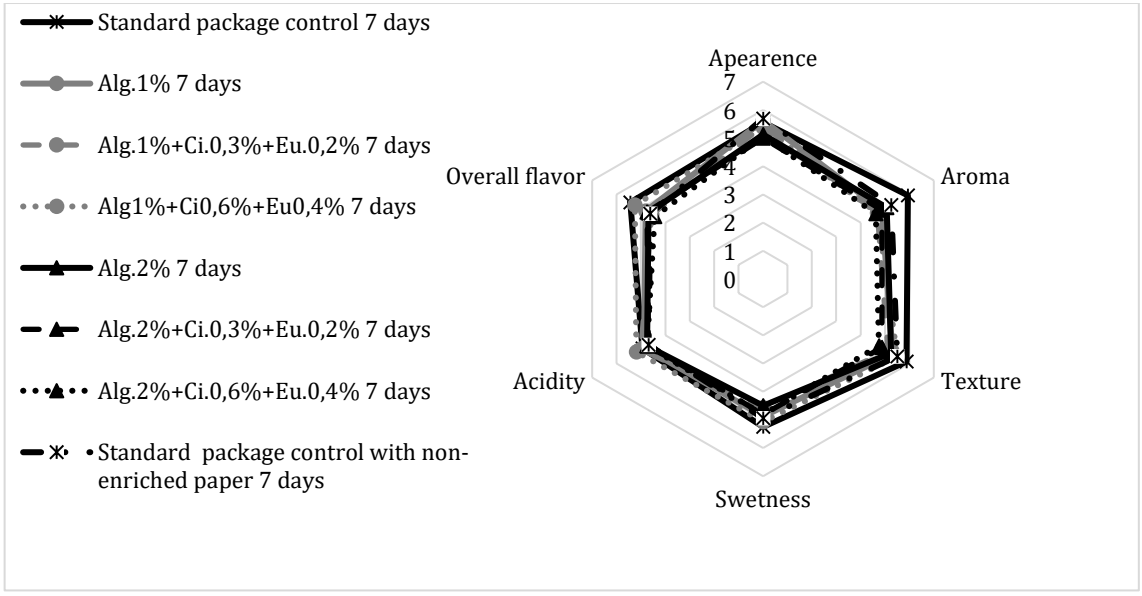


Figure 4.11b. Sensory panel after 7 days of storage.

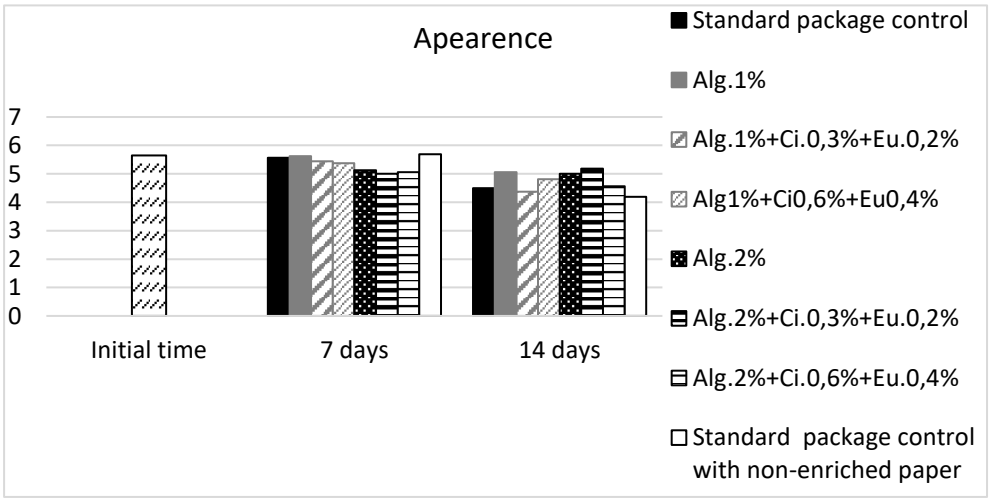


Figure 4.11c. Apearence after 14 days of storage.

Chapter V - *The effect of active packaging enriched with vegetal extracts on the storage of 'Strawberry Festival' strawberry fruits*

The effect of active packaging enriched with vegetal extracts on the storage of 'Strawberry Festival' strawberry fruits

Cristino Dores[1,2], Ana I. Vieira[1,2], Adriana C. Guerreiro[1,2,3], Custódia L. Gago[1,2,3], M. Graça Miguel[2], M. Leonor Faleiro[3], A. Dantuma[4], & M. Dulce Antunes[1,2]

[1]CEOT, [2]MeditBio, [3]CBMR, Faculdade de Ciências e Tecnologia, Edf. 8, Campus Gambelas, 8005-139 Faro, Portugal, [4]KCPK, IJsselburcht 3, 6825 BS Arnhem, The Netherlands.

Abstract

Strawberries are among the most popular berries consumed worldwide. The perishability of these fruits is widely known and a motive of concern. The aim of this work was to evaluate the fresh strawberry quality through storage in different active packaging. The strawberry (*Fragaria x ananassa* 'Strawberry Festival') fruits were harvest from a local farm in South Portugal and stored at 4°C ±0.5 in active packaging enriched with vegetal extracts, placed in standard strawberry package control (Polypropylene plastic trays (8cm*10cm*4cm)) and a standard strawberry package with non-enriched paper control. Measurements of color (L*a*b*), firmness, °Brix, weight loss, microbial content, anthocyanins and sensory panels were performed. Through storage, there were no significant differences among active packaging for the most quality parameters studied. Nevertheless, the A treatment performed slightly better. Further studies are needed to improve these packages.

Keywords: *Fragaria x ananassa.*, fruit, storage, quality, vegetable extracts.

INTRODUCTION

The most popular cultivated strawberry is the dessert strawberry (*Fragaria x ananassa*). Annual world production of this species has steadily grown through the ages, with quantities doubling in the last 20 years to over 2.5 million tones (Hancock et al., 2008).

Strawberry are highly perishable fruits due to their extreme tenderness, vulnerability to mechanical damage, high level of respiration and their susceptibility to fungal spoilage (Patil and Suryawanshi, 2014). Losses of fresh fruits and vegetables in developed countries are estimated to range from 2 to 23 %, with an overall average of 12 % losses between production and consumption sites (Kader and Rolle, 2004).

Many markets for strawberries are great distances from the production points. Thus, effective handling procedures are required to prevent excessive deterioration (Ragaria, 2003). Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption. Active Packaging is an innovative concept that can be defined as a mode of packaging in which the package, the product, and the environment interact to prolong shelf life or enhance safety or sensory properties, while maintaining the quality of the product. This is particularly important in the area of fresh and extended shelf-life foods (Prasad and Kochhar, 2014).

The aim of this work was to test 6 active packaging (based on essential oils/extracts) and 2 controls (non-enriched paper and without paper packages) and evaluate their effect on the storage ability of strawberry fruit.

MATERIAL AND METHODS

The strawberry fruits 'Strawberry Festival', origin from Faro, South Portugal, were purchased at the eating ripe stage from a local producer.

The active packages were identified from A to H and controls as G (standard strawberry package) and H (standard strawberry package with non-enriched paper control).

The prepared active paper sheets were cut and placed into standard strawberry trays, covering all the bottom and the sides of the trays. After that, strawberry fruits were placed into the packages and storage at 4 ˚C for 14 days. Quality measurements were performed at initial storage time, 7 and 14 days.

The microbiological parameters that were determined included aerobic mesophilic microorganisms, psychrophilic microorganisms and moulds and yeasts. The counts of aerobic mesophilic were done according to the standard Portuguese NP-4405 (2002) using Plate Count Agar medium (Biokar, Paris, France). The counts of psychrophilic were performed according to ISO 21528-2 (2004) using Plate Count Agar medium (Biokar, Paris, France). The counts of moulds and yeasts were done according to the ISO 21527-2 (2008) using Dichloran Rose-Bengal Chloramphenicol Agar (Biokar, Paris, France). The color was measured by a Minolta Chroma meter CR-300 (EC Minolta, Japan) using the CIE Lab scale (L*, a* and b*).

The firmess was determined by puncture with a Chatillon TCD200 and Digital Force Gauge DFIS 50 (Jonh Chatillon & Sons, Inc., USA) fitted with a 4 mm diameter probe at a depth of 7 mm. For the % ◦Brix determination a digital refractometer HI 96801 (Hanna instruments, USA) was used, measuring the fruits juice sugar content.

The weight loss was expressed as a percentage of the initial weight.

The total anthocyanin content was measured using a modified pH differential method (Lee et al., 2005). Absorbance of anthocyanin at 520 nm and 700 nm in different pH buffers (pH 1.0 and 4.5) were measured, respectively. Absorbance readings were converted to total mg of Cyanidin 3-glucoside per 1g of fresh weight of sample using the molar extinction coefficient of 26,900 and absorbance of A.

Anthocyanin pigment concentration was, therefore, expressed as Cyanidin-3-glucoside equivalents, as follows:

$$\frac{A \times MW \times DF \times 10^3}{\varepsilon \times l}$$

= (A520 nm − A700 nm)pH 1.0 − (A520 nm − A700 nm)pH 4.5
MW = 449.2 g/mol = value of the molecular weight of Cyanidin-3-glucoside
DF = dilution factor
ε = 26,900 molar extinction coefficient for Cyanidin-3-glucoside, in L × mol − 1 × cm − 1
103= factor for conversion from g to mg
l = path length in cm.

Sensory panel was performed with 15 semi-trained panelists. Panel members were asked to evaluate the appearance, aroma, texture, sweetness, acidity and overall flavor on the base of a 7 point hedonic scale: 1 – dislike definitely; 2 – dislike; 3 – dislike mildly; 4 – neither like nor dislike; 5 – like mildly; 6 – like; 7 – like definitely. Overall liking was calculated as a mean of the sensory parameters evaluated. This panel was performed at initial time, 7 and 14 days of storage.

RESULTS AND DISCUSSION

Color

The analysis of color is an important consideration when determining the efficacy of a variety of postharvest treatments. Consumers can easily be influenced by preconceived ideas of how a fruit or vegetable should appear (McGuire, 1992). During storage, the L* (lightness, 100= white; 0= black) showed a decrease after 7 days, were small differences among treatments were noticed and at day 14, were treatment D and F continued decreasing contrary to the rest of the treatments that presented a small increase of L* values. After 14 days, no significant statistical differences ($P<0.05$) among treatments where recorded (Figure 5.1). Regarding the a* (+,red; -, green) color parameter, a decrease tendency of all treatments was recorded, being D and F the treatments with lowest values(Figure5.2). The same happened with the b*(+, yellow; -, blue) parameter, were a decreasing tendency was measured in all treatments. The same treatments, D and F, where the ones who showed lowest values(Figure5.3). Despite having some small differences among treatments regarding L*, a* and b* values, those are not significant. The decrease of color parameters on fruits are resulting from normal oxidation of phenolic compounds responsible for the browning and ripening of fruits (Butkhup and Samappito, 2011).

Firmness, Total soluble solids and weight loss

All treatments showed very similar fruit weight loss values in the first 7 days, increasing during storage. At 14th day of storage significant differences among several treatments were measured. E and B were the treatments with the higher weight loss, on the other hand the G,H,A and C showed lowest and similar weight loss values. Most of the treatments presented a higher weight loss than the 2 control treatments(G;H) with the exception of the A treatment, which had the lowest value among treatments(Figure 5.4).

The firmness values did not show any statistically difference ($P<0.05$) among treatments after 7 days of storage, exhibiting a small increase of firmness in all treatments, except for F, that showed a small decrease. This increase can be due to the storage in cold. After 14 days of storage an increase of all treatments, except for the B was measured, showing any statistically difference ($P<0.05$) except for the E and F treatments that are statistically different ($P>0.05$) being the E the treatment with highest firmness and consequently the F with the lowest (Figure 5.5).

Regarding the Total soluble solids values (^{o}Brix), there was some small oscillations depending the treatment but an increasing tendency was measured, where all treatments showed higher ^{o}Brix values after 14 days of storage compared to the initial time as described before (Azodanlou, R., Darbellay, C., Villettaz, J. C., Luisier, J. L., Amadò, 2004). Despite those differences among treatments, all of them present results between ≈ 7 and 8.7(Figure 5.6).

Microbial counts

The yeast and moulds values were, during all storage very close to the limits of 3 Log_{10} cfu/g established by Barth et al.(2009), and, in some treatments slightly above them. The yeast and moulds counts show no statistically significance differences ($P<0.05$) for the first 7 days of storage among treatments, and at 14th day a few differences were measured, where the standard strawberry package control G which was the treatment with lowest values was statistically different from the D and F which were the treatments with highest values (Figure 5.7).

According to (Barth et al., 2009), the limits for microbial populations on minimally fresh processed fruit for safe consumption are 7 log10 cfu/g for aerobic bacteria. Regarding the aerobic mesophilic bacteria, all treatments showed values below the limits. Until the seventh day of storage no significant statistically differences ($P<0.05$) were measured, with the B treatment being the one with the lowest value(≈0.7 log10 cfu/g) (Figure 5.8).

The H and C treatments were the only two showing psychrophilic growth on the first 7 days, after 14 days only the F and G showed no growth, despite the rest of the treatments presented psychrophilic growth on after 14 days, those values were always under the limit of 8 Log_{10} cfu/g according to Barth et al. (2009), being the maximum value recorded 2.8 Log_{10} cfu/g (E treatment)(Figure 5.9).

Anthocyanins

For the anthocyanins values, there were not statistically significant differences ($P<0.05$) among treatments during storage. However was possible to assess an increasing tendency of all treatments as described by Wang and Lin (2000), except for the two controls treatments(G and H) by the end of the storage period(Figure 5.10).

Sensory panel

To verify the consumer's preference of the fruits exposed to the different treatments a sensory panel was performed. At the initial time, the fruits performed the top score in appearance ≈7, and an overall flavor of ≈6, being the rest of the parameters score between ≈5 and ≈6. After 7 days, all treatments performed very similar scores (≈4 and 5) showing a decreasing tendency that stabilized by the 14th day of storage showing similar results to the 7th day of storage. These results indicate a good acceptance of the fruit by the panellists for up to 14 days of storage (Figure 5.11.a;b;c).

CONCLUSION

The results of this study show that strawberries (*Fragaria x ananassa.* 'Strawberry Festival'*)* are of good quality and can be stored for at least 14 days, being only limited by the microbial growth, which limits should be conceived, once the consumers acceptance did not exclude the fruits regardless their microbial load. Although all treatments performed well till 14 days of storage, the A treatment, scored higher in the sensory panel evaluation as well as less weight loss compared with the rest of the treatments after 14 days of storage. Further studies are required to improve the package manufacturing and test their effect in extending the storage period.

Literature cited

Azodanlou, R., Darbellay, C., Villettaz, J. C., Luisier, J. L., Amadò, R. (2004). Changes in flavour and texture during the ripening of strawberries. Eur Food Res Technol *218*, 167–172.

Barth, M., Hankinson, T.R., Zhuang, H., and Breidt, F. (2009). Microbiological Spoilage of Fruits and Vegetables. In Compendium of the Microbiological Spoilage of Foods and Beverages, pp. 135–183.

Butkhup, L., and Samappito, S. (2011). changes in physico-chemical properties , polyphenol compounds and antiradical activity during development and ripening of maoluang (Antidesma bunius L. Spreng) fruits. J. Fruit Ornam. Plant Res. *19*, 85–99.

Espina, L., Somolinos, M., Lorán, S., Conchello, P., García, D., and Pagán, R. (2011). Chemical composition of commercial citrus fruit essential oils and evaluation of their antimicrobial activity acting alone or in combined processes. Food Control *22*, 896–902.

Hancock, J. F., Sjulin, T.M., and Lobos, G.A. (2008). Strawberries. In Temperate Fruit Crop Breeding, pp. 393–438.

ISO 21528-2:2004 - Microbiology of food and animal feeding stuffs -Horizontal methods for the detection and enumeration of Enterobacteriaceae - Part 2: Colony-count method. International Standards Organization, Switzerland.

ISO 21527-2:2008. Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for the Enumeration of Yeasts and Moulds – Part 2: Colony Count Technique in Products with Water Activity Less Than or Equal to 0.95. International Standards Organization, Switzerland

Kader, A.K., and Rolle, R.S. (2004). The role of post-harvest management in assuring the quality and safety of horticultural produce. Fao Agric. Serv. Bull. 1–22.

Lee, J., Durst, R.W., and Wrolstad, R.E. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. J. AOAC Int. *88*, 1269–1278.

McGuire, R.G. (1992). Reporting of objective color measurements. HortScience *27*, 1254–1255.

P-4405:2002. Food Microbiology – General Rules for Microorganism Counts. Colonies Count at 30 ºC. Instituto Português da Qualidade, Lisboa, Portugal (in Portuguese).

Patil, J.S., and Suryawanshi, N.S. (2014). Fruit Rot of Strawberry Caused By Alternaria Alternata Control Using Homoeopathic Medicines . Int. J. Pharm. Sci. Invent. *3*, 57–58.

Prasad, P., and Kochhar, A. (2014). Active Packaging in Food Industry : A Review. IOSR J. Environ. Sci. Toxicol. Food Technol. *8*, 1–7.

Ragaria, T.F. (2003). Growth of Botrytis cinerea and Strawberry Quality in Ozone-enriched Atmospheres. Food Microbiol. Saf. Growth *68*, 1798–1802.

Rhim, J. (2004). Physical and mechanical properties of water resistant sodium alginate films. LWT - Food Sci. Technol. *37*, 323–330.

Wang, S.Y., and Lin, H. (2000). Antioxidant Activity in Fruits and Leaves of Blackberry , Raspberry , and Strawberry Varies with Cultivar and Developmental Stage. J. Agric. Food Chem. *48*, 140–146.

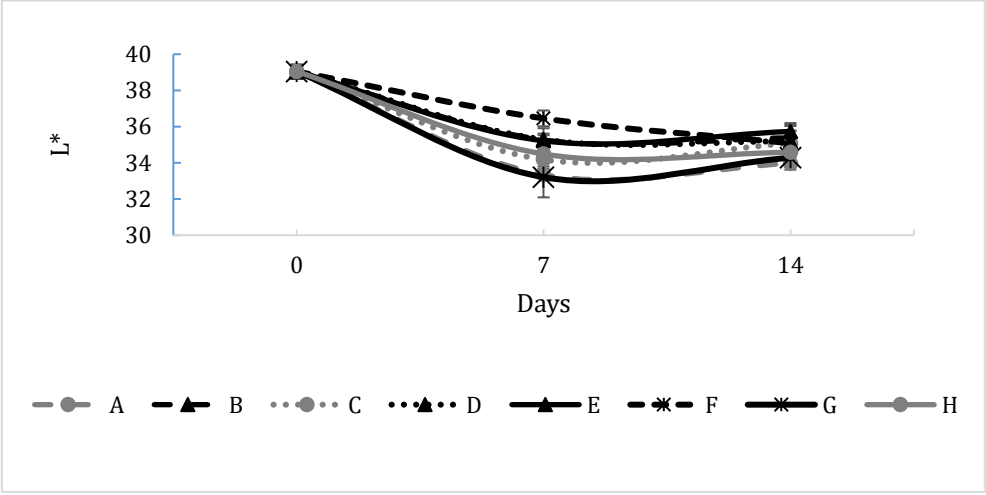


Figure 5.1- Lightness (L*) color parameter of strawberries through 14 days of storage at 4 ºC.

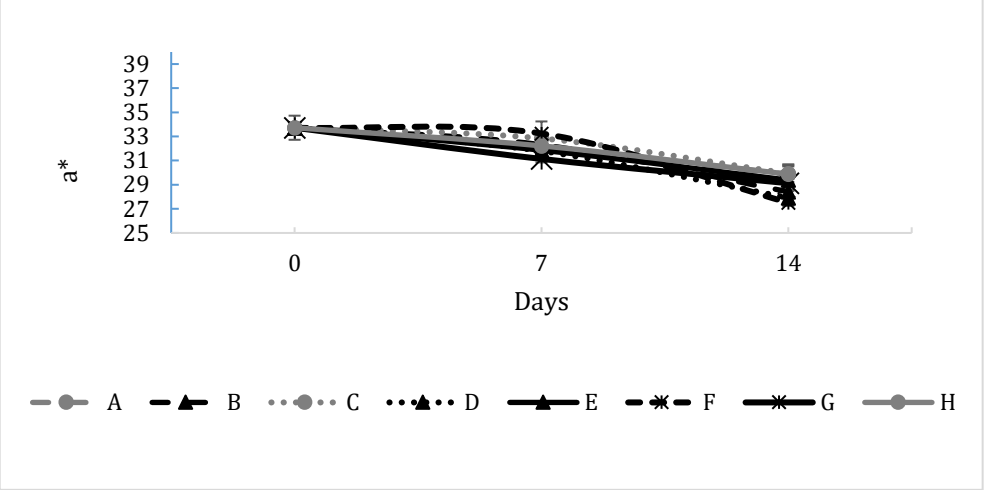


Figure 5.2- a* color parameter of strawberries through 14 days of storage at 4 ºC.

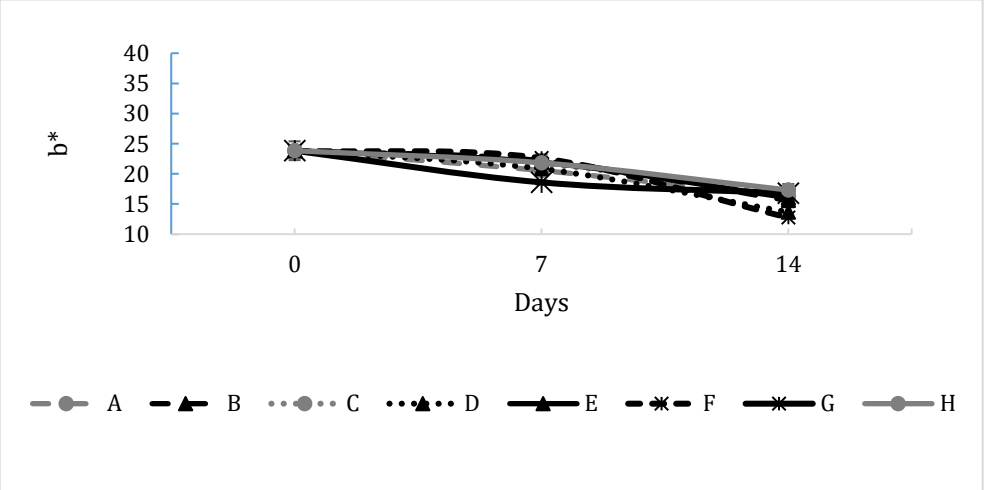


Figure 5.3 - b* color parameter of strawberries through 14 days of storage at 4 ºC.

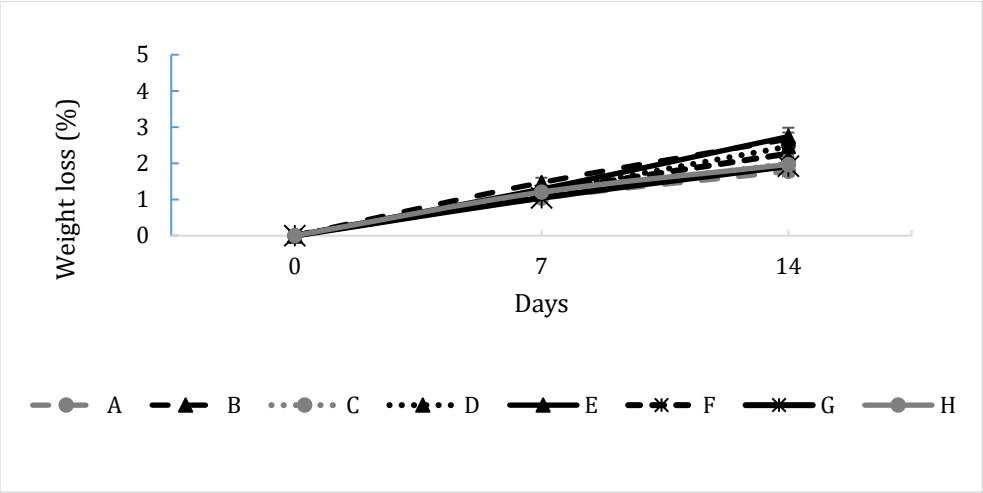


Figure 5.4 – Weight loss (%) of strawberries through 14 days of storage at 4 ºC.

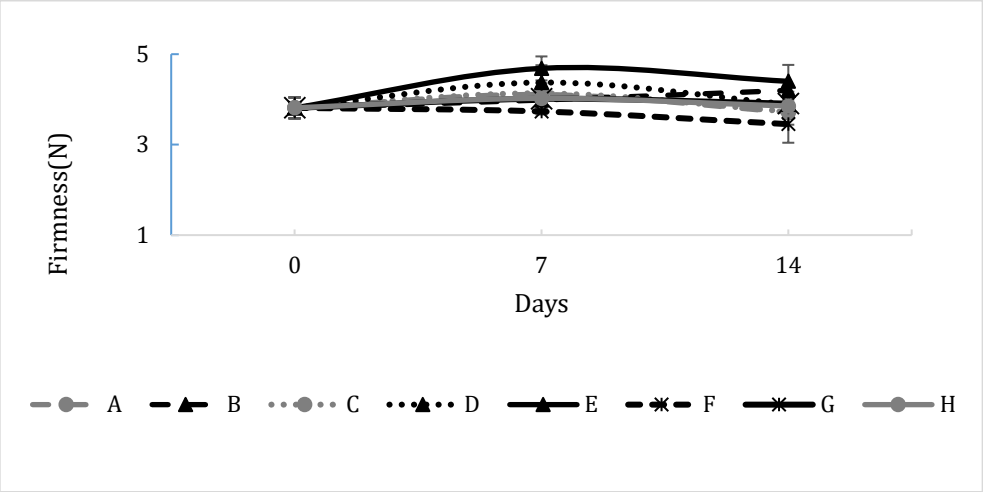


Figure 5.5 – Firmness(N) of strawberries through 14 days of storage at 4 ºC.

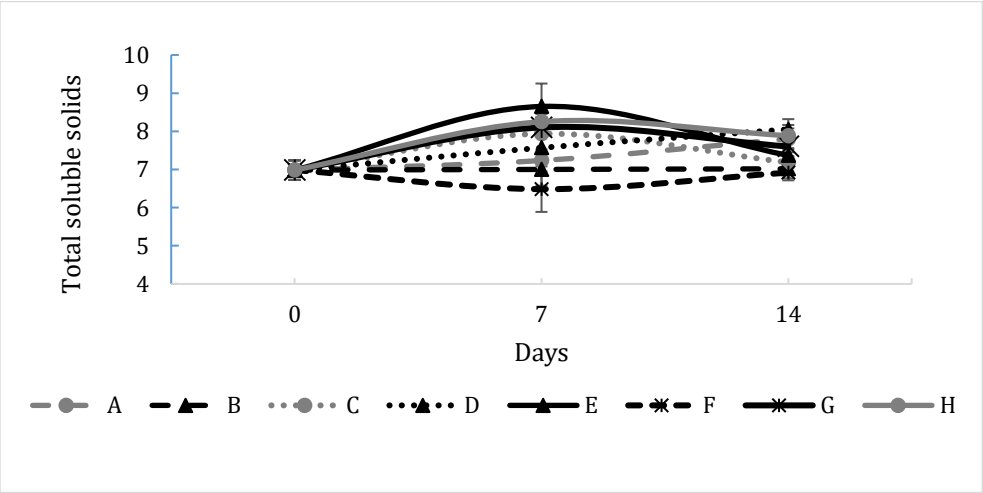


Figure 5.6 –Total soluble solids (˚Brix) of strawberries through 14 days of storage at 4 ºC.

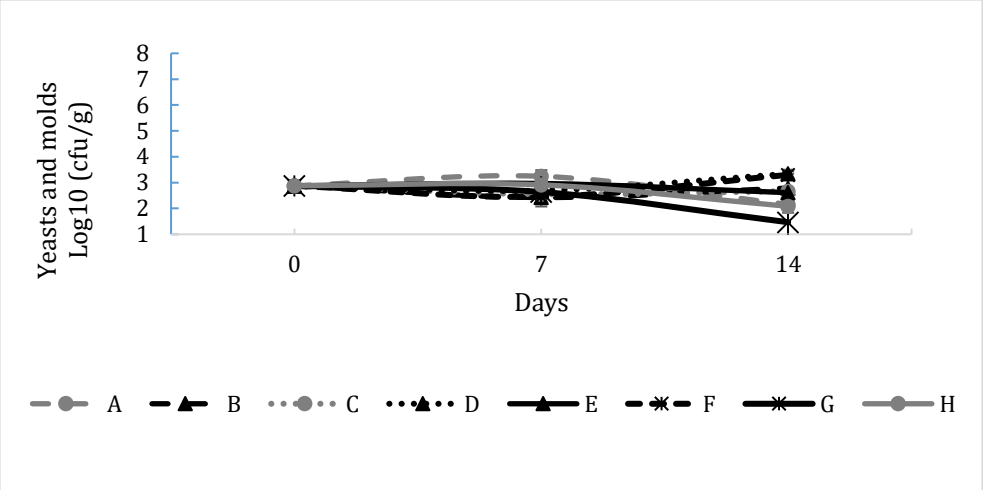


Figure 5.7 – Yeasts and molds Log_{10} (cfu/g) of strawberries through 14 days of storage at 4 ºC.

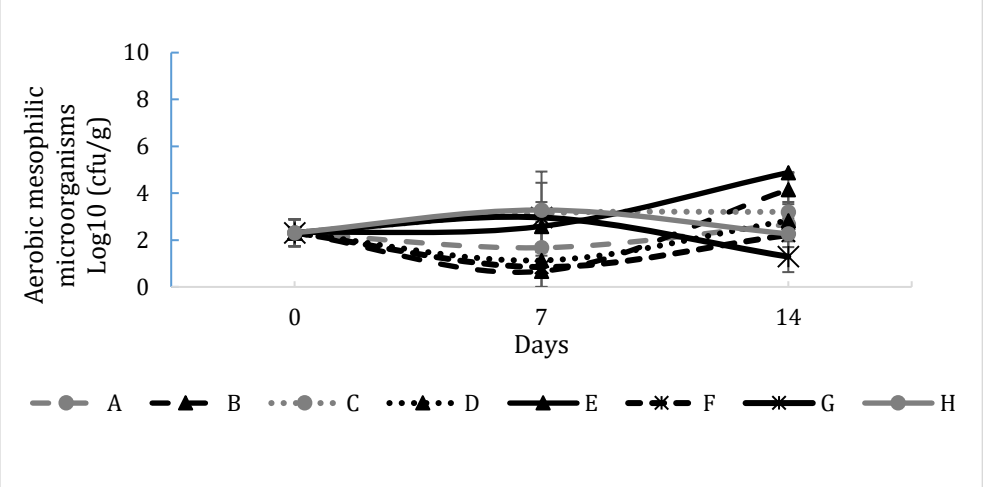


Figure 5.8 – Aerobic mesophilic microorganisms Log_{10}(cfu/g) of strawberries through 14 days of storage at 4 ºC.

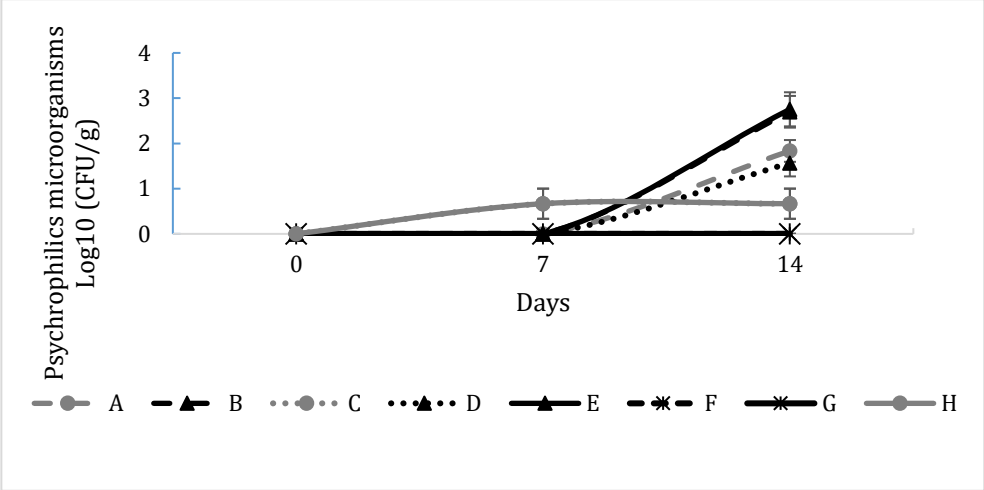


Figure 5.9 – Psychrophilic microorganisms Log_{10}(cfu/g) of strawberries through 14 days of storage at 4 ºC.

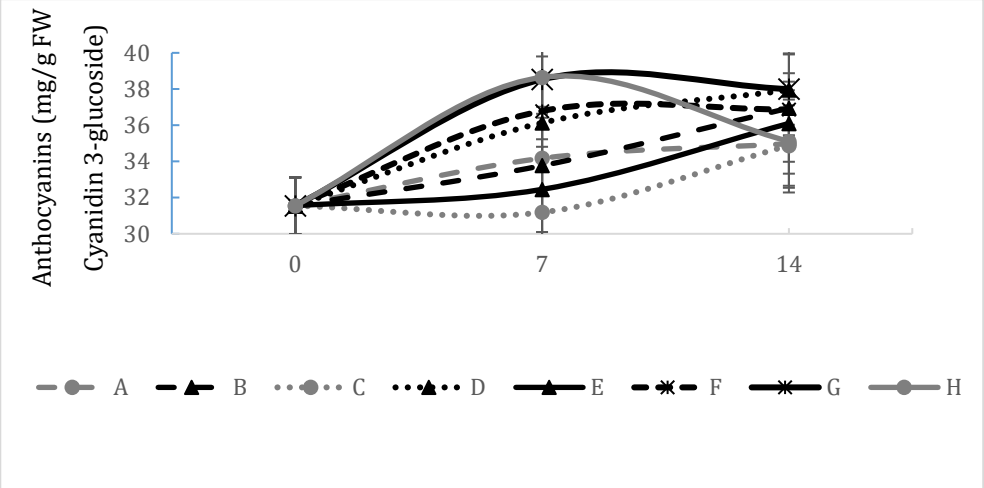


Figure 5.10 – Anthocyanins (mg/g FW Cyanidin 3-glucoside) of strawberries through 14 days of storage at 4 ºC.

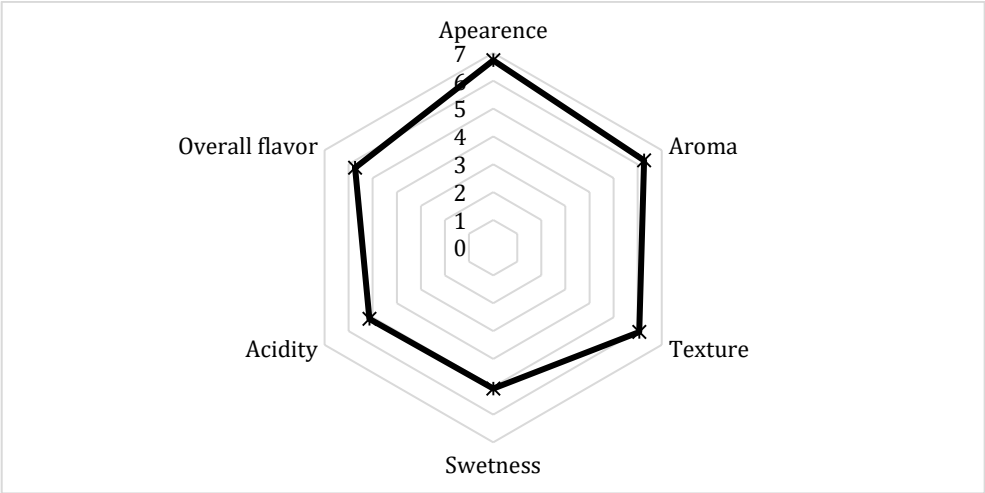


Figure 5.11a- Sensory panel at initial time.

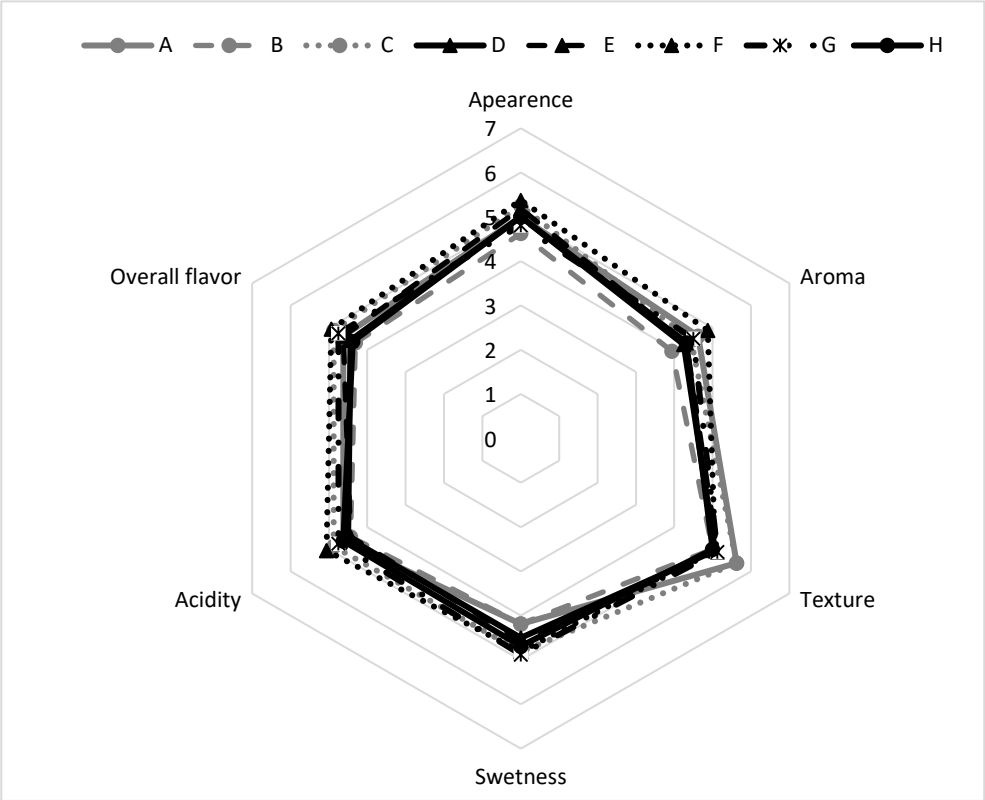


Figure 5.11b - Sensory panel after 7 days of storage

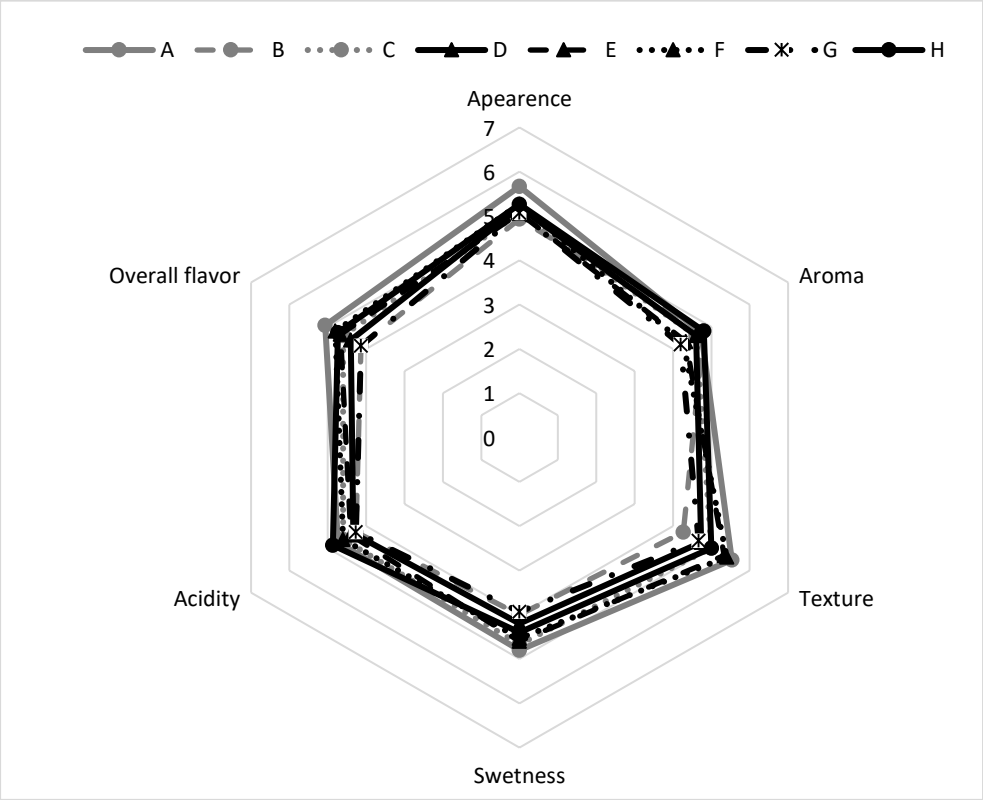


Figure 5.11c - Sensory panel after 14 days of storage.

***Chapter VI** – Conclusions and future perspectives*

In this study, an innovative way of preserving and maintaining fruit quality was tested. This work had the goal of measuring and understanding how fruit quality could be affected by using active packaging on his preservation. Therefore, some important conclusive points should be emphasized:

- In a general way, it was not possible to claim an ideal treatment, still, some active packaging that combine on their compositions Alginate with Essential oils compounds showed good indicators of being good quality maintainers.
- All products were food safe through all storage period and were not negatively affect by any active packaging tested.
- Kiwifruit snacks can be stored for at least 4 four months, showing very good appearance for at least 3 months.
- Strawberries are of good quality and can be stored for at least 14 days, being only limited by the microbial growth.
- Some microbiologic limits should be conceived, once the consumer's acceptance did not exclude the fruits regardless their microbial load. These limits are now outdated and very reductive, especially when the tested products are new and different from what is in the market.
- The fact that those active packages did not show a significant improvement in storage as compared to controls, may be due to the fact that fruit used were healthy, without significant microbial contamination, so the antimicrobial effect was not so evident.

With this work, an important step for active packaging affirmation was performed, reveling some good indications, but also some throwbacks on their use. There are some aspects that can take the type of active packaging tested further:

- The process of adding solutions with the active compounds to the paper should be revised. Due to some compounds volatilization and their unknown maintenance on the paper, a more stable structure that could ensure an optimum active compound retention should be studied.
- A good preservation method that can keep the package characteristics though storage, allowing companies to have a stock of active packaging with the same quality that they had in the moment of bought.
- Testing the volatilization rate of the compounds on the paper through time.

- New active compounds and formulations based on the tested ones can also be improved, developed and tested
- Test the active packaging in different food products, and situations in which fresh fruit have more probability of microbial spoilage.

Appendix

Appendix I – Poster present at IX International Symposium on Kiwifruit

THE EFFECT OF ACTIVE PACKAGING ON THE STORAGE OF KIWIFRUIT SNACKS

Cristino Dores[1,2], Ana I. Vieira[1,2], Adriana C. Guerreiro[1,2,3], Custódia L. Gago[1,2,3], M. Graça Miguel[2], M. Leonor Faleiro[3], A. Dantuma[4], & M. Dulce Antunes[1,2]

[1]CEOT, [2]MeditBio, [3]CBMR,[4]KCPK, Faculdade de Ciências e Tecnologia, Edf. 8, Campus Gambelas, 8005-139 Faro, Portugal

INTRODUCTION

Fruit snacks are becoming very popular because all the fresh fruit nutrients are concentrated maintaining the fruit benefits. Kiwifruit is an important fruit. *Actinidia deliciosa* cv. Hayward is the predominant cultivar up to now (Drzewiecki et al., 2016).

In response to the dynamic changes in current consumer demand and market trends, the area of active packaging is becoming increasingly significant.

Research and development of antimicrobial materials for food applications, such is expected to grow in the next decade with the advent of new polymer materials and antimicrobials (Appendini and Hotchkiss, 2002).

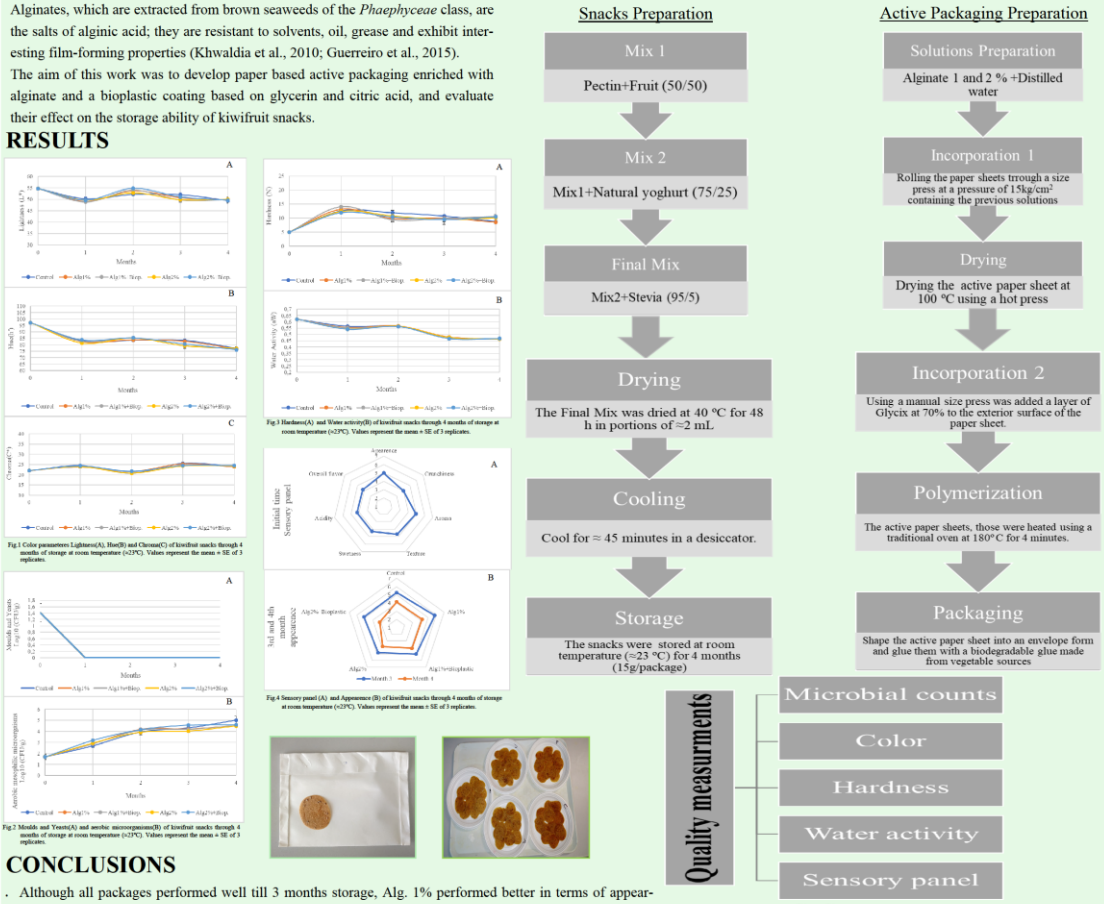
Alginates, which are extracted from brown seaweeds of the *Phaephyceae* class, are the salts of alginic acid; they are resistant to solvents, oil, grease and exhibit interesting film-forming properties (Khwaldia et al., 2010; Guerreiro et al., 2015).

The aim of this work was to develop paper based active packaging enriched with alginate and a bioplastic coating based on glycerin and citric acid, and evaluate their effect on the storage ability of kiwifruit snacks.

MATERIAL AND METHODS

For the snacks, the base ingredients were kiwifruits (*Actinidia deliciosa)* cv Hayward, natural yoghurt and pectin +ascorbic acid solution. The active packages used in this experiment were paper based (120g/m^2) enriched with alginate and a bioplastic coating named Glycix (Pantics BV) based on glycerin and citric acid.

5 different treatments were performed: Alginate 1%, Alginate 1% and a layer of Glycix at 70% on the exterior surface of the paper, Alginate 2%, Alginate 2% and a layer of Glycix at 70% on the exterior surface of the paper, and a control paper package without coating. Alginate 1 and 2 % as well as Glicix 70% solutions were made with distilled water.



RESULTS

Fig.1 Color parameters Lightness(A), Hue(B) and Chroma(C) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC). Values represent the mean ± SE of 3 replicates.

Fig.3 Hardness(A) and Water activity(B) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC). Values represent the mean ± SE of 3 replicates.

Fig.4 Sensory panel (A) and Appearence (B) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC). Values represent the mean ± SE of 3 replicates.

Fig.2 Moulds and Yeasts(A) and aerobic microorganisms(B) of kiwifruit snacks through 4 months of storage at room temperature (≈23ºC). Values represent the mean ± SE of 3 replicates.

CONCLUSIONS

- Although all packages performed well till 3 months storage, Alg. 1% performed better in terms of appearance.
- After 4 months, appearance was reduced to the limits of consumer's acceptance and at that time control samples showed slightly higher microbial counts.
- The counts of *Enterobacteriaceae* were always negative during the four months of storage. Since these new kind of innovative food products reached the market recently, microbiological limits should be conceived, once the information about this is very limited.
- Kiwifruit (*Actinidia deliciosa* cv. Hayward*)* snacks are of good quality and can be stored for at least 4 months.

REFERENCES

- Appendini, P., and Hotchkiss, J.H. (2002). Review of antimicrobial food packaging. Innov. Food Sci. Emerg. Technol. *3*, 113–126.
- Drzewiecki, J., Latocha, P., Leontowicz, M., Park, Y.S., Najman, K., Weisz, M., Ezra, A. and Gorinstein, S. (2016). Analytical Methods Applied to Characterization of *Actinidia arguta*, *Actinidia deliciosa*, and *Actinidia eriantha* Kiwi Fruit Cultivars. Food Anal. Methods *9*, 1353-1366.
- Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2015). The effect of alginate-based edible coatings enriched with essential oils constituents on *Arbutus unedo L.* fresh fruit storage. Postharvest Biol. Technol. *100*, 226–233.
- Khwaldia, K., Arab-Tehrany, E., and Desobry, S. (2010). Biopolymer Coatings on Paper Packaging Materials. Compr. Rev. Food Sci. Food Saf. *9*, 82–91.

Appendix II - Statistical analysis of chapter III

2.1. Analysis of each treatment through time

2.1.1. Control treatment

Table 1. Variation of L* values through time – Control treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
5	3	49,5133			
2	3	50,2600	50,2600		
4	3		52,0467	52,0467	
3	3			52,2100	
1	3				54,8067
Sig.		,385	,055	,846	1,000

Table 2. Variation of a* values through time – Control treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	-2,7467		
3	3		2,3700	
2	3		2,9300	
4	3		2,9400	
5	3			5,3367
Sig.		1,000	,164	1,000

Table 3. Variation of b* values through time – Control treatment

Duncan						
Time	N	Subset for alpha = .05				
		1	2	3	4	5
3	3	20,7400				
1	3		21,8700			
5	3			23,5767		
2	3				24,4033	
4	3					25,4900
Sig.		1,000	1,000	1,000	1,000	1,000

Time

1- Initial time
2- 1st Month
3- 2sd Month
4- 3rd Month
5- 4th Month

Table 4. Variation of Hue(h°) values through time – Control treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
5	3	77,2167		
2	3		83,0967	
4	3		83,4033	
3	3		83,4600	
1	3			97,1600
Sig.		1,000	,712	1,000

Table 5. Variation of Chroma(C*) values through time – Control treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
3	3	20,8867			
1	3		22,0433		
5	3			24,1900	
2	3			24,5833	
4	3				25,6633
Sig.		1,000	1,000	,247	1,000

Table 6. Variation of Hardness (N) values through time – Control treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	5,0133		
5	3		8,7867	
4	3			10,7600
3	3			11,9467
2	3			12,6133
Sig.		1,000	1,000	,051

Table 7. Variation of aw values through time – Control treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
5	3	,4667			
4	3		,4767		
3	3			,5600	
2	3			,5667	

1	3				,6233
Sig.		1,000	1,000	,145	1,000

Table 8. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Control treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	1,1500		
2	3		2,6967	
3	3			3,9467
4	3			4,3100
5	3			5,0167
Sig.		1,000	1,000	,065

Table 9. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Control treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,0000	
3	3	,0000	
4	3	,0000	
5	3	,0000	
1	3		,5833
Sig.		1,000	1,000

2.1.2. Alginate 1% treatment

Table 10. Variation of L* values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
2	3	49,0400		
5	3	49,7967	49,7967	
4	3		50,7133	
3	3			53,7967
1	3			54,8067
Sig.		,282	,199	,160

Time

1- Initial time
2- 1st Month
3- 2sd Month
4- 3rd Month
5- 4th Month

Table 11. Variation of a* values through time – Alginate 1% treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	-2,7467			
3	3		2,3133		
2	3		3,1000	3,1000	
4	3			3,2200	
5	3				5,5267
Sig.		1,000	,053	,744	1,000

Table 12. Variation of a* values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	21,5133		
1	3	21,8700		
5	3		23,3100	
2	3		23,6967	
4	3			25,1300
Sig.		,456	,421	1,000

Table 13. Variation of Hue(hº) values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
5	3	76,6900		
2	3		82,5233	
4	3		82,6667	
3	3		83,8333	
1	3			97,1600
Sig.		1,000	,158	1,000

Table 14. Variation of Chroma(C*) values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	21,6500		
1	3	22,0433		
2	3		23,9033	
5	3		23,9633	

4	3			25,3433
Sig.		,427	,902	1,000

Table 15. Variation of Hardness(N) values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	5,0133		
5	3		8,5200	
3	3		9,8800	
4	3		10,0267	
2	3			13,1867
Sig.		1,000	,060	1,000

Table 16. Variation of aw values through time – Alginate 1% treatment

Duncan						
Time	N	Subset for alpha = .05				
		1	2	3	4	5
5	3	,4667				
4	3		,4800			
2	3			,5533		
3	3				,5700	
1	3					,6233
Sig.		1,000	1,000	1,000	1,000	1,000

Table 17. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	1,1500		
2	3		2,8833	
3	3			4,1867
4	3			4,2067
5	3			4,5067
Sig.		1,000	1,000	,500

Table 18. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,0000	
3	3	,0000	
4	3	,0000	
5	3	,0000	
1	3		,5833
Sig.		1,000	1,000

2.1.3. Alginate 1% + Bioplastic treatment

Table 19. Variation of L* values through time – Alginate 1%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	48,9133	
4	3	49,7533	
5	3	49,8933	
3	3		54,0833
1	3		54,8067
Sig.		,318	,435

Time

1- Initial time
2- 1st Month
3- 2sd Month
4- 3rd Month
5- 4th Month

Table 20. Variation of a* value through time – Alginate 1%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	-2,7467		
3	3		1,7133	
2	3		3,0400	
4	3			4,5667
5	3			5,4867
Sig.		1,000	,051	,154

Table 21. Variation of b* values through time – Alginate 1%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	21,4600	
1	3	21,8700	
2	3		23,6833
5	3		23,7100
4	3		24,0767
Sig.		,410	,450

Table 22. Variation of Hue(h°) values through time – Alginate 1%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
5	3	76,9733		
4	3	79,2267		
2	3		82,6733	
3	3		85,4100	
1	3			97,1600
Sig.		,167	,101	1,000

Table 23. Variation of Chroma(C*) values through time – Alginate 1%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	21,5300	
1	3	22,0433	
2	3		23,8833
5	3		24,3433
4	3		24,5467
Sig.		,239	,153

Table 24. Variation of Hardness(N) values through time – Alginate 1%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	5,0133		
3	3		9,3800	
4	3		9,8667	

5	3		10,5867	
2	3			14,0533
Sig.		1,000	,276	1,000

Table 25. Variation of aw values through time – Alginate 1%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
5	3	,4700		
4	3	,4767		
2	3		,5533	
3	3		,5600	
1	3			,6233
Sig.		,098	,098	1,000

Table 26. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Alginate 1%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	1,1500		
2	3		2,8800	
3	3			4,1233
4	3			4,1800
5	3			4,5167
Sig.		1,000	1,000	,383

Table 27. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Alginate 1%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,0000	
3	3	,0000	
4	3	,0000	
5	3	,0000	
1	3		,5833
Sig.		1,000	1,000

2.1.4. Alginate 2%

Table 28. Variation of L* values through time – Alginate 2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
2	3	49,6467		
4	3	49,8233		
5	3	50,0500		
3	3		52,8767	
1	3			54,8067
Sig.		,499	1,000	1,000

Time

1- Initial time
2- 1st Month
3- 2sd Month
4- 3rd Month
5- 4th Month

Table 29. Variation of a* values through time – Alginate 2%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	-2,7467			
3	3		1,7400		
2	3			3,6033	
4	3			4,5933	4,5933
5	3				5,4067
Sig.		1,000	1,000	,070	,126

Table 30. Variation of b* values through time – Alginate 2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	20,6967		
1	3		21,8700	
2	3			23,6633
5	3			23,6900
4	3			23,8667
Sig.		1,000	1,000	,626

Table 31. Variation of Hue(h°) values through time – Alginate 2%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
5	3	77,1300			
4	3	79,1133	79,1133		
2	3		81,3200		
3	3			85,2133	
1	3				97,1600
Sig.		,121	,088	1,000	1,000

Table 32. Variation of Chroma(C*) values through time – Alginate 2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	20,7767		
1	3		22,0433	
2	3			23,9467
5	3			24,3033
4	3			24,3267
Sig.		1,000	1,000	,355

Table 33. Variation of Hardness(N) values through time – Alginate 2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	5,0133		
4	3		9,4667	
5	3		10,1067	
3	3		10,7533	10,7533
2	3			12,3733
Sig.		1,000	,178	,085

Table 34. Variation of aw value through time – Alginate 2%

Duncan						
Time	N	Subset for alpha = .05				
		1	2	3	4	5
5	3	,4633				
4	3		,4767			
2	3			,5433		

3	3				,5633	
1	3					,6233
Sig.		1,000	1,000	1,000	1,000	1,000

Table 35. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Alginate 2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	1,1500		
2	3		2,9333	
3	3		3,9233	3,9233
4	3			4,0233
5	3			4,4800
Sig.		1,000	,051	,263

Table 36. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,0000	
3	3	,0000	
4	3	,0000	
5	3	,0000	
1	3		,5833
Sig.		1,000	1,000

2.1.5. Alginate 2%+ Bioplastic

Table 37. Variation of L* values through time – Alginate 2%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
5	3	49,6033	
2	3	49,6400	
4	3	51,0300	
1	3		54,8067
3	3		54,8667
Sig.		,257	,959

Time

1- Initial time
2- 1st Month
3- 2sd Month
4- 3rd Month
5- 4th Month

Table 38. Variation of a* values through time – Alginate 2%+Bioplastic treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	-2,7467			
3	3		1,7700		
2	3		2,6400		
4	3			4,0133	
5	3				5,8467
Sig.		1,000	,079	1,000	1,000

Table 39. Variation of b* values through time – Alginate 2%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	21,6700	
1	3	21,8700	
5	3		23,8567
2	3		24,2067
4	3		24,2500
Sig.		,761	,571

Table 40. Variation of Hue(hº) values through time – Alginate 2%+Bioplastic treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
5	3	76,1667			
4	3		80,5767		
2	3			83,7300	
3	3			85,3333	
1	3				97,1600
Sig.		1,000	1,000	,197	1,000

Table 41. Variation of Chroma(C*) values through time – Alginate 2%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	21,7433	
1	3	22,0433	
2	3		24,3667
5	3		24,5733
4	3		24,6000
Sig.		,627	,717

Table 42. Variation of Hardness(N) values through time – Alginate 2%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	5,0133	
4	3		9,4667
3	3		10,4133
5	3		10,5067
2	3		11,9867
Sig.		1,000	,086

Table 43. Variation of aw values through time – Alginate 2%+Bioplastic treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
4	3	,4700			
5	3	,4700			
2	3		,5400		
3	3			,5633	
1	3				,6233
Sig.		1,000	1,000	1,000	1,000

Table 44. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Alginate 2%+Bioplastic treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	1,1500		
2	3		3,1800	
3	3		4,1533	4,1533
4	3			4,5600
5	3			4,8567
Sig.		1,000	,055	,164

Table 45. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Alginate 2%+Bioplastic treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,0000	
3	3	,0000	
4	3	,0000	
5	3	,0000	
1	3		,5833
Sig.		1,000	1,000

2.2 Analysis of treatments by months

2.2.1. 1st Month of storage

Table 46. Variation of L* values in the 1st month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
3	3	48,9133
2	3	49,0400
5	3	49,6400
4	3	49,6467
1	3	50,2600
Sig.		,196

Treatments

1- Control
2- Alginate 1%
3- Alginate 1% + Bioplastic
4- Alginate 2%
5- Alginate 2% + Bioplastic

Table 47. Variation of a* values in the 1st month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
5	3	2,6400	
1	3	2,9300	2,9300
3	3	3,0400	3,0400
2	3	3,1000	3,1000
4	3		3,6033
Sig.		,227	,089

Table 48. Variation of b* values in the 1st month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	23,6633
3	3	23,6833
2	3	23,6967
5	3	24,2067
1	3	24,4033
Sig.		,294

Table 49. Variation of Hue(h°) values in the 1st month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	81,3200	
2	3	82,5233	82,5233
3	3	82,6733	82,6733
1	3	83,0967	83,0967
5	3		83,7300
Sig.		,087	,227

Table 50. Variation of Chroma (C*) values in the 1st month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
3	3	23,8833
2	3	23,9033
4	3	23,9467
5	3	24,3667
1	3	24,5833
Sig.		,303

Table 51. Variation of Hardness (N) values in the 1st month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
5	3	11,9867	
4	3	12,3733	12,3733
1	3	12,6133	12,6133
2	3	13,1867	13,1867
3	3		14,0533
Sig.		,176	,069

Table 52. Variation of aw values in the 1st month of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
5	3	,5400		
4	3	,5433		
2	3		,5533	
3	3		,5533	
1	3			,5667
Sig.		,448	1,000	1,000

Table 53. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values in the 1st month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	2,6967
3	3	2,8800
2	3	2,8833
4	3	2,9333
5	3	3,1800
Sig.		,125

2.2.2 2sd Month of storage

Table 54. Variation of L* values in the 2sd month of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	52,2100		
4	3	52,8767	52,8767	
2	3	53,7967	53,7967	53,7967
3	3		54,0833	54,0833
5	3			54,8667
Sig.		,060	,138	,184

Treatments

1- Control
2- Alginate 1%
3- Alginate 1% + Bioplastic
4- Alginate 2%
5- Alginate 2% + Bioplastic

Table 55. Variation of a* values in the 2sd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	1,7133	
4	3	1,7400	
5	3	1,7700	
2	3		2,3133
1	3		2,3700
Sig.		,805	,795

Table 56. Variation of b* values in the 2sd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	20,6967	
1	3	20,7400	
3	3		21,4600
2	3		21,5133
5	3		21,6700
Sig.		,891	,529

Table 57. Variation of Hue(hº) values in the 2sd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
1,00	3	83,4600	
2,00	3	83,8333	
4,00	3		85,2133
5,00	3		85,3333
3,00	3		85,4100
Sig.		,539	,756

Table 58. Variation of Chroma(C*) values in the 2sd month of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
4	3	20,7767		
1	3	20,8867	20,8867	
3	3		21,5300	21,5300
2	3			21,6500
5	3			21,7433
Sig.		,723	,059	,516

Table 59. Variation of Hardness(N) values in the 2sd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	9,3800	
2	3	9,8800	9,8800
5	3	10,4133	10,4133
4	3	10,7533	10,7533
1	3		11,9467
Sig.		,217	,076

Table 60. Variation of aw values in the 2sd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	,5600
3	3	,5600
4	3	,5633
5	3	,5633
2	3	,5700
Sig.		,080

Table 61. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values in the 2sd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	3,9233
1	3	3,9467
3	3	4,1233
5	3	4,1533
2	3	4,1867
Sig.		,342

2.2.3. 3rd Month of storage

Table 62. Variation of L* values in the 3rd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
3	3	49,7533
4	3	49,8233
2	3	50,7133
5	3	51,0300
1	3	52,0467
Sig.		,057

Treatments

1- Control
2- Alginate 1%
3- Alginate 1% + Bioplastic
4- Alginate 2%
5- Alginate 2% + Bioplastic

Table 63. Variation of a* values in the 3rd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	2,9400
2	3	3,2200
5	3	4,0133
3	3	4,5667
4	3	4,5933
Sig.		,098

Table 64. Variation of b* values in the 3rd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	23,8667	
3	3	24,0767	
5	3	24,2500	24,2500
2	3	25,1300	25,1300
1	3		25,4900
Sig.		,062	,061

Table 65. Variation of Hue(h°) values in the 3rd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	79,1133
3	3	79,2267
5	3	80,5767
2	3	82,6667
1	3	83,4033
Sig.		,083

Table 66. Variation of Chroma(C*) values in the 3rd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	24,3267	
3	3	24,5467	24,5467
5	3	24,6000	24,6000
2	3	25,3433	25,3433
1	3		25,6633
Sig.		,080	,058

Table 67. Variation of Hardness(N) values in the 3rd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	9,4667
5	3	9,4667
3	3	9,8667
2	3	10,0267
1	3	10,7600
Sig.		,427

Table 68. Variation of aw values in the 3rd month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
5	3	,4700
1	3	,4767
3	3	,4767
4	3	,4767
2	3	,4800
Sig.		,105

Table 69. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values in the 3rd month of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	4,0233	
3	3	4,1800	
2	3	4,2067	
1	3	4,3100	4,3100
5	3		4,5600
Sig.		,076	,094

2.2.4. 4th Month of storage

Table 70. Variation of L* values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	49,5133
5	3	49,6033
2	3	49,7967
3	3	49,8933
4	3	50,0500
Sig.		,660

Treatments

1- Control
2- Alginate 1%
3- Alginate 1% + Bioplastic
4- Alginate 2%
5- Alginate 2% + Bioplastic

Table 71. Variation of a* values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	5,3367
4	3	5,4067
3	3	5,4867
2	3	5,5267
5	3	5,8467
Sig.		,315

Table 72. Variation of b* values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
2	3	23,3100
1	3	23,5767
4	3	23,6900
3	3	23,7100
5	3	23,8567
Sig.		,349

Table 73. Variation of Hue(h°) values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
5	3	76,1667
2	3	76,6900
3	3	76,9733
4	3	77,1300
1	3	77,2167
Sig.		,394

Table 74. Variation of Chroma(C*) values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
2	3	23,9633
1	3	24,1900
4	3	24,3033
3	3	24,3433
5	3	24,5733
Sig.		,283

Table 75. Variation of Hardness (N) values in the 4th month of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
2	3	8,5200		
1	3	8,7867	8,7867	
4	3	10,1067	10,1067	10,1067
5	3		10,5067	10,5067
3	3			10,5867
Sig.		,070	,052	,554

Table 76. Variation of aw values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	,4633
1	3	,4667
2	3	,4667
3	3	,4700
5	3	,4700
Sig.		,124

Table 77. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values in the 4th month of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	4,4800
2	3	4,5067
3	3	4,5167
5	3	4,8567
1	3	5,0167
Sig.		,135

Appendix III - Statistical analysis of chapter IV

3.1.Analysis each treatment through time

3.1.1 Standard strawberry package control

Table 78. Variation of L* values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	45,946777780
2	3	46,372777780
1	3	48,472222220
3	3	49,693222220
Sig.		,093

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 79. Variation of a* values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,7727777800	
3	3	33,4583333300	33,4583333300
4	3	34,2288888900	34,2288888900
2	3		35,81000

Sig.		,204	,056

Table 80. Variation of b* values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	30,0773333302
1	3	32,1977777800
3	3	33,3175555600
2	3	34,1461111100
Sig.		,070

Table 81. Variation of Hue(hº) values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	41,0856050300
2	3	43,5599911804
1	3	44,2707313400
3	3	44,7784918600
Sig.		,141

Table 82. Variation of Chroma(C*) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	45,6583459000	
1	3	46,3445203500	
3	3	47,3373577100	47,3373577100
2	3		49,5818091600
Sig.		,205	,091

Table 83. Variation of Firmness (N) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	4,4066666671	
1	3	4,9666666670	4,9666666670
3	3		5,3688888890

2	3		5,6777777780
Sig.		,130	,074

Table 84. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	,6666666670	
1	3	1,3180808360	
4	3		2,3920304200
3	3		2,8965472600
Sig.		,150	,252

Table 85. Variation of Moulds and Yeasts Log10 (CFU/g) values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	1,6250204210
1	3	2,4311668890
4	3	2,4830308440
3	3	2,8965472600
Sig.		,104

Table 86. Variation of Total Soluble Solid (ºBrix) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	11,90000	
4	3	11,9666666700	
3	3	13,80000	13,80000
1	3		14,50000
Sig.		,057	,418

Table 87. Variation of Weight loss (%) values through time – Standard strawberry package control

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			

2	3		1,8994471000		
3	3			2,9033186970	
4	3				4,1098990190
Sig.		1,000	1,000	1,000	1,000

Table 88. Variation of Anthocyanins values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	8,5229244110	
1	3	8,5346964060	
2	3	11,5662949200	11,5662949200
4	3		12,0898389101
Sig.		,076	,725

3.1.2 Alginate 1% treatment

Table 89. Variation of L* values through time – Alginate 1% treatment

L[a]		
Duncan		
Time	N	Subset for alpha = .05
		1
3	3	45,9905555604
4	3	47,0995555600
2	3	47,7366666700
1	3	48,4722222200
Sig.		,066

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 90. Variation of a* values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,7727777800	
4	3	34,8074444400	34,8074444400
3	3		35,56250
2	3		35,5655555600
Sig.		,053	,440

Table 91. Variation of b* values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,1977777800	
3	3	32,6711111100	
4	3	33,3268888900	
2	3		35,6816666700
Sig.		,231	1,000

Table 92. Variation of Hue(hº) values through time – Alginate 1% treatment

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	42,4673215600
4	3	43,6584265804
1	3	44,2707313400
2	3	44,9343381300
Sig.		,074

Table 93. Variation of Chroma(C*) values through time – Alginate 1% treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	46,3445203500		
4	3		48,2802417200	
3	3		48,3728265204	
2	3			50,4996498000
Sig.		1,000	,909	1,000

Table 94. Variation of Firmness(N) values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	4,4755555561	
1	3	4,9666666670	

3	3	5,7444444440	5,7444444440
2	3		6,3444444441
Sig.		,055	,302

Table 95. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	,	
1	3		1,3180808360
2	3		1,3333333330
3	3		2,5061713130
Sig.		1,000	,055

Table 96. Variation of Yeasts and Moulds (CFU/g) values through time – Alginate 1% treatment

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	2,1173941730
2	3	2,3820426790
1	3	2,4311668890
3	3	2,5061713130
Sig.		,375

Table 97. Variation of Total Soluble Solids(ºBrix) values through time – Alginate 1% treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	11,35000	
3	3	11,5333333300	
4	3	12,0166666701	
1	3		14,50000
Sig.		,521	1,000

Table 98. Variation of Weight loss (%) values through time – Alginate 1% treatment

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		1,8434555450		
3	3			2,8721952570	
4	3				4,2389596390
Sig.		1,000	1,000	1,000	1,000

Table 99. Variation of Anthocyanins values through time – Alginate 1% treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	8,5346964060
2	3	9,3166047090
4	3	10,1858736100
3	3	12,1796778200
Sig.		,059

3.2.2. Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Table 100. Variation of L* values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	46,4972222200
4	3	47,8998888900
1	3	48,4722222200
3	3	48,9588888904
Sig.		,084

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 101. Variation of a* values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	32,7727777800
2	3	34,5616666700
4	3	34,85504

3	3	34,8805555600
Sig.		,057

Table 102. Variation of b* values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,1977777800	
4	3	33,2872222204	33,2872222204
3	3	34,3755555600	34,3755555600
2	3		35,6733333300
Sig.		,113	,087

Table 103. Variation of Hue (hº) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	43,5897455100
1	3	44,2707313400
3	3	44,4079306200
2	3	45,7993153200
Sig.		,142

Table 104. Variation of Chroma (C*) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	46,3445203500	
4	3	48,2965711000	48,2965711000
3	3		49,0881804000
2	3		49,7280348300
Sig.		,094	,219

Table 105. Variation of Firmness(N) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	4,8577777780	
1	3	4,9666666670	
3	3	5,0888888891	

2	3		6,0888888891
Sig.		,585	1,000

Table 106. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
2	3	,		
4	3	,		
1	3		1,3180808360	
3	3			2,5581339380
Sig.		1,000	1,000	1,000

Table 107. Variation of Yeasts and Moulds Log10 (CFU/g) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	2,4311668890
3	3	2,5581339380
2	3	2,6278871450
4	3	2,9823144240
Sig.		,194

Table 108. Variation of Total Soluble solids (ºBrix) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	11,25000	
3	3	11,75000	
4	3	12,9166666700	12,9166666700
1	3		14,50000
Sig.		,096	,098

Table 109. Variation of Weight loss (%) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		2,0630001720		
3	3			3,0217616410	
4	3				4,1432246391
Sig.		1,000	1,000	1,000	1,000

Table 110. Variation of Psychrophilic microorganisms Log_{10}(cfu/g) values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
3	3	,	
4	3		1,5663233350
Sig.		1,000	1,000

Table 111. Variation of – Anthocyanins values through time - Alginate 1%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	8,5346964060	
4	3	8,8289962830	
3	3	9,8779429990	9,8779429990
2	3		10,5941759600
Sig.		,097	,326

3.2.3. Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Table 112. Variation of L* values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	43,10804	

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

2	3		47,4316666700
3	3		48,0033333304
1	3		48,4722222200
Sig.		1,000	,387

Table 113. Variation of a* values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,7727777800	
4	3	34,46600	34,46600
2	3		35,3777777800
3	3		35,78000
Sig.		,103	,208

Table 114. Variation of b* values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
4	3	28,34500		
1	3		32,1977777800	
3	3		33,5211111100	33,5211111100
2	3			35,0455555604
Sig.		1,000	,095	,061

Table 115. Variation of Hue(hº) values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	39,2646062500	
3	3		43,0268797600
1	3		44,2707313400
2	3		44,7541434004
Sig.		1,000	,197

Table 116. Variation of Chroma(C*) values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
4	3	44,6896705800		
1	3		46,3445203500	
3	3			49,0913243400

2	3			49,8985553400
Sig.		1,000	1,000	,273

Table 117. Variation of Firmness (N) values through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	4,1622222221	
1	3	4,9666666670	4,9666666670
3	3	5,0444444441	5,0444444441
2	3		5,4888888890
Sig.		,062	,235

Table 118. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	1,1326466700	
1	3	1,3180808360	1,3180808360
2	3	1,7476793500	1,7476793500
3	3		2,9985450650
Sig.		,459	,066

Table 119. Variation of Yeast and Moulds Log10 (CFU/g) through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	,	
1	3		2,4311668890
2	3		2,7889632300
3	3		2,9985450650
Sig.		1,000	,078

Table 120. Variation of Total Soluble Solids(ºBrix) through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	11,7333333300	
3	3	12,55000	12,55000
2	3	13,80000	13,80000
1	3		14,50000

Sig.		,057	,070

Table 121. Variation of Weight loss (%) through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		1,9651644890		
3	3			2,8131931520	
4	3				4,2594311111
Sig.		1,000	1,000	1,000	1,000

Table 122. Variation of Anthocyanins through time - Alginate 1%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	8,4188351921	
1	3	8,5346964060	
3	3	8,7434944241	
4	3		12,1852540300
Sig.		,774	1,000

3.2.4 Alginate 2%

Table 123. Variation of L* values through time - Alginate 2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	46,23800
2	3	46,7344444404
1	3	48,4722222200
3	3	49,1655555600
Sig.		,087

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 124. Variation of a* values through time - Alginate 2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	32,7727777800
4	3	34,0217777800
2	3	35,2383333300
3	3	35,2872222204
Sig.		,053

Table 125. Variation of b* values through time - Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,1977777800	
4	3	32,2498888900	
3	3	33,9022222200	33,9022222200
2	3		35,8488888900
Sig.		,249	,177

Table 126. Variation of Hue(hº) values through time - Alginate 2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	43,3815841000
3	3	43,6982806400
1	3	44,2707313400
2	3	45,3795628204
Sig.		,192

Table 127. Variation of Chroma (C*) values through time - Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	46,3445203500	
4	3	46,9335939300	
3	3	49,0881849500	49,0881849500
2	3		50,3569594900
Sig.		,070	,344

Table 128. Variation of Firmness (N) values through time - Alginate 2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	4,6533333330
3	3	4,80001
1	3	4,9666666670
2	3	5,4555555560
Sig.		,067

Table 129. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time - Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	1,3180808360	
4	3	1,8844041710	1,8844041710
2	3	1,9067197680	1,9067197680
3	3		3,1301350520
Sig.		,349	,068

Table 130. Variation of Yeasts and Moulds Log10 (CFU/g) values through time - Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	2,4311668890	
2	3	2,9123975480	2,9123975480
4	3	2,9640315340	2,9640315340
3	3		3,1301350520
Sig.		,091	,455

Table 131. Variation of Total Soluble Solids(ºBrix) values through time - Alginate 2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	11,95001	
4	3	12,90000	12,90000
2	3	13,20001	13,20001
1	3		14,50000

Sig.		,202	,113

Table 132. Variation of Weight loss (%) values through time - Alginate 2%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		2,3070901930		
3	3			3,2819503200	
4	3				4,4833137190
Sig.		1,000	1,000	1,000	1,000

Table 133. Variation of Anthocyanins values through time - Alginate 2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	8,5346964060
3	3	9,1177199500
2	3	9,8376703840
4	3	10,3822800500
Sig.		,230

3.2.5 Alginate 2%+ Citral 0,3%+Eugenol 0,2%

Table 134. Variation of Variation of L* values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	47,2394444400
4	3	47,35000
3	3	48,3453333300
1	3	48,4722222200
Sig.		,385

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 135. Variation of Variation of a* values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	32,7727777800
4	3	33,05000
2	3	34,3827777800
3	3	35,2394444400
Sig.		,069

Table 136. Variation of Variation of b* values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	31,7177777802
1	3	32,1977777800
3	3	34,2252222200
2	3	34,5194444400
Sig.		,055

Table 137. Variation of Variation of Hue(h*) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	43,8848054100
3	3	43,9851524300
1	3	44,2707313400
2	3	44,9818984100
Sig.		,454

Table 138. Variation of Variation of Chroma(C*) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
4	3	45,8784689600		

1	3	46,3445203500	46,3445203500	
2	3		48,8294572200	48,8294572200
3	3			49,2180720000
Sig.		,704	,069	,751

Table 139. Variation of Firmness (N) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	4,9666666670
3	3	5,0222222220
4	3	5,10001
2	3	5,9777777780
Sig.		,075

Table 140. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
4	3	,		
1	3		1,3180808360	
2	3		2,2731813120	2,2731813120
3	3			3,1392264140
Sig.		1,000	,072	,097

Table 141. Variation of Yeasts and Moulds Log10 (CFU/g) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	2,0487093450	
1	3	2,4311668890	2,4311668890
2	3	2,9260504170	2,9260504170
3	3		3,1392264140
Sig.		,074	,136

Table 142. Variation of Total Soluble Solids(ºBrix) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	10,20001	
2	3		13,95001
4	3		14,05000
1	3		14,50000
Sig.		1,000	,596

Table 143. Variation of Weight loss (%) values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		2,0454433330	
3	3		3,1845989180	
4	3			4,5731310130
Sig.		1,000	,058	1,000

Table 144. Variation of Anthocyanins values through time - Alginate 2%+ Citral 0,3%+ Eugenol 0,2%

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	8,5235439900
1	3	8,5346964060
4	3	8,6288723671
3	3	8,9913258981
Sig.		,725

3.2.6. Alginate 2%+ Citral 0,6%+Eugenol 0,4%

Table 145. Variation of L* values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	45,5937777800
2	3	46,5772222200
3	3	47,0122222200
1	3	48,4722222200
Sig.		,057

Time

1- Initial time
2- 7 days
3- 10 days
4- 14 days

Table 146. Variation of a* values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	32,7727777800
2	3	33,1766666700
3	3	34,2916666700
4	3	34,49600
Sig.		,137

Table 147. Variation of b* values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	31,8076666700
1	3	32,1977777800
3	3	32,49000
2	3	34,4972222200
Sig.		,153

Table 148. Variation of Hue(Hº) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	42,5326359300
3	3	43,3341697700
1	3	44,2707313400
2	3	45,9044698700
Sig.		,080

Table 149. Variation of Chroma(C*) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	46,3445203500
4	3	47,0415637300
3	3	47,3035112900
2	3	47,9501518200
Sig.		,300

Table 150. Variation of Firmness (N) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	4,2866666670	
1	3	4,9666666670	4,9666666670
3	3		5,2666666670
2	3		5,5888888891
Sig.		,106	,149

Table 151. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	1,3180808360
4	3	1,7670099990
2	3	2,7947545950
3	3	2,9174775360
Sig.		,072

Table 152. Variation of Yeasts and Moulds Log10 (CFU/g) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	2,2709711190
1	3	2,4311668890
3	3	2,9174775360
4	3	2,9936562200
Sig.		,223

Table 153. Variation of Total Soluble Solids(ºBrix) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	11,4833333300	
2	3	13,1333333301	13,1333333301
3	3	13,35000	13,35000
1	3		14,50000
Sig.		,065	,157

Table 154. Variation of Weight loss (%) values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		1,6070878580		
3	3			2,5897466620	
4	3				3,6272965260
Sig.		1,000	1,000	1,000	1,000

Table 155. Variation of Anthocyanins values through time - Alginate 2%+ Citral 0,6%+ Eugenol 0,4%

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	8,0718711280	
1	3	8,5346964060	8,5346964060
2	3	8,9120198270	8,9120198270
4	3		13,2577447300
Sig.		,697	,053

3.2.7. Standard strawberry package control with non-enriched paper

Table 156. Variation of L* values through time - Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	45,7242222200
3	3	47,7066666704
2	3	47,7366666700
1	3	48,4722222200
Sig.		,061

Table 157. Variation of a* values through time - Standard strawberry package control with non-enriched paper

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	32,7727777800	
4	3	33,6057777804	
3	3		35,6627777800
2	3		35,9283333300
Sig.		,341	,755

Table 158. Variation of b* values through time - Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	31,9305555602
1	3	32,1977777800
2	3	33,6483333300
3	3	34,0611111100
Sig.		,203

Table 159. Variation of Hue(hº) values through time -Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	43,0229412400
4	3	43,2115117400
3	3	43,5289880200
1	3	44,2707313400
Sig.		,511

Table 160. Variation of Chroma(C*) values through time -Standard strawberry package control with non-enriched paper

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	46,3445203500	
4	3	46,5077562104	
2	3		49,3234513300
3	3		49,4210575300
Sig.		,866	,920

Table 161. Variation of Firmness (N) values through time -Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
4	3	4,5555555561
1	3	4,9666666670
3	3	5,3044444441
2	3	5,3333333331
Sig.		,145

Table 162. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time -Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	1,3180808360
2	3	2,0263937490
4	3	2,3114994840
3	3	3,2890084360
Sig.		,087

Table 163. Variation of Yeasts and Molds Log10 (CFU/g) values through time -Standard strawberry package control with non-enriched paper

Duncan			
Time	N	Subset for alpha = .05	
		1	2
4	3	2,0487093450	
1	3	2,4311668890	2,4311668890
2	3	2,7505460730	2,7505460730
3	3		3,2890084360
Sig.		,184	,113

Table 164. Variation of Total Soluble Solids (ºBrix) values through time -Standard strawberry package control with non-enriched paper

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	11,5833333300	
4	3	12,9333333300	12,9333333300
2	3	13,0166666701	13,0166666701
1	3		14,50000
Sig.		,170	,138

Table 165. Variation of Weight loss (%) values through time -Standard strawberry package control with non-enriched paper

Duncan					
Time	N	Subset for alpha = .05			
		1	2	3	4
1	3	,			
2	3		1,6193902390		
3	3			2,6271870210	
4	3				3,7844609300
Sig.		1,000	1,000	1,000	1,000

Table 166. Variation of Total Soluble Solids (ºBrix) values through time -Standard strawberry package control with non-enriched paper

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	8,5346964060
2	3	9,1778190831
4	3	9,1846344490
3	3	9,7608426270
Sig.		,513

3.2. Analysis of treatments by days

3.2.1. 7 days of storage

Table 167. Variation of L* values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	46,3727777800
3	3	46,4972222200
7	3	46,5772222200
5	3	46,7344444404
6	3	47,2394444400
4	3	47,4316666700
2	3	47,7366666700
8	3	47,7366666700
Sig.		,341

Treatments

1- Standard strawberry package control
2- Alginate 1%
3- Alginate 1% + Citral 0.3% + Eugenol 0.2%
4- Alginate 1% + Citral 0.6% + Eugenol 0.4%
5- Alginate 2%
6- Alginate 2% + Citral 0.3% + Eugenol 0.2%
7- Alginate 2% + Citral 0.6% + Eugenol 0.4%
8- Standard strawberry package control with non-enriched paper

Table 168. Variation of a* values after 7days of storage

Duncan					
Treatments	N	Subset for alpha = .05			
		1	2	3	4
7	3	33,1766666700			
6	3		34,3827777800		
3	3		34,5616666700	34,5616666700	

5	3		35,2383333300	35,2383333300	35,2383333300
4	3		35,3777777800	35,3777777800	35,3777777800
2	3		35,5655555600	35,5655555600	35,5655555600
1	3			35,81000	35,81000
8	3				35,9283333300
Sig.		1,000	,069	,056	,274

Table 169. Variation of b* values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
8	3	33,6483333300
1	3	34,1461111100
7	3	34,4972222200
6	3	34,5194444400
4	3	35,0455555604
3	3	35,6733333300
2	3	35,6816666700
5	3	35,8488888900
Sig.		,220

Table 170. Variation of Hue(hº) values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
8	3	43,0229412400
1	3	43,5599911804
4	3	44,7541434004
2	3	44,9343381300
6	3	44,9818984100
5	3	45,3795628204
3	3	45,7993153200
7	3	45,9044698700
Sig.		,083

Table 171. Variation of Chroma(C*) values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
7	3	47,9501518200
6	3	48,8294572200
8	3	49,3234513300
1	3	49,5818091600
3	3	49,7280348300
4	3	49,8985553400
5	3	50,3569594900
2	3	50,4996498000
Sig.		,066

Table 172. Variation of Firmness (N)values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
8	3	5,3333333331
5	3	5,4555555560
4	3	5,4888888890
7	3	5,5888888891
1	3	5,6777777780
6	3	5,9777777780
3	3	6,0888888891
2	3	6,3444444441
Sig.		,124

Table 173. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values after 7days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	,	
1	3	,6666666670	,6666666670
2	3	1,3333333330	1,3333333330
4	3	1,7476793500	1,7476793500
5	3	1,9067197680	1,9067197680
8	3	2,0263937490	2,0263937490
6	3	2,2731813120	2,2731813120

7	3		2,7947545950
Sig.		,055	,070

Table 174. Variation of Yeasts and Moulds Log10 (CFU/g) values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
1	3	1,6250204210
7	3	2,2709711190
2	3	2,3820426790
3	3	2,6278871450
8	3	2,7505460730
4	3	2,7889632300
5	3	2,9123975480
6	3	2,9260504170
Sig.		,078

Table 175. Variation of Total Soluble Solids(ºBrix) values after 7days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	11,25000	
2	3	11,35000	
1	3	11,90000	11,90000
8	3	13,0166666701	13,0166666701
7	3	13,1333333301	13,1333333301
5	3	13,20001	13,20001
4	3		13,80000
6	3		13,95001
Sig.		,096	,082

Table 176. Variation of Weight loss (%) values after 7days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
7	3	1,6070878580	
8	3	1,6193902390	
2	3	1,8434555450	1,8434555450
1	3	1,8994471000	1,8994471000

4	3	1,9651644890	1,9651644890
6	3	2,0454433330	2,0454433330
3	3	2,0630001720	2,0630001720
5	3		2,3070901930
Sig.		,084	,076

Table 177. Variation of Anthocyanins values after 7days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	8,4188351921
6	3	8,5235439900
7	3	8,9120198270
8	3	9,1778190831
2	3	9,3166047090
5	3	9,8376703840
3	3	10,5941759600
1	3	11,5662949200
Sig.		,059

3.2.2. 10 days of storage

Table 178. Variation of L* values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
2	3	45,9905555604	
7	3	47,0122222200	47,0122222200
8	3	47,7066666704	47,7066666704
4	3	48,0033333304	48,0033333304
6	3	48,3453333300	48,3453333300
3	3	48,9588888904	48,9588888904
5	3	49,1655555600	49,1655555600
1	3		49,6932222200
Sig.		,057	,103

Treatments

1- Standard strawberry package control
2- Alginate 1%
3- Alginate 1% + Citral 0.3% + Eugenol 0.2%
4- Alginate 1% + Citral 0.6% + Eugenol 0.4%
5- Alginate 2%
6- Alginate 2% + Citral 0.3% + Eugenol 0.2%
7- Alginate 2% + Citral 0.6% + Eugenol 0.4%
8- Standard strawberry package control with non-enriched paper

Table 179. Variation of a* values after 10 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	33,4583333300		
7	3	34,2916666700	34,2916666700	
3	3		34,8805555600	34,8805555600
6	3		35,2394444400	35,2394444400
5	3		35,2872222204	35,2872222204
2	3		35,56250	35,56250
8	3		35,6627777800	35,6627777800
4	3			35,78000
Sig.		,180	,055	,195

Table 180. Variation of b* values after 10 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
7	3	32,49000
2	3	32,6711111100
1	3	33,3175555600
4	3	33,5211111100
5	3	33,9022222200
8	3	34,0611111100
6	3	34,2252222200
3	3	34,3755555600
Sig.		,278

Table 181. Variation of Hue(hº) values after 10 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
2	3	42,4673215600
4	3	43,0268797600
7	3	43,3341697700
8	3	43,5289880200
5	3	43,6982806400
6	3	43,9851524300

3	3	44,4079306200
1	3	44,7784918600
Sig.		,160

Table 182. Variation of Chroma(C*) values after 10 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
7	3	47,3035112900
1	3	47,3373577100
2	3	48,3728265204
3	3	49,0881804000
5	3	49,0881849500
4	3	49,0913243400
6	3	49,2180720000
8	3	49,4210575300
Sig.		,115

Table 183. Variation of Firmness(N) values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
5	3	4,80001	
6	3	5,0222222220	5,0222222220
4	3	5,0444444441	5,0444444441
3	3	5,0888888891	5,0888888891
7	3	5,2666666670	5,2666666670
8	3	5,3044444441	5,3044444441
1	3	5,3688888890	5,3688888890
2	3		5,7444444440
Sig.		,137	,064

Table 184. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
2	3	2,5061713130	
3	3	2,5581339380	2,5581339380
1	3	2,8965472600	2,8965472600
7	3	2,9174775360	2,9174775360

4	3	2,9985450650	2,9985450650
5	3	3,1301350520	3,1301350520
6	3	3,1392264140	3,1392264140
8	3		3,2890084360
Sig.		,087	,051

Table 185. Variation of Yeasts and Moulds Log10 (CFU/g) values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
2	3	2,5061713130	
3	3	2,5581339380	2,5581339380
1	3	2,8965472600	2,8965472600
7	3	2,9174775360	2,9174775360
4	3	2,9985450650	2,9985450650
5	3	3,1301350520	3,1301350520
6	3	3,1392264140	3,1392264140
8	3		3,2890084360
Sig.		,087	,051

Table 186. Variation of Total Soluble Solids(ºBrix) values after 10 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
6	3	10,20001		
2	3	11,5333333300	11,5333333300	
8	3	11,5833333300	11,5833333300	
3	3	11,75000	11,75000	11,75000
5	3	11,95001	11,95001	11,95001
4	3		12,55000	12,55000
7	3		13,35000	13,35000
1	3			13,80000
Sig.		,106	,098	,061

Table 186. Variation of Weight loss (%) values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
7	3	2,5897466620	

8	3	2,6271870210	
4	3	2,8131931520	2,8131931520
2	3	2,8721952570	2,8721952570
1	3	2,9033186970	2,9033186970
3	3	3,0217616410	3,0217616410
6	3	3,1845989180	3,1845989180
5	3		3,2819503200
Sig.		,057	,122

Table 187. Variation of Anthocyanins values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
7	3	8,0718711280	
1	3	8,5229244110	
4	3	8,7434944241	
6	3	8,9913258981	
5	3	9,1177199500	
8	3	9,7608426270	9,7608426270
3	3	9,8779429990	9,8779429990
2	3		12,1796778200
Sig.		,212	,081

3.2.3. 14 days of storage

Table 188. Variation of L* values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	43,10804	
7	3		45,5937777800
8	3		45,7242222200
1	3		45,9467777800
5	3		46,23800
2	3		47,0995555600
6	3		47,35000
3	3		47,8998888900
Sig.		1,000	,085

Treatments

1- Standard strawberry package control
2- Alginate 1%
3- Alginate 1% + Citral 0.3% + Eugenol 0.2%
4- Alginate 1% + Citral 0.6% + Eugenol 0.4%
5- Alginate 2%
6- Alginate 2% + Citral 0.3% + Eugenol 0.2%
7- Alginate 2% + Citral 0.6% + Eugenol 0.4%
8- Standard strawberry package control with non-enriched paper

Table 189. Variation of a* values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
6	3	33,05000	
8	3	33,6057777804	33,6057777804
5	3	34,0217777800	34,0217777800
1	3	34,2288888900	34,2288888900
4	3	34,46600	34,46600
7	3	34,49600	34,49600
2	3		34,8074444400
3	3		34,85504
Sig.		,090	,142

Table 190. Variation of b* values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	28,34500	
1	3	30,0773333302	30,0773333302
6	3		31,7177777802
7	3		31,8076666700
8	3		31,9305555602
5	3		32,2498888900
3	3		33,2872222204
2	3		33,3268888900
Sig.		,251	,065

Table 191. Variation of Hue(h°) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	39,2646062500	
1	3	41,0856050300	41,0856050300
7	3		42,5326359300
8	3		43,2115117400
5	3		43,3815841000
3	3		43,5897455100
2	3		43,6584265804
6	3		43,8848054100
Sig.		,186	,078

Table 192. Variation of Chroma(C*) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	44,6896705800	
1	3	45,6583459000	45,6583459000
6	3	45,8784689600	45,8784689600
8	3	46,5077562104	46,5077562104
5	3	46,9335939300	46,9335939300
7	3	47,0415637300	47,0415637300
2	3		48,2802417200
3	3		48,2965711000
Sig.		,109	,077

Table 193. Variation of Firmness(N) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	4,1622222221	
7	3	4,2866666670	4,2866666670
1	3	4,4066666671	4,4066666671
2	3	4,4755555561	4,4755555561
8	3	4,5555555561	4,5555555561
5	3	4,6533333330	4,6533333330
3	3	4,8577777780	4,8577777780
6	3		5,10001
Sig.		,106	,062

Table 194. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
2	3	,	
3	3	,	
6	3	,	
4	3	1,1326466700	1,1326466700
7	3		1,7670099990
5	3		1,8844041710
8	3		2,3114994840
1	3		2,3920304200

Sig.		,128	,099

Table 195. Variation of Yeasts and Moulds Log10 (CFU/g) values after 10 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
4	3	,	
6	3		2,0487093450
8	3		2,0487093450
2	3		2,1173941730
1	3		2,4830308440
5	3		2,9640315340
3	3		2,9823144240
7	3		2,9936562200
Sig.		1,000	,097

Table 196. Variation of Total Soluble Solids(ºBrix) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
7	3	11,4833333300	
4	3	11,7333333300	
1	3	11,9666666700	
2	3	12,0166666701	
5	3	12,90000	12,90000
3	3	12,9166666700	12,9166666700
8	3	12,9333333300	12,9333333300
6	3		14,05000
Sig.		,067	,124

Table 197. Variation of Weight loss (%) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
7	3	3,6272965260	
8	3	3,7844609300	3,7844609300
1	3	4,1098990190	4,1098990190
3	3	4,1432246391	4,1432246391
2	3	4,2389596390	4,2389596390

4	3	4,2594311111	4,2594311111
5	3		4,4833137190
6	3		4,5731310130
Sig.		,129	,065

Table 198. Variation of Psychrophilic microorganisms Log10 (CFU/g) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
4	3	,	
5	3	,	
6	3	,	
7	3	,	
8	3	,	
3	3		1,5663233350
Sig.		1,000	1,000

Table 199. Variation of Anthocyanins values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
6	3	8,6288723671	
3	3	8,8289962830	8,8289962830
8	3	9,1846344490	9,1846344490
2	3	10,1858736100	10,1858736100
5	3	10,3822800500	10,3822800500
1	3	12,0898389101	12,0898389101
4	3	12,1852540300	12,1852540300
7	3		13,2577447300
Sig.		,110	,051

Appendix IV - Statistical analysis of chapter V

4.1 Analysis each treatment through time

4.1.1. Standard strawberry package control

Table 200. Variation of L* values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	33,2053333300	
3	3	34,2793333300	
1	3		39,0453333300
Sig.		,086	1,000

Time

1- Initial time
2- 7 days
3- 14 days

Table 201. Variation of a* values through time – Standard strawberry package c

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	29,12200		
2	3		31,1366666700	
1	3			33,72200
Sig.		1,000	1,000	1,000

Table 202. Variation of b* values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	16,79400	
2	3	18,5886666702	
1	3		23,8373333300
Sig.		,071	1,000

Table 203. Variation of Hue(h^o) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2

3	3	29,9966423000	
2	3	30,7175894800	
1	3		35,0304502300
Sig.		,645	1,000

Table 204. Variation of Chroma (C*) values through time – Standard strawberry package control

C*[a]				
Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	33,6626984904		
2	3		36,2995548300	
1	3			41,3679093404
Sig.		1,000	1,000	1,000

Table 205. Variation of Firmness (N) values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	3,8133333330
3	3	3,9066666670
2	3	4,0133333330
Sig.		,628

Table 206. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	1,2916870880
1	3	2,3120203720
2	3	2,9630632040
Sig.		,294

Table 207. Variation of Yeast and Moulds Log10 (CFU/g) values through time – Standard strawberry package control

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	1,4659800030
2	3	2,6343633290
1	3	2,8745755840
Sig.		,079

Table 208. Variation of Total Soluble Solids (ºBrix) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	6,9833333330	
3	3	7,60001	7,60001
2	3		8,10000
Sig.		,127	,201

Table 209. Variation of Fruits + Packages Weight loss (%)values through time – Standard strawberry package control

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0072477360	
3	3			1,8668307840
Sig.		1,000	1,000	1,000

Table 210. Variation of Packages Weight loss (%) values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	-,5188806470	
3	3	-,4606055890	
1	3		5,7933333331
Sig.		,586	1,000

Table 211. Variation of Fruits Weight loss (%) values through time – Standard strawberry package control

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0429486040	
3	3			1,9212365580
Sig.		1,000	1,000	1,000

Table 212. Variation of Anthocyanins values through time – Standard strawberry package control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	31,5520446100	
3	3		37,9975216900
2	3		38,5343866200
Sig.		1,000	,842

4.1.2. Standard strawberry package with non-enriched paper control

Table 213. Variation of L* values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	34,4853333300	
3	3	34,5766666700	
1	3		39,0453333300
Sig.		,904	1,000

Time

1- Initial time
2- 7 days
3- 14 days

Table 214. Variation of a* values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	29,87000	
2	3		32,2166666700

1	3		33,72200
Sig.		1,000	,126

Table 215. Variation of b* values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	17,3213333300	
2	3		21,8306666700
1	3		23,8373333300
Sig.		1,000	,116

Table 216. Variation of Hue(h^{o}) values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	29,7542005100	
2	3		34,0240937100
1	3		35,0304502300
Sig.		1,000	,381

Table 217. Variation of Chroma (C*) values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	34,5949009000	
2	3		38,9668896500
1	3		41,3679093404
Sig.		1,000	,091

Table 218. Variation of Firmness (N) values through time – Standard strawberry package with non-enriched paper control

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	3,8133333330
3	3	3,8533333330
2	3	4,0233333330
Sig.		,524

Table 219. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – Standard strawberry package with non-enriched paper control

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	2,2652933390
1	3	2,3120203720
2	3	3,2815824540
Sig.		,520

Table 220. Variation of Yeast and Moulds Log10 (CFU/g) values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	2,0810126830	
1	3		2,8745755840
2	3		2,9112997050
Sig.		1,000	,891

Table 221. Variation of Total Soluble Solids(ºBrix) values through time – Standard strawberry package with non-enriched paper control

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	6,9833333330	
3	3	7,8833333330	7,8833333330
2	3		8,25000
Sig.		,079	,422

Table 222. Variation of Fruits + Packages Weight loss (%)values through time – Standard strawberry package with non-enriched paper control

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0316126210	
3	3			1,8084205890
Sig.		1,000	1,000	1,000

Table 223. Variation of Packages Weight loss (%) values through time – Standard strawberry package with non-enriched paper control

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
2	3	-3,5530976580		
3	3		-2,3946586040	
1	3			8,6333333331
Sig.		1,000	1,000	1,000

Table 224. Variation of Fruits Weight loss (%) values through time – Standard strawberry package with non-enriched paper control

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,2027366950	
3	3			1,9671570070

Sig.		1,000	1,000	1,000

Table 225. Variation of Psychrophilic microorganisms Log10(cfu/g) values through time – Standard strawberry package with non-enriched paper control

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	,
2	3	,6666666670
3	3	,6666666670
Sig.		,145

Table 226. Variation of Anthocyanins values through time – Standard strawberry package with non-enriched paper control

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
3	3	35,1096654300
2	3	38,6456009900
Sig.		,077

4.1.3. A treatment

Table 227. Variation of L*values through time – A treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	33,3426666700	
3	3	33,9706666700	
1	3		39,0453333300
Sig.		,392	1,000

Time

1- Initial time
2- 7 days
3- 14 days

Table 228. Variation of a*values through time – A treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	29,8566666700		
2	3		32,1473333300	
1	3			33,72200
Sig.		1,000	1,000	1,000

Table 229. Variation of b*values through time – A treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	16,1486666700		
2	3		20,55402	
1	3			23,8373333300
Sig.		1,000	1,000	1,000

Table 230. Variation of Hue(hº) values through time – A treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	28,2621674802	
2	3		32,4318316400
1	3		35,0304502300
Sig.		1,000	,052

Table 231. Variation of Chroma(C*) values through time – A treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	33,9735242100		
2	3		38,2122852800	
1	3			41,3679093404
Sig.		1,000	1,000	1,000

Table 232. Variation of Firmness (N) values through time – A treatment

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	3,72000
1	3	3,8133333330
2	3	4,1066666670
Sig.		,315

Table 233. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – A treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	1,6737297660
1	3	2,3120203720
3	3	2,67112132100
Sig.		,310

Table 233. Variation of Yeast and Moulds Log10 (CFU/g) values through time – A treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	2,1590404180	
1	3		2,8745755840
2	3		3,2424052740
Sig.		1,000	,122

Table 234. Variation of Total Soluble Solids (ºBrix) values through time – A treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	6,9833333330
2	3	7,2333333330
3	3	7,80001
Sig.		,089

Table 235. Variation of Fruits + Packages Weight loss (%) values through time – A treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		,8523276040	
3	3			1,5925854350
Sig.		1,000	1,000	1,000

Table 236. Variation of Packages Weight loss (%) values through time – A treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	-4,3471155320	
3	3	-3,5535876070	
1	3		8,8166666670
Sig.		,124	1,000

Table 237. Variation of Fruits Weight loss (%) values through time– A treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0379755140	
3	3			1,7770807430
Sig.		1,000	1,000	1,000

Table 238. Variation of Psychrophilic microorganisms Log_{10}(cfu/g) values through time– A treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
3	3		1,83333333300
Sig.		1,000	1,000

Table 239. Variation of Anthocyanins values through time– A treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
2	3	34,1728624504
3	3	34,9801734800
Sig.		,356

4.1.4. B treatment

Table 240. Variation of L* values through time– B treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	35,2646666704	
3	3	35,3766666700	
1	3		39,0453333300
Sig.		,883	1,000

Time

1- Initial time
2- 7 days
3- 14 days

Table 241. Variation of a* values through time– B treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	28,4166666700		
2	3		32,3113333304	
1	3			33,72200
Sig.		1,000	1,000	1,000

Table 242. Variation of b* values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05

		1	2
3	3	15,58400	
2	3		22,1733333302
1	3		23,8373333300
Sig.		1,000	,184

Table 243. Variation of Hue(hº) values through time– B treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	28,3582943602	
2	3		34,1585402700
1	3		35,0304502300
Sig.		1,000	,516

Table 244. Variation of Chroma values through time– B treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	32,4956787000		
2	3		39,2990873700	
1	3			41,3679093404
Sig.		1,000	1,000	1,000

Table 245. Variation of Firmness (N) values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	3,8133333330
2	3	3,9866666670
3	3	4,20000
Sig.		,402

Table 246. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05

		1	2
2	3	,6666666670	
1	3	2,3120203720	2,3120203720
3	3		4,1485347340
Sig.		,110	,081

Table 247. Variation of Yeasts and Moulds Log10 (CFU/g) values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	2,4243337570
3	3	2,7869275630
1	3	2,8745755840
Sig.		,413

Table 248. Variation of Total Soluble Solids(ºBrix) values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	6,9833333330
2	3	7,
3	3	7,0166666671
Sig.		,946

Table 249. Variation of Fruits + Packages Weight loss (%)values through time - B treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,000		
2	3		1,2860292630	
3	3			2,4749905680
Sig.		1,000	1,000	1,000

Table 250. Variation of Package Weight loss (%)values through time - B treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	-3,1950948860	
3	3	-2,3478820710	
1	3		8,6566666671
Sig.		,095	1,000

Table 251. Variation of Fruits Weight loss (%) values through time - B treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,4666062360	
3	3			2,6681250590
Sig.		1,000	1,000	1,000

Table 252. Variation of Psychrophilic microorganisms Log_{10}(cfu/g) values through time– B treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
3	3		2,6989700040
Sig.		1,000	1,000

Table 253. Variation of Anthocyanins values through time– B treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
2	3	33,7676579904
3	3	36,9473358100
Sig.		,390

4.1.5. C treatment

Table 254. Variation of L* values through time – C treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	34,17600	
3	3	35,08200	
1	3		39,0453333300
Sig.		,280	1,000

Time

1- Initial time

2- 7 days

3- 14 days

Table 255. Variation of a*values through time – C treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	29,93400	
2	3		32,8373333300
1	3		33,72200
Sig.		1,000	,226

Table 256. Variation of b*values through time – C treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	16,4806666700	
2	3		21,6793333302
1	3		23,8373333300
Sig.		1,000	,123

Table 257. Variation of Hue (h°) values through time – C treatment

Duncan		
Time	N	Subset for alpha = .05

		1	2
3	3	28,4070661800	
2	3		33,3076953700
1	3		35,0304502300
Sig.		1,000	,251

Table 258. Variation of Chroma(C*) values through time – C treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	34,2871153300	
2	3		39,3824689300
1	3		41,3679093404
Sig.		1,000	,103

Table 259. Variation of Firmness (N) values through time – C treatment

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	3,7333333330
1	3	3,8133333330
2	3	4,1333333330
Sig.		,276

Table 260. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – C treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	2,3120203720
2	3	3,1351937070
3	3	3,2033092460
Sig.		,267

Table 261. Variation of Yeasts and Moulds Log10 (CFU/g) values through time – C treatment

Duncan		
Time	N	Subset for

		alpha = .05
		1
2	3	2,5510708380
3	3	2,6666666670
1	3	2,8745755840
Sig.		,116

Table 262. Variation of Total Soluble Solids(ºBrix) values through time – C treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	6,9833333330
3	3	7,1833333330
2	3	7,9333333330
Sig.		,109

Table 263. Variation of Fruits + Package Weight loss (%) values through time– C treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		,9250247790	
3	3			1,7798344500
Sig.		1,000	1,000	1,000

Table 264. Variation of Packages Weight loss (%) values through time– C treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	-5,2332195680	
3	3	-4,2851725450	
1	3		8,79001
Sig.		,068	1,000

Table 265. Variation of Fruits Weight loss (%) values through time– C treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,1375790900	
3	3			1,9891773390
Sig.		1,000	1,000	1,000

Table 266. Variation of Psychrophilic microorganisms Log_{10}(cfu/g) values through time– C treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	,
2	3	,6666666670
3	3	,6666666670
Sig.		,145

Table 261. Variation of Anthocyanins values through time– C treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	31,1840148702
1	3	31,5520446100
3	3	34,8791821600
Sig.		,591

4.1.6. D treatment

Table 267. Variation of L*values through time– D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2

Time

1- Initial time
2- 7 days
3- 14 days

3	3	35,18600	
2	3	35,2833333300	
1	3		39,0453333300
Sig.		,924	1,000

Table 268. Variation of a*values through time– D treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	27,91200		
2	3		31,7933333300	
1	3			33,72200
Sig.		1,000	1,000	1,000

Table 269. Variation of b*values through time– D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	13,6486666700	
2	3		20,8386666702
1	3		23,8373333300
Sig.		1,000	,051

Table 270. Variation of Hue(hº) values through time– D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	25,6848793800	
2	3		32,8827263800
1	3		35,0304502300
Sig.		1,000	,178

Table 271. Variation of Chroma(C*) values through time– D treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	31,1356080400		
2	3		38,1167965400	
1	3			41,3679093404
Sig.		1,000	1,000	1,000

Table 272. Variation of Firmness (N) values through time– D treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	3,8133333330
3	3	3,8933333330
2	3	4,3733333331
Sig.		,368

Table 273. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – D treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	1,1326466700
1	3	2,3120203720
3	3	2,8266827620
Sig.		,198

Table 274. Variation of Yeasts and Moulds Log10 (CFU/g) values through time – D treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	2,6930604150
1	3	2,8745755840
3	3	3,3416456560
Sig.		,111

Table 275. Variation of Total Soluble Solids (ºBrix) values through time – D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	6,9833333330	
2	3	7,5666666671	7,5666666671
3	3		8,05000
Sig.		,201	,279

Table 276. Variation of Fruits + Packages Weight loss (%)values through time – D treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0398302130	
3	3			2,2396483430
Sig.		1,000	1,000	1,000

Table 277. Variation of Packages Weight loss (%) values through time – D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	-4,5468040150	
2	3	-4,3113109700	
1	3		8,66000
Sig.		,897	1,000

Table 278. Variation of Fruits Weight loss (%) values through time – D treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,2164224110	
3	3			2,4633252900
Sig.		1,000	1,000	1,000

Table 279. Variation of Psychrophilic microorganisms Log_{10}(cfu/g) values through time – D treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
3	3		1,5663233350
Sig.		1,000	1,000

Table 280. Variation of Anthocyanins values through time – D treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
2	3	36,1307311000
3	3	37,9442379200
Sig.		,250

4.1.7. E treatment

Table 281. Variation of L* values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	35,21600	
3	3	35,7326666700	
1	3		39,0453333300
Sig.		,378	1,000

Time

1- Initial time
2- 7 days
3- 14 days

Table 282. Variation of a* values through time – E treatment

Duncan		
Time	N	Subset for alpha = .05

		1	2	3
3	3	29,3793333300		
2	3		31,8566666700	
1	3			33,72200
Sig.		1,000	1,000	1,000

Table 283. Variation of b* values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	16,0373333300	
2	3		21,9233333302
1	3		23,8373333300
Sig.		1,000	,088

Table 284. Variation of Hue(hº) values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	28,3117267800	
2	3		34,4166543300
1	3		35,0304502300
Sig.		1,000	,509

Table 285. Variation of Chroma(C*) values through time – E treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
3	3	33,5308983700		
2	3		38,7072626900	
1	3			41,3679093404
Sig.		1,000	1,000	1,000

Table 286. Variation of Firmness (N) values through time – E treatment

Duncan		
Time	N	Subset for alpha = .05

		1
1	3	3,8133333330
3	3	4,40000
2	3	4,6866666670
Sig.		,056

Table 287. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	2,3120203720	
2	3	2,5852916190	
3	3		4,8825359221
Sig.		,603	1,000

Table 288. Variation of Yeast Moulds Log10 (CFU/g) values through time – E treatment

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	2,6086916010
1	3	2,8745755840
2	3	2,9645872540
Sig.		,599

Table 289. Variation of Total Soluble Solids(ºBrix) values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	6,9833333330	
3	3	7,3666666671	7,3666666671
2	3		8,65000
Sig.		,517	,061

Table 290. Variation of Fruits + Packages Weight loss (%)values through time – E treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0534563560	
3	3			2,4636731820
Sig.		1,000	1,000	1,000

Table 291. Variation of Packages Weight loss (%)values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
2	3	-5,3533363881	
3	3	-5,0131245020	
1	3		8,780000
Sig.		,500	1,000

Table 292. Variation of Fruits Weight loss (%)values through time – E treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,2879076340	
3	3			2,7370449560
Sig.		1,000	1,000	1,000

Table 293. Variation of Psychrophilic microorganisms Log_{10} (cfu/g) values through time – E treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
1	3	,	
2	3	,	
3	3		2,7533571290
Sig.		1,000	1,000

Table 294. Variation of Anthocyanins values through time – E treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
2	3	32,4547707600
3	3	36,0991325900
Sig.		,223

4.1.8. F treatment

Table 295. Variation of L* values through time – F treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	35,0846666704	
2	3	36,45400	
1	3		39,0453333300
Sig.		,111	1,000

Time

1- Initial time

2- 7 days

3- 14 days

Table 296. Variation of a* values through time – F treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	27,5126666700	
2	3		33,2426666700
1	3		33,72200
Sig.		1,000	,498

Table 297. Variation of b* values through time – F treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2

3	3	12,7566666700	
2	3		22,6026666700
1	3		23,8373333300
Sig.		1,000	,171

Table 298. Variation of Hue (hº) values through time – F treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	24,5971623100	
2	3		34,0816459600
1	3		35,0304502300
Sig.		1,000	,383

Table 299. Variation of Chroma (C*) values through time – F treatment

Duncan			
Time	N	Subset for alpha = .05	
		1	2
3	3	30,3884199200	
2	3		40,2423386700
1	3		41,3679093404
Sig.		1,000	,185

Table 300. Variation of Firmness (N) values through time – F treatment

Duncan		
Time	N	Subset for alpha = .05
		1
3	3	3,4533333330
2	3	3,7333333330
1	3	3,8133333330
Sig.		,400

Table 301. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values through time – F treatment

Duncan		
Time	N	Subset for alpha = .05

		1
2	3	,8480226810
3	3	2,2136593520
1	3	2,3120203720
Sig.		,152

Table 302. Variation of Yeasts and Moulds Log10 (CFU/g) values through time – F treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	2,4523271340
1	3	2,8745755840
3	3	3,2982184080
Sig.		,066

Table 303. Variation of Total Soluble Solids(ºBrix) values through time – F treatment

Duncan		
Time	N	Subset for alpha = .05
		1
2	3	6,4833333330
3	3	6,9166666670
1	3	6,9833333330
Sig.		,417

Table 304. Variation of Fruits + Packages Weight loss (%)values through time – F treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,0104137100	
3	3			2,1028038900
Sig.		1,000	1,000	1,000

Table 305. Variation of Packages Weight loss (%) values through time – F treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
2	3	-4,8948030830		
3	3		-2,7376506080	
1	3			8,6466666670
Sig.		1,000	1,000	1,000

Table 306. Variation of Fruits Weight loss (%)values through time – F treatment

Duncan				
Time	N	Subset for alpha = .05		
		1	2	3
1	3	,		
2	3		1,2112008020	
3	3			2,2675295230
Sig.		1,000	1,000	1,000

Table 307. Variation of Anthocyanins values through time – F treatment

Duncan		
Time	N	Subset for alpha = .05
		1
1	3	31,5520446100
2	3	36,7862453500
3	3	36,8717472100
Sig.		,058

4.2. Analysis of treatments by days

4.2.1. Initial time

Table 308. Variation of Packages Weight loss (%) values on initial time

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	5,7933333331		
2	3		8,6333333331	
8	3		8,6466666670	
6	3		8,6566666671	
7	3		8,66000	
5	3			8,78001
4	3			8,79001
3	3			8,8166666670
Sig.		1,000	,554	,405

Treatments

1 - Standard strawberry package control
2 - Standard strawberry package with non-enriched paper control
3 - A
4 - C
5 - E
6 - B
7 - D
8 - F

4.2.2. 7 days of storage

Table 309. Variation of L* values after 7 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	33,2053333300		
3	3	33,3426666700	33,3426666700	
4	3	34,17600	34,17600	
2	3	34,4853333300	34,4853333300	
5	3		35,21600	35,21600
6	3		35,2646666704	35,2646666704
7	3		35,2833333300	35,2833333300
8	3			36,45400
Sig.		,172	,051	,186

Treatments

1 - Standard strawberry package control
2 - Standard strawberry package with non-enriched paper control
3 - A
4 - C
5 - E
6 - B
7 - D
8 - F

Table 310. Variation of a* values after 7 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	31,1366666700		
7	3	31,7933333300	31,7933333300	
5	3	31,8566666700	31,8566666700	
3	3	32,1473333300	32,1473333300	32,1473333300
2	3	32,2166666700	32,2166666700	32,2166666700
6	3		32,3113333304	32,3113333304
4	3		32,8373333300	32,8373333300
8	3			33,2426666700
Sig.		,057	,069	,054

Table 311. Variation of b* values after 7 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
1	3	18,5886666702	
3	3	20,55402	20,55402
7	3		20,8386666702
4	3		21,6793333302
2	3		21,8306666700
5	3		21,9233333302
6	3		22,1733333302
8	3		22,6026666700
Sig.		,055	,074

Table 312. Variation of Hue(h^o) values after 7 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
1	3	30,7175894800	
3	3	32,4318316400	32,4318316400

7	3	32,8827263800	32,8827263800
4	3	33,3076953700	33,3076953700
2	3		34,0240937100
8	3		34,0816459600
6	3		34,1585402700
5	3		34,4166543300
Sig.		,070	,173

Table 313. Variation of Chroma(C*) values after 7 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	36,2995548300		
7	3		38,1167965400	
3	3		38,2122852800	
5	3		38,7072626900	
2	3		38,9668896500	38,9668896500
6	3		39,2990873700	39,2990873700
4	3		39,3824689300	39,3824689300
8	3			40,2423386700
Sig.		1,000	,094	,082

Table 314. Variation of Firmness (N) values after 7 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
8	3	3,7333333330
6	3	3,9866666670
1	3	4,0133333330
2	3	4,0233333330
3	3	4,1066666670
4	3	4,1333333330
7	3	4,3733333331
5	3	4,6866666670
Sig.		,079

Table 315. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values after 7 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
6	3	,6666666670
8	3	,8480226810
7	3	1,1326466700
3	3	1,6737297660
5	3	2,5852916190
1	3	2,9630632040
4	3	3,1351937070
2	3	3,2815824540
Sig.		,109

Table 316. Variation of Yeasts and Moulds Log10 (CFU/g) values after 7 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
6	3	2,4243337570
8	3	2,4523271340
4	3	2,5510708380
1	3	2,6343633290
7	3	2,6930604150
2	3	2,9112997050
5	3	2,9645872540
3	3	3,2424052740
Sig.		,080

Table 317. Variation of Total Soluble Solids(ºBrix) values after 7 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3

8	3	6,4833333330		
6	3	7,	7,	
3	3	7,2333333330	7,2333333330	7,2333333330
7	3	7,5666666671	7,5666666671	7,5666666671
4	3		7,9333333330	7,9333333330
1	3		8,10000	8,10000
2	3		8,25000	8,25000
5	3			8,65000
Sig.		,120	,085	,054

Table 318. Variation of Fruits + Packages Solids(ºBrix) values after 7 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	,8523276040	
4	3	,9250247790	
1	3	1,0072477360	
8	3	1,0104137100	
2	3	1,0316126210	
7	3	1,0398302130	
5	3	1,0534563560	
6	3		1,2860292630
Sig.		,118	1,000

Table 319. Variation of Packages Weight loss (%) values after 7 days of storage

Duncan					
Treatments	N	Subset for alpha = .05			
		1	2	3	4
5	3	-5,3533363880			
4	3	-5,2332195680			
8	3	-4,8948030830			
3	3	-4,3471155320	-4,3471155320		
7	3	-4,3113109700	-4,3113109700		
2	3		-3,5530976580	-3,5530976580	
6	3			-3,1950948860	
1	3				,51888064700
Sig.		,063	,130	,460	1,000

Table 320. Variation of Fruits Weight loss (%) values through time after 7 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
3	3	1,0379755140	
1	3	1,0429486040	
4	3	1,1375790900	
2	3	1,2027366950	1,2027366950
8	3	1,2112008020	1,2112008020
7	3	1,2164224110	1,2164224110
5	3	1,2879076340	1,2879076340
6	3		1,4666062360
Sig.		,072	,053

Table 321. Variation of Psychrophilic microorganisms Log_{10} (cfu/g) values after 7 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
1	3	,000	
3	3	,000	
5	3	,000	
6	3	,000	
7	3	,000	
8	3	,000	
2	3		,666666667000
4	3		,666666667000
Sig.		1,000	1,000

Table 322. Variation of Anthocyanins Log_{10} (cfu/g) values after 7 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	31,1840148702
5	3	32,4547707600
6	3	33,7676579904

3	3	34,1728624504
7	3	36,1307311000
8	3	36,7862453500
1	3	38,5343866200
2	3	38,6456009900
Sig.		,281

4.2.3. 14 days of storage

Table 323. Variation of L* values after 14 days of storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
3	3	33,9706666700
1	3	34,2793333300
2	3	34,5766666700
4	3	35,08200
8	3	35,0846666704
7	3	35,18600
6	3	35,3766666700
5	3	35,7326666700
Sig.		,065

Treatments

1 - Standard strawberry package control
2 - Standard strawberry package with non-enriched paper control
3 - A
4 - C
5 - E
6 - B
7 - D
8 - F

Table 324. Variation of a* values after 14 days of storage

a[a]			
Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
8	3	27,5126666700	
7	3	27,91200	27,91200
6	3	28,4166666700	28,4166666700
1	3	29,12200	29,12200
5	3	29,3793333300	29,3793333300
3	3		29,8566666700
2	3		29,87000
4	3		29,93400

Sig.		,098	,081

Table 325. Variation of b* values after 14 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
8	3	12,7566666700		
7	3	13,6486666700	13,6486666700	
6	3		15,58400	15,58400
5	3			16,0373333300
3	3			16,1486666700
4	3			16,4806666700
1	3			16,79400
2	3			17,3213333300
Sig.		,407	,083	,158

Table 326. Variation of Hue(hº) values after 14 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
8	3	24,597162310		
7	3	25,684879380	25,684879380	
3	3		28,262167480	28,262167480
5	3		28,311726780	28,311726780
6	3		28,358294360	28,358294360
4	3		28,407066180	28,407066180
2	3			29,754200510
1	3			29,996642300
Sig.		,443	,093	,278

Table 327. Variation of Chroma (C*) values after 14 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
8	3	30,388419920		
7	3	31,135608040	31,135608040	
6	3	32,495678700	32,495678700	32,495678700

5	3		33,530898370	33,530898370
1	3		33,662698490	33,662698494
3	3			33,973524210
4	3			34,287115330
2	3			34,594900900
Sig.		,111	,066	,133

Table 328. Variation of Firmness (N) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
8	3	3,4533333330	
3	3	3,72000	3,72000
4	3	3,7333333330	3,7333333330
2	3	3,8533333330	3,8533333330
7	3	3,8933333330	3,8933333330
1	3	3,9066666670	3,9066666670
6	3	4,20000	4,20000
5	3		4,40000
Sig.		,104	,136

Table 329. Variation of Aerobic mesophilic microorganisms Log10 (CFU/g) values after 14 days of storage

Duncan					
Treatments	N	Subset for alpha = .05			
		1	2	3	4
1	3	1,2916870880			
8	3	2,2136593520	2,2136593520		
2	3	2,2652933390	2,2652933390		
3	3	2,6711213210	2,6711213210	2,6711213210	
7	3	2,8266827620	2,8266827620	2,8266827620	
4	3		3,2033092460	3,2033092460	3,2033092460
6	3			4,1485347340	4,1485347340
5	3				4,8825359221
Sig.		,097	,273	,103	,059

Table 330. Variation of Yeasts and Moulds Log10 (CFU/g) values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2

1	3	1,4659800030	
2	3	2,0810126830	2,0810126830
3	3	2,1590404180	2,1590404180
5	3	2,6086916010	2,6086916010
4	3	2,6666666670	2,6666666670
6	3	2,7869275630	2,7869275630
8	3		3,2982184080
7	3		3,3416456560
Sig.		,050	,063

Table 331. Variation of Total Soluble Solids(ºBrix) values after 14 days of storage

Duncan					
Treatments	N	Subset for alpha = .05			
		1	2	3	4
8	3	6,9166666670			
6	3	7,0166666671	7,0166666671		
4	3	7,1833333330	7,1833333330	7,1833333330	
5	3	7,3666666671	7,3666666671	7,3666666671	7,3666666671
1	3	7,60001	7,60001	7,60001	7,60001
3	3		7,80001	7,80001	7,80001
2	3			7,8833333330	7,8833333330
7	3				8,05000
Sig.		,098	,061	,091	,098

Table 332. Variation of Fruits + Packages Weight loss (%)values after 14 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
3	3	1,5925854350		
4	3	1,7798344500	1,7798344500	
2	3	1,8084205890	1,8084205890	
1	3	1,8668307840	1,8668307840	
8	3		2,1028038900	2,1028038900
7	3		2,2396483430	2,2396483430
5	3			2,4636731820
6	3			2,4749905680
Sig.		,260	,072	,132

Table 333. Variation of Packages Weight loss (%)values after 14 days of storage

Duncan			
Treatments	N	Subset for alpha = .05	
		1	2
5	3	-5,013124502	
7	3	-4,546804015	
4	3	-4,285172545	
3	3	-3,553587607	
8	3	-2,737650608	-2,737650608
2	3	-2,394658604	-2,394658604
6	3	-2,347882071	-2,347882071
1	3		-,4606055890
Sig.		,051	,079

Table 334. Variation of Fruits Weight loss (%)values after 14 days of storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
3	3	1,7770807430		
1	3	1,9212365580		
2	3	1,9671570070	1,9671570070	
4	3	1,9891773390	1,9891773390	
8	3	2,2675295230	2,2675295230	2,2675295230
7	3		2,4633252900	2,4633252900
6	3			2,6681250590
5	3			2,7370449560
Sig.		,072	,065	,079

Table 335 Variation of Psychrophilic microorganisms Log_{10} (cfu/g) values after 14 days if storage

Duncan				
Treatments	N	Subset for alpha = .05		
		1	2	3
1	3	,000		
8	3	,000		

2	3	,6666666670		
4	3	,6666666670		
7	3		1,5663233350	
3	3		1,8333333330	
6	3			2,6989700040
5	3			2,7533571290
Sig.		,142	,512	,893

Table 336. Variation of Anthocyanins values after 14 days if storage

Duncan		
Treatments	N	Subset for alpha = .05
		1
4	3	34,879182160
3	3	34,980173480
2	3	35,109665430
5	3	36,099132590
8	3	36,871747210
6	3	36,947335810
7	3	37,944237920
1	3	37,997521690
Sig.		,435