EXHIBIT "B"

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Zobel

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[54] **PACKAGING METHOD**

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Related U.S. Application Data

[63] Continuation of Ser. No. 623,675, Dec. 6, 1990, abandoned, which is a continuation of Ser. No. 377,071, Jul. 10, 1989, abandoned.

[30] **Foreign Application Priority Data**

Jul. 15, 1988 [GB] United Kingdom 8816951

[51] **Int. Cl.**[6] **B65B 11/00**; B65B 31/00

[52] **U.S. Cl.** **53/461**; 53/432; 426/415; 426/419

[58] **Field of Search** 53/141, 396, 432, 53/449, 469, 461; 383/100, 102, 103; 426/410, 415, 419

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,043,071	7/1962	Sadell	53/141
3,224,898	12/1965	Spencer .	
3,264,167	8/1966	Sands .	
3,271,560	9/1966	Schott, Jr. .	
3,334,803	8/1967	Abbey .	
3,546,327	12/1970	Ruda .	
3,657,610	4/1987	Komatsu et al. .	
4,735,843	4/1988	Noda .	
4,876,146	10/1989	Isaka et al.	428/347

FOREIGN PATENT DOCUMENTS

0039115	11/1981	European Pat. Off. .	
243965	11/1987	European Pat. Off. .	
54-40793	3/1978	Japan	B65D 85/52
53-51096	5/1978	Japan .	
62-235086	10/1987	Japan .	
2068991	8/1981	United Kingdom .	
2179025	8/1985	United Kingdom .	

OTHER PUBLICATIONS

Briones et al., *International Journal of Food Science and Technology* (1992), 27, 493–505.

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[57] **ABSTRACT**

The invention provides methods of packaging plant materials. The plant materials are packaged in a perforate polymeric film, the film being of a polymer having a water vapor transmission rate and an oxygen transmission rate which improve the shelf lives of the packaged materials. The film is selected so that the water vapor transmission rate is substantially that inherent to the film, and the oxygen transmission rate is controlled by the size and/or frequency of perforations in the film. Typically the perforations will have a mean diameter of not more than 100 microns, and preferably from 40 to 60 microns. The frequency of perforations will usually be not more than 1000 per square meter, although at least 10 per square meter will usually be required.

9 Claims, No Drawings

PACKAGING METHOD

This application is a continuation of application Ser. No. 07/623,675 filed Dec. 6, 1990, now abandoned, which is a continuation of application Ser. No. 07/377,071 filed Jul. 10, 1989, now abandoned.

This invention concerns the storage or packaging of plant materials.

During storage, plant materials continue to respire even when the materials have been removed from the plant on which they were growing or when the plant material has been dug out of the ground. Thus fruit and vegetables, for example, continue to place demands on the surrounding atmosphere during storage, and deterioration of the quality of the plant materials occurs through water loss and surrounding levels of oxygen and carbon dioxide which do not favour their remaining fresh.

The freshness of fruit and vegetables can be prolonged by packaging, and this can have the added advantage of reducing damage when the fresh produce is displayed on a supermarket shelf. However, there are problems with the use of many packaging materials as the atmosphere within the package changes as respiration proceeds. This can be a particular problem with plant materials which undergo a climacteric stage during ripening, when a sharp rise in the rate of respiration occurs. Thus, while polymeric films, e.g. polyolefin films, can improve the shelf life of fruit and vegetables, a point can come during their storage when deterioration is accelerated by the changes in the atmosphere within the package.

Various proposals have been made for overcoming the problems with storing plant materials in packages made from polymeric films. British Patent Specifications 1106265 and 1134667, for example, describe control of the atmosphere within a package so that the oxygen content is less than that of normal air while the carbon dioxide content is greater than that of normal air, this being effected by the use of imperforate polyethylene sheet of a thickness that it is permeable to oxygen and carbon dioxide and of an area sufficient to allow the sealed-in produce to establish and maintain a controlled atmosphere within the package. Although oxygen and carbon dioxide levels are controlled by this method, the water content of the atmosphere is not and this can lead to undesirable water levels which can increase deterioration of the packaged materials.

Films with very high water permeability are proposed in Japanese Patent Publication 62.148247, 50 to 300 holes per square centimeter being made in the film, each hole being from 50 to 300 microns in diameter. These films are proposed for wrapping cut flowers where the water vapour permeability has to be sufficient to remove condensed water droplets.

Other proposals include the use of gas and water-vapour impermeable films which have permeable windows let into them, the windows being made of more permeable materials. Alternatively, composite containers have been proposed in which one side of the container is made from an impervious plastics film and another side is made from a microporous film.

According to the present invention there is provided a method of packaging plant material, the method comprising packaging the plant material in a perforate polymeric film, the film being of a polymer having a water vapour transmission rate and an oxygen transmission rate which improve the shelf life of the packaged plant material, the water vapour transmission rate being substantially that inherent to the film and the oxygen transmission rate being controlled by the size and/or frequency of the perforations in the film.

The method of the present invention enables a wide variety of plant materials to be given particularly good shelf lives without the use of complicated or costly windows or combinations of films of different permeability. In particular, the respiration rate of the packaged plant materials can be slowed down, but undesirable anaerobic conditions can be avoided. Furthermore, the film can be selected so that oxygen and carbon dioxide transmission rates are substantially equal, and these can surprisingly be selected independently of the water vapour transmission rate of the film.

Although the present invention finds particular value in the packaging of plant materials separated from the growing plant, it can also be used for the packaging of intact plants.

The water vapour permeability of the films used in accordance with the present invention can be selected by the type of polymer used for the film. Examples of polymers which can be used include regenerated cellulose, homo and copolymers of polyolefins, e.g. with vinyl acetate or methyl acrylate, polyesters, polyamides and polycarbonates. The films can furthermore be multilayer structures, for example laminates, and they can include one or more layers, e.g. a heat sealable layer. Films of regenerated cellulose can be used to achieve water vapour permeability over a wide range, typically up to 800 g m^{-2} day^{-1} measured at 25° C. and 75 percent relative humidity for a film 24 microns thick. Lower permeabilities can be achieved by the use of a thicker film, but it is generally preferred to apply a coating to the film when it is desired to reduce its inherent permeability to water vapour. Suitable materials for the purpose are known in the art. Thus water vapour permeabilities of 100–800 g m^{-2} day^{-1} can be achieved, and if desired lower values, e.g. down to 80 g m^{-2} day^{-1}, or even lower, e.g. as little as 10 g m^{-2} day^{-1} can be achieved. When a coating is present, the permeability will usually be less than 500 g m^{-2} day^{-1}.

Polyolefin films can also be used in accordance with the present invention, the inherent water vapour permeability of films of such materials tending to be substantially less than that of uncoated regenerated cellulose films of the same thickness. Polyethylene films 30 microns thick typically have water vapour permeabilities of about 4 g m^{-2} day^{-1}, while polypropylene films of the same thickness typically have water vapour permeabilities of 1–2 g m^{-2} day^{-1}.

The water vapour permeability of the film will be selected to suit the respiration requirements of the plant material to be packaged, and therefore there are no overall preferences for water vapour permeability other than that the permeability be selected to optimise the storage life of the packaged plant material.

The oxygen permeability of the films used in accordance with the present invention will usually be not more than 200000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$ as measured at 25° C. and 75 percent relative humidity. As with water vapour permeability, different plant materials require films with different oxygen permeabilities, and permeabilities of not more than 100000, e.g. less than 50000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$ are often preferred. Lower oxygen permeabilities still can also be achieved, for example less than 10000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$. The oxygen permeability will, however, be greater than that inherent for the material of the film, and typically it should be at least 900 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$ greater than that of the material of the film. This usually means at least 3500 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$.

The oxygen permeability of films is achieved by perforations in the film. The size of the perforations affects the oxygen permeability of the film, and they are preferably up to 100 microns and they can be as low as 20 microns or less.

A more preferred range is 40 to 60 microns and, advantageously they are of about 50 microns mean diameter. If the perforations are too large, control of oxygen permeability is not possible, and if the perforations are too small large number of holes are required which in particular adds to the cost of the film. Typically it is preferred to have up to 1000 perforations in the film per square meter of film surface, but as few as 10 perforations or even less can be used. This is very significantly lower than the frequency of perforations in the films proposed in Japanese Patent Publication 62.148247 which proposes 50 to 300 holes per square centimeter, i.e. at least five hundred times fewer perforations for the same area of film. As will be appreciated, the size and number of perforations in films in accordance with the invention will be selected according to the plant material to be packaged. However, there should be sufficient perforations in the film that each package of plant material has at least one perforation. This usually requires at least 50 perforations per square meter. Usually the film will have fewer than 500 perforations per square meter, and typically from 100 to 300 per square meter.

It should be noted that the perforations in the films used in accordance with the invention are very small, and in general the films are clear despite these perforations.

The holes or perforations in the films can be produced by known methods. It is, however, unlikely that they will be sufficiently small to achieve the desired oxygen permeability if mechanical puncturing methods are used, and the preferred methods are electrical discharge and optical means, e.g. using a laser.

In most applications, it will be necessary to be able to heat seal films of the present invention, in particular to ensure that the oxygen permeability depends on the perforations in the film rather than leaks in the package. Various heat sealable layers can therefore be present on films of the present invention, and as will be appreciated these will affect the inherent water vapour permeability of the films. Of course, the film itself may be of a heat sealable material.

As will be appreciated by those skilled in the art, any heat sealable layer or other layer should not obscure the perforations in the film, and the perforations will therefore usually be made in a film already having such layers. These layers, which can be selected from those known in the art, can be formed in known manner, for example by co-extrusion or by coating.

In packaging plant materials, the film will be selected to meet the requirements of the material to be packaged, both in terms of water vapour permeability (i.e. the type and thickness of polymer used for the film) and oxygen permeability (i.e. the size and frequency of perforations, these also differing for the same material under different temperature conditions.) Obviously when very small numbers of perforations are used, e.g. about 10 per square meter, the amount of film used for an individual pack should be such as to include at least one perforation in the surface of the film so that oxygen can pass between the interior of the pack and the atmosphere outside.

Various types of fruits, vegetables, herbs and flowers have shown particularly good shelf lives when packaged using a method of the present invention. Thus broccoli, carrots, mushrooms and tomatoes, which represent a wide variety of plant materials in terms of requirements for oxygen, carbon dioxide and water vapour during respiration, have all shown extended shelf lives when compared with those packed in hitherto proposed polymeric packaging films.

The following Examples are given by way of illustration only. All parts are by weight and all temperatures are in °C. unless stated otherwise.

EXAMPLE 1

After discarding any showing signs of damage, carrots were washed, placed for 1 minute in chilled water containing 25 ppm of chlorine, and then rinsed with cold water. The carrots were allowed to dry, and packs were prepared by heat sealing them in a variety of films, each pack having internal dimensions of 20 cm×18 cm and containing approximately 0.35 kg of carrots. A similar quantity of carrots on an open tray without any wrapping film acted as a control. The samples were all stored at 20° C. and 50 percent relative humidity.

The films used were as follows:

(A)—heat sealable oriented polypropylene 25 microns thick and having 100 holes per square meter, the mean diameter of the holes being about 50 microns

(B)—as film (A) but with 68 holes per square meter

(C)—as film (A) but with 34 holes per square meter

(D)—as film (A) but without any holes

(E)—imperforate polyethylene cling film 25 microns thick

(F)—imperforate polyvinyl chloride stretch wrap film 25 microns thick

All of the packs having a film over the carrots had a much improved shelf life compared with the unwrapped control. The packs had mould free shelf lives of at least seven days, the unwrapped carrots becoming dried, shrivelled and unacceptable after three days. The packs wrapped with the imperforate films (D), (E) and (F) either became anaerobic within three days or were becoming so by 10 days. The carrots wrapped in film (B) were particularly good, those wrapped in films (A) and (C) being somewhat less so but still significantly better than those wrapped in the other films.

Water losses from all of the packaged carrots were acceptable in all cases at less than 1% by weight after 10 days.

EXAMPLE 2

The procedure of Example 1 was repeated for tomatoes except that they were packed in trays of six after washing and then drying for one hour. The calices were not removed.

Each tray was wrapped in one of the films (A) and (C)–(F) of Example 1, and a further tray was left unwrapped as a control.

The unwrapped tomatoes became very soft and mouldy after four days, and those wrapped in film (F) became mouldy after three days. Film (A), with 100 holes per square meter, led to widespread mould after seven days, the tomatoes having become soft after four days. However, tomatoes packed in film (C) remaince firm even after six days.

EXAMPLE 3

Packs of unwashed calabrese were prepared by wrapping 150 g of the calabrese on trays 025 m×0.185 m (area 0.0925 m^2), the films being:

(G)—25 micron thick heat sealable oriented polypropylene film

(H)—film (G) with 21 holes over pack area

(I)—film (G) with 7 holes over pack area

For comparison purposes, 150 g samples of calabrese were packed in 25 microns thick polyvinyl chloride cling film or simply left unwrapped.

The unwrapped pack was very limp and showed browning after two days at 20° C. and 50 percent relative humidity.

Under the same conditions, the calabrese packed in the polyvinyl chloride cling film showed yellowing after two days whereas the perforated films of the present invention did not show adverse signs until nearly six days. After three days, the calabrese packed in the unperforated polypropylene film showed dry ends and it was limper than that in the perforated film. At 4° C., calabrese stored in films of the present invention were still very good and fresh after 17 days and of better appearance than any of the samples packed using the other films.

EXAMPLE 4

Using the procedure of Example 3, 200 g of unwashed mushrooms were packed in a variety of films as follows:

(J)—unperforated heat sealable regenerated cellulose film 25 microns thick and having a water vapour permeability of 80 g m^{-2} day^{-1}—pack size 0.25 m×0.185 m (area 0.0925 m^2)

(K)—film (J) with 53 holes over pack area—pack size 0.175 m×0.125 m (area 0.0875 m^2)

(L)—as film (K) but with 25 holes over same pack area

(M)—as film (K) but with 12 holes over same pack area

Comparison tests were also carried out using 25 micron thick polyvinyl chloride cling film with 200 g of mushrooms on a 0.175 m×0.125 m tray and with the same amount of mushrooms unwrapped, the packs being stored at 20° C. and 50 percent relative humidity.

The unwrapped mushrooms were unacceptable after two days, as were those packed in the cling film and in film (J). The mushrooms packed in film (K) were still acceptable approaching six days, whereas those packed in films (L) and (M) were showing significant signs of deterioration after three days.

A similar series of tests at 4° C. using of the present invention based on the same regenerated cellulose film but with 12, 25 and 50 holes respectively over the back area showed very good results at up to 20 days whereas the unperforated film and the cling film led to an unacceptable product in some cases mould formation after only two days.

I claim:

1. A method of packaging plant material in a perforate polymeric film comprising selecting a perforate polymeric film having from 10 to 1000 perforations per square meter, said perforations having a mean diameter of 20 to 100 microns, said film having a water vapour transmission rate which is substantially the same as the rate for the film without perforations and having an oxygen transmission rate which is controlled by the size and/or frequency of the perforations in the film, placing the plant material in the perforate polymeric film and sealing the film to form a package containing the plant material, such that improved shelf life of the packaged plant material is obtained.

2. A method according to claim **1**, wherein the perforate polymeric film comprises regenerated cellulose or a polyolefin.

3. A method according to claim **1**, wherein the film comprises a polyamide, a polyester or a polycarbonate each with a heat sealable layer thereon.

4. A method according to claim **1**, wherein the perforations have a mean diameter of 40 to 60 microns.

5. A method according to claim **4**, wherein the perforations have a mean diameter of about 50 microns.

6. A method according to claim **1**, wherein the film has a water vapour transmission rate of not more than 800 g m^{-2} day^{-1} $atmosphere^{-1}$, measured at 25° C. and 75 percent relative humidity.

7. A method according to claim **1**, wherein the film has an oxygen permeability of not more than 200000 cm^3 m^{-2} day^{-1}, measured at 25° C. and 75 percent relative humidity.

8. A method according to claim **1**, wherein the plant material comprises fruit, vegetables, herbs or cut flowers.

9. A method as claimed in claim **1** in which the perforate polymeric film has at least 50 perforations/m^2.

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(12) **United States Patent**
Zobel

(10) **Patent No.: US 6,296,923 B1**
(45) **Date of Patent: Oct. 2, 2001**

(54) **PERFORATED POLYMERIC FILM WITH LIMITED OXYGEN AND WATER PERMEABILITY**

(75) Inventor: **Michael George Reinhardt Zobel**, Bridgwater (GB)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/257,431**

(22) Filed: **Jun. 8, 1994**

Related U.S. Application Data

(63) Continuation of application No. 07/910,561, filed on Jul. 8, 1992, now abandoned, which is a continuation of application No. 07/629,621, filed on Dec. 18, 1990, now abandoned, which is a continuation of application No. 07/377,082, filed on Jul. 10, 1989, now abandoned.

(30) **Foreign Application Priority Data**

Jul. 15, 1988 (GB) 8816950

(51) **Int. Cl.**[7] **B65B 55/00**

(52) **U.S. Cl.** **428/137**; 428/131; 428/220; 428/315.5; 428/536; 428/516; 428/347; 428/338; 428/339; 428/523; 428/913; 426/415; 426/419; 426/326; 426/316; 426/410; 426/118; 426/395; 53/396; 53/141; 53/432; 53/469; 53/449

(58) **Field of Search** 428/131, 220, 428/315.5, 536, 516, 137, 347, 338, 339, 523, 913; 426/415, 419, 326, 316, 410, 118, 395; 383/102, 103; 53/396, 141, 432, 469, 449

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,085,608	*	4/1963	Mathues	383/103
3,224,898		12/1965	Spencer	117/76
3,264,167		8/1966	Sands	161/111
3,271,560		9/1966	Schott, Jr.	219/243
3,334,803		8/1967	Abbey	229/53
3,471,597	*	10/1969	Schirmer	264/25
3,546,327		12/1970	Ruda	264/156
3,795,749	*	3/1974	Cummin et al.	426/326
3,880,966	*	4/1975	Zimmerman et al.	264/25
4,657,610		4/1987	Komatsu et al.	156/87
4,735,843		4/1988	Noda	428/137
4,876,146	*	10/1989	Isaka et al.	428/347
4,886,372	*	12/1989	Greengrass et al.	383/100
4,897,274	*	1/1990	Candida et al.	426/127
4,935,271	*	6/1990	Schirmer	428/35.2

FOREIGN PATENT DOCUMENTS

0039115	*	11/1981	(EP) .
0155035	*	9/1985	(EP) .
0270764	*	6/1988	(EP) .
1106265	*	3/1968	(GB) .
1134667	*	11/1968	(GB) .
2068991	*	12/1980	(GB) .
2179025	*	2/1987	(GB) .
53-51096		5/1978	(JP) B32B/7/02
54-40793		3/1979	(JP) B65D/85/52
148247	*	7/1987	(JP) .
62-235086/1987		10/1987	(JP) .

OTHER PUBLICATIONS

Briones et al., International Journal of Food Science and Technology (1992), 27, 493–505.

* cited by examiner

Primary Examiner—William P. Watkins, III
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(57) **ABSTRACT**

The invention provides polymeric films for the storage or packing of plant material, the film being perforate and having a water vapor permeability of not more than 800 g m^{-2} day^{-1} and an oxygen permeability of not more than 200000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$, both permeabilities being measured at 25° C. with a relative humidity of 75 percent. Examples of polymers which can be used to make the film are regenerated cellulose, homo and copolymers of polyolefins, e.g. with vinyl acetate or methyl acrylate, polyesters and polyamides. Various plant materials, for example carrots, tomatoes, calabrese and mushrooms heat sealed in packs of films of the invention have shown improved shelf lives compared with similar plant materials packaged for example in polyethylene cling film or polyvinyl chloride stretch wrap.

19 Claims, No Drawings

PERFORATED POLYMERIC FILM WITH LIMITED OXYGEN AND WATER PERMEABILITY

This application is a Continuation of application Ser. No. 07/910,561, filed Jul. 8, 1992, now abandoned, which is a Continuation of application Ser. No. 07/629,621, filed Dec. 18, 1990, now abandoned, which is a Continuation of application Ser. No. 07/377,082, filed Jul. 10, 1989, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns polymeric films, and in particular polymeric films for the storage or packaging of plant materials.

2. Description of the Prior Art

During storage, plant materials continue to respire even when the materials have been removed from the plant on which they were growing or when the plant material has been dug out of the ground. Thus fruit and vegetables, for example, continue to place demands on the surrounding atmosphere during storage, and deterioration of the quality of the plant materials occurs through water loss and surrounding levels of oxygen and carbon dioxide which do not favour their remaining fresh.

The freshness of fruit and vegetables can be prolonged by packaging, and this can have the added advantage of reducing damage when the fresh produce is displayed on a supermarket shelf. However, there are problems with the use of many packaging materials as the atmosphere within the package changes as respiration proceeds. This can be a particular problem with plant materials which undergo a climacteric stage during ripening, when a sharp rise in the rate of respiration occurs. Thus, while polymeric films, e.g. polyolefin films, can improve the shelf life of fruit and vegetables, a point can come during their storage when deterioration is accelerated by the changes in the atmosphere within the package.

Various proposals have been made for overcoming the problems with storing plant materials in packages made from polymeric films. British Patent Specifications 1106265 and 1134667, for example, describe control of the atmosphere within a package so that the oxygen content is less than that of normal air while the carbon dioxide content is greater than that of normal air, this being effected by the use of imperforate polyethylene sheet of a thickness that it is permeable to oxygen and carbon dioxide and of an area sufficient to allow the sealed-in produce to establish and maintain a controlled atmosphere within the package. Although oxygen and carbon dioxide levels are controlled by this method, the water content of the atmosphere is not and this can lead to undesirable water levels which can increase deterioration of the packaged materials.

Films with very high water permeability are proposed in Japanese Patent Publication 62.148247, 50 to 300 holes per square centimetre being made in the film, each hole being from 50 to 300 microns in diameter. These films are proposed for wrapping cut flowers where the water vapour permeability has to be sufficient to remove condensed water droplets.

Other proposals include the use of as and water-vapour impermeable films which have permeable windows let into them, the windows being made of more permeable materials. Alternatively, composite containers have been proposed

in which one side of the container is made from an impervious plastics film and another side is made from a microporous film.

SUMMARY OF THE INVENTION

According to the present invention there is provided a polymeric film for the storage or packaging of plant material, the film being perforate and having a water vapour permeability of not more than 800 g m^{-2} day^{-1} and an oxygen permeability of not more than 200000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$, both permeabilities being measured at 25° C. with a relative humidity of 75 percent.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Films of the present invention have the advantage of providing packages with the desired degree of oxygen permeability to give good storage life to plant materials stored in them while at the same time enabling the water permeability of the packages to be controlled to a desired level, this being achieved without the necessity for special windows or a number of films for the one package. Films of the present invention can be produced which are generally stiffer than conventional cling film, thus enabling them to be used more readily on horizontal or vertical form fill seal packaging machinery. Furthermore, they will usually be clear as the perforations used are very small.

The water vapour permeability of the films of the present invention can be selected by the type of polymer used for the film. Examples of polymers which can be used include regenerated cellulose, homo and copolymers of polyolefins, e.g. with vinyl acetate or methyl acrylate, polyesters and polyamides. The films can furthermore be laminates and/or can include one or more layers, e.g. a heat sealable layer. Films of regenerated cellulose can be used to achieve water vapour permeability over a wide range, typically up to 800 g m^{-2} day^{-1} measured at 25° C. and 75 percent relative humidity for a film 24 microns thick. Lower permeabilities can be achieved by the use of a thicker film, but it is generally preferred to apply a coating to the film when it is desired to reduce its permeability to water vapour. Suitable materials for the purpose are known in the art. Thus water vapour permeabilities of 100–800 g m^{-2} day^{-1} can be achieved, and if desired lower values, e.g. down to 80 g m^{-2} day^{-1}, or even lower, e.g. as little as 10 g m^{-2} day^{-1} can be achieved. When a coating is present, the permeability will usually be less than 500 g m^{-2} day day^{-1}.

Polyolefins can also be used to make films of the present invention, the inherent water vapour permeability of films of such materials tending to be substantially less than that of uncoated regenerated cellulose films of the same thickness. Polyethylene films 30 microns thick typically have water vapour permeabilities of about 4 g m^{-2} day^{-1}, while polypropylene films of the same thickness typically have water vapour permeabilities of 1–2 g m^{-2} day^{-1}.

The water vapour permeability of the film will be selected to suit the respiration requirements of the plant material to be packaged, and therefore there are no overall preferences for water vapour permeability other than that the permeability be selected to optimise the storage life of the packaged plant material.

The oxygen permeability of films of the present invention is not more than 200000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$ as measured at 25° C. and 75 percent relative humidity. As with water vapour permeability, different plant materials require films with different oxygen permeabilities, and permeabili-

ties of not more than 100000, e.g. less than 50000 cm^3 m^{-2} day^{-1} atmosphere $^{-1}$ are often preferred. Lower oxygen permeabilities still can be achieved, for example less than 10000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$. The oxygen permeability will, however, be greater than that inherent for the material of the film, and typically it should be at least 900 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$ greater than that of the material of the film. This usually means at least 3500 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$.

The oxygen permeability of films of the present invention is achieved by perforations in the film. The size of the perforations affects the oxygen permeability of the film, and they are preferably from 20 to 100 microns, more preferably 40 to 60 microns and advantageously about 50 microns mean diameter. If the perforations are too large, control of oxygen permeability is not possible, and if the holes are too small, large numbers of holes are required which in particular adds to the cost of the film. Typically it is preferred to have up to 1000 perforations in the film per square metre of film surface, but as few as 10 perforations or even less can be used. These sizes (20 to 100 microns, preferably 40 to 60 microns) and numbers (100 to 1000 per m^2 of film surface) represent a percentage of perforations in the range of 3.14×10^{-7} to 7.85×10^{-4}%, preferably 1.26×10^{-6} to 2.83×10^{-4}% of the total film surface. This is very significantly lower than the frequency of perforations in the films proposed in Japanese Patent Publication 62.148247 which proposes 50 to 300 holes per square centimeter, i.e. at least five hundred times fewer perforations for the same area of film. As will be appreciated, the size and number of perforations in films in accordance with the invention will be selected according to the plant material to be packaged. However, there should be sufficient perforations in the film that each package of plant material has at least one perforation. This usually requires at least 50 perforations per square meter. Usually the film will have fewer than 500 perforations per square meter, and typically from 100 to 300 per square meter.

The holes or perforations in films of the present invention can be produced by known methods. It is, however, unlikely that they will be sufficiently small to achieve the desired oxygen permeability if mechanical puncturing methods are used, and the preferred methods are electrical discharge and optical means, e.g. using a laser.

In most applications, it will be necessary to be able to heat seal films of the present invention, in particular to ensure that the oxygen permeability depends on the perforations in the film rather than leaks in the package. Various heat sealable layers can therefore be present on films of the present invention, and as will be appreciated these will affect the inherent water vapour permeability of the films. Of course, the film itself may be of a heat sealable material.

As will be appreciated by those skilled in the art, any heat sealable layer or other layer should not obscure the perforations in the film, and the perforations will therefore usually be made in a film already having such layers. These layers, which can be selected from those known in the art, can be formed in known manner, for example by co-extrusion or by coating.

In packaging plant materials, the film will be selected to meet the requirements of the material to be packaged, both in terms of water vapour permeability (i.e. the type and thickness of polymer used for the film) and oxygen permeability (i.e. the size and frequency of perforations, these also differing for the same material under different temperature conditions.) Obviously when very small numbers of perforations are used, e.g. about 10 per square meter, the amount of film used for an individual pack should be such as to include at least one perforation in the surface of the film so that oxygen can pass between the interior of the pack and the atmosphere outside.

Various types of fruits, vegetables, herbs and flowers have shown particularly good shelf lives when stored in packages made from films of the present invention. Thus broccoli, carrots, mushrooms and tomatoes, which represent a wide variety of plant materials in terms of requirements for oxygen, carbon dioxide and water vapour during respiration, have all shown extended shelf lives when compared with those packed in hitherto proposed polymeric packaging films.

The following Examples are given by way of illustration only. All parts are by weight and all temperatures are in °C. unless stated otherwise.

EXAMPLE 1

After discarding any showing signs of damage, carrots were washed, placed for 1 minute in chilled water containing 25 ppm of chlorine, and then rinsed with cold water. The carrots were allowed to dry, and packs were prepared by heat sealing them in a variety of films, each pack having internal dimensions of 20 cm×18 cm and containing approximately 0.35 kg of carrots. A similar quantity of carrots on an open tray without any wrapping film acted as a control. The samples were all stored at 20° C. and 50 percent relative humidity.

The films used were as follows:

(A)—heat sealable oriented polypropylene 25 microns thick and having 100 holes per square meter, the mean diameter of the holes being about 50 microns

(B)—as film (A) but with 68 holes per square meter

(C)—as film (A) but with 34 holes per square meter

(D)—as film (A) but without any holes

(E)—imperforate polyethylene cling film 25 microns thick

(F)—imperforate polyvinyl chloride stretch wrap film 25 microns thick

All of the packs having a film over the carrots had a much improved shelf life compared with the unwrapped control. The packs had mould free shelf lives of at least seven days, the unwrapped carrots becoming dried, shrivelled and unacceptable after three days. The packs wrapped with the imperforate films (D), (E) and (F) either became anaerobic within three days or were becoming so by 10 days. The carrots wrapped in film (B) were particularly good, those wrapped in films (A) and (C) being somewhat less so but still significantly better than those wrapped in the other films.

Water losses from all of the packaged carrots were acceptable in all cases at less than 1% by weight after 10 days.

EXAMPLE 2

The procedure of Example 1 was repeated for tomatoes except that they were packed in trays of six after washing and then drying for one hour. The calices were not removed.

Each tray was wrapped in one of the films (A) and (C)–(F) of Example 1, and a further tray was left unwrapped as a control.

The unwrapped tomatoes became very soft and mouldy after four days, and those wrapped in film (F) became mouldy after three days. Film (A), with 100 holes per square meter, led to widespread mould after seven days, the toma-

toes having become soft after four days. However, tomatoes packed in film (C) remained firm even after six days.

EXAMPLE 3

Packs of unwashed calabrese were prepared by wrapping 150 g of the calabrese on trays 025 m×0.185 m (area 0.0925 m^2), the films being:

(G)—25 micron thick heat sealable oriented polypropylene film

(H)—film (G) with 21 holes over pack area

(I)—film (G) with 7 holes over pack area

For comparison purposes, 150 g samples of calabrese were packed in 25 microns thick polyvinyl chloride cling film or simply left unwrapped.

The unwrapped pack was very limp and showed browning after two days at 20° C. and 50 percent relative humidity. Under the same conditions, the calabrese packed in the polyvinyl chloride cling film showed yellowing after two days whereas the perforated films of the present invention did not show adverse signs until nearly six days. After three days, the calabrese packed in the unperforated polypropylene film showed dry ends and it was limper than that in the perforated film. At 4° C., calabrese stored in films of the present invention were still very good and fresh after 17 days and of better appearance than any of the samples packed using the other films.

EXAMPLE 4

Using the procedure of Example 3, 200 g of unwashed mushrooms were packed in a variety of films as follows:

(J)—unperforated heat sealable regenerated cellulose film 25 microns thick and having a water vapour permeability of 80 g m^{-2} day^{-1}—pack size 0.25 m×0.185 m (area 0.0925 m^2)

(K)—film (J) with 53 holes over pack area—pack size 0.175 m×0.125 m (area 0.0875 m^2)

(L)—as film (K) but with 25 holes over same pack area

(M)—as film (K) but with 12 holes over same pack area

Comparison tests were also carried out using 25 micron thick polyvinyl chloride cling film with 200 g of mushrooms on a 0.175 m×0.125 m tray and with the same amount of mushrooms unwrapped, the packs being stored at 20° C. and 50 percent relative humidity.

The unwrapped mushrooms were unacceptable after two days, as were those packed in the cling film and in film (J). The mushrooms packed in film (K) were still acceptable approaching six days, whereas those packed in films (L) and (M) were showing significant signs of deterioration after three days.

A similar series of tests at 4° C. using films of the present invention based on the same regenerated cellulose film but with 12, 25 and 50 holes respectively over the pack area showed very good results at up to 20 days whereas the unperforated film and the cling film led to an unacceptable product and in some cases mould formation after only two days.

What is claimed is:

1. A polymeric film for the storage or packaging of plant material, the film having from 10 to 1000 perforations per square meter therein, wherein the mean diameter of the perforations is from 20 to 100 microns, said film having a water vapour permeability of not more than 800 g m^{-2} day^{-1} and an oxygen permeability of not more than 200000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$, both permeabilities being measured at 25° C. with a relative humidity of 75 percent.

2. A film according to claim **1**, wherein the film is of regenerated cellulose.

3. A film according to claim **2**, wherein the regenerated cellulose has a coating thereon which modifies the water vapour permeability of the film.

4. A film according to claim **1**, wherein the water vapour permeability is from 100 to 800 g m^{-2} day^{-1}.

5. A film according to claim **1**, wherein the water vapour permeability is at least 10 g m^{-2} day^{-1}.

6. A film according to claim **1**, wherein the film is of a polyolefin.

7. A film according to claim **6**, wherein the polyolefin is polyethylene or polypropylene.

8. A film according to claim **1**, wherein the oxygen permeability of the film is not more than 100000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$.

9. A film according to claim **8**, wherein the oxygen permeability of the film is less than 50000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$.

10. A film according to claim **9**, wherein the oxygen permeability is less than 10000 cm^3 m^{-2} day^{-1} $atmosphere^{-1}$.

11. A film according to claim **1**, wherein the mean diameter of the perforations is from 40 to 60 microns.

12. A film according to claim **11**, wherein the mean diameter of the perforations is about 50 microns.

13. A film according to claim **1**, which is clear.

14. A film according to claim **1**, having at least one heat sealable surface.

15. A film according to claim **1**, having perforations therein representing from 1.26×10^{-6} to 2.83×10^{-4} percent of the film surface area.

16. A film according to claim **1**, wherein the water vapour permeability is at least 80 g $m^{31\ 2}$ day^{-1}.

17. A respiring plant material packaged in the polymeric film of claim **1**.

18. The packaged respiring plant material of claim **17** wherein the respiring plant material is a fruit or vegetable.

19. The packaged material according to claim **18** wherein the fruit or vegetable is broccoli, carrots, mushrooms or tomatoes.

* * * * *

US006441340B1

(12) **United States Patent**
Varriano-Marston

(10) **Patent No.: US 6,441,340 B1**
(45) **Date of Patent: Aug. 27, 2002**

(54) **REGISTERED MICROPERFORATED FILMS FOR MODIFIED/CONTROLLED ATMOSPHERE PACKAGING**

(76) Inventor: **Elizabeth Varriano-Marston**, 18 Wilson Rd., Windham, NH (US) 03087

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/528,290**

(22) Filed: **Mar. 17, 2000**

Related U.S. Application Data

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(51) **Int. Cl.**[7] **B23K 26/36**
(52) **U.S. Cl.** **219/121.7**
(58) **Field of Search** 219/121.6, 121.61, 219/121.62, 121.67, 121.7, 121.71, 121.83

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,553,017	A	* 11/1985	Addleman	219/121.61
4,777,338	A	10/1988	Cross	
4,842,875	A	6/1989	Anderson	
4,879,078	A	11/1989	Antoon, Jr.	
4,910,032	A	3/1990	Antoon, Jr.	
4,916,285	A	* 4/1990	Baur et al.	219/121.72
4,923,650	A	5/1990	Antoon et al.	
4,923,703	A	5/1990	Antoon et al.	
4,962,085	A	* 10/1990	deBarbadillo, II et al.	148/277
5,302,798	A	* 4/1994	Inagawa et al.	219/121.7
5,714,762	A	* 2/1998	Li et al.	250/559.2
5,832,699	A	11/1998	Zobel	
6,050,832	A	* 4/2000	Lee et al.	439/91
6,229,114	B1	* 5/2001	Andrews et al.	219/121.72

FOREIGN PATENT DOCUMENTS

CA	1307031		9/1992
EP	282180	A3	9/1988
EP	351116	A2	1/1990
GB	2200618	A	8/1988
GB	2221692	A	2/1990

* cited by examiner

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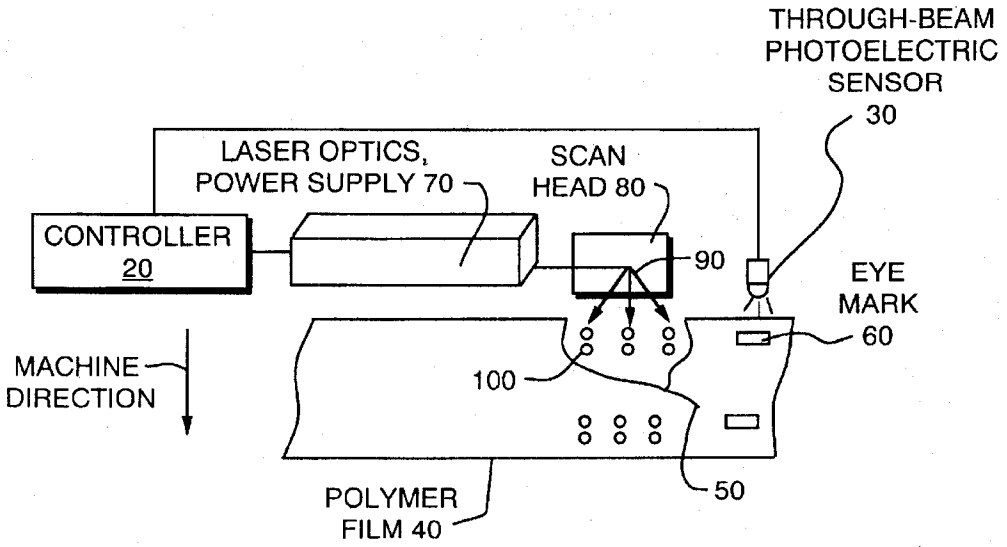
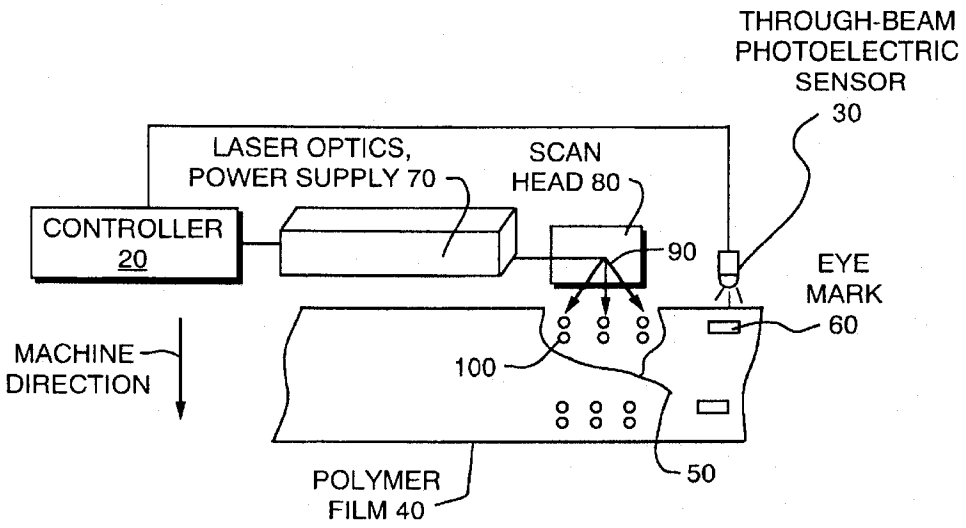
(74) *Attorney, Agent, or Firm*—Scott J. Asmus; Vernon C. Maine; Maine & Asmus

(57) **ABSTRACT**

Microperforated packaging materials for use in modifying or controlling the flow of oxygen and carbon dioxide into and/out of a fresh produce container, where the microperforations are specifically tailored in size, location and number for the specific produce. A packaging system of designating specifically tailored microperforated containers for particular fresh produce to optimally preserve the produce. A method of making the registered microperforations on the packaging material using a CO_2 laser and a sensor mechanism.

8 Claims, 5 Drawing Sheets

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PHOTOELECTRIC
SENSOR
30
LASER OPTICS,
POWER SUPPLY 70
SCAN
HEAD 80
CONTROLLER
20
90
EYE
MARK
60
MACHINE
DIRECTION
100
50
POLYMER
FILM 40

FIG. 1

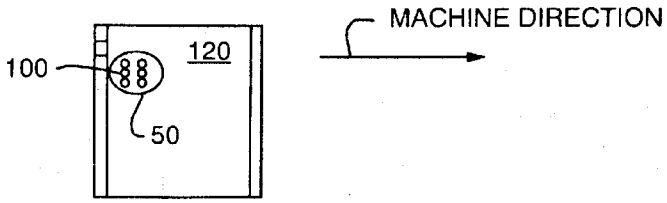

MACHINE DIRECTION
100
120
50

FIG. 2

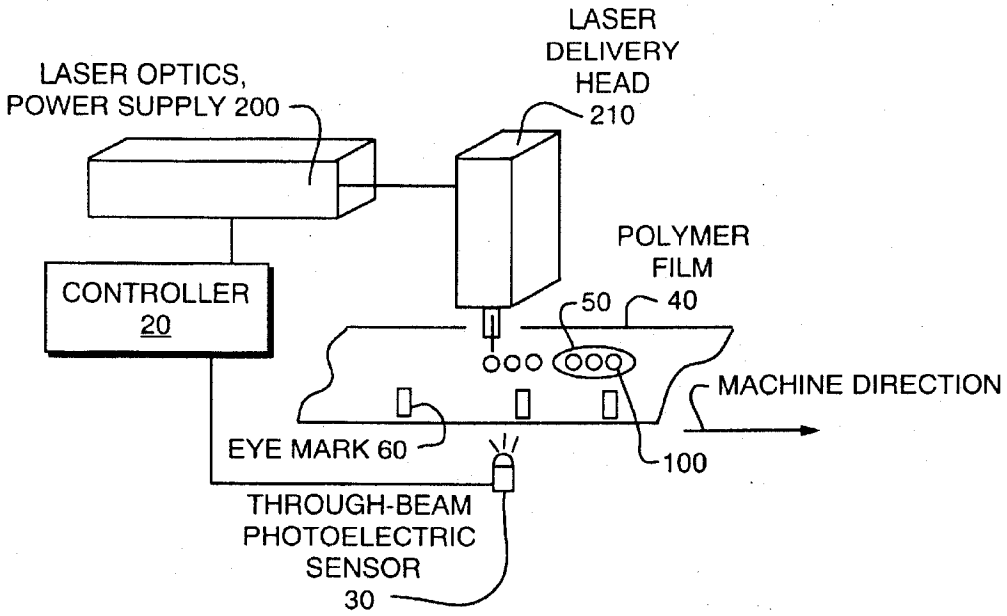
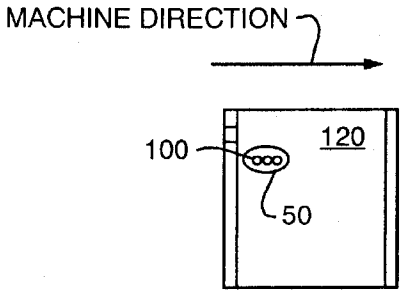

LASER OPTICS, POWER SUPPLY 200
LASER DELIVERY HEAD 210
CONTROLLER 20
POLYMER FILM
50
40
MACHINE DIRECTION
EYE MARK 60
100
THROUGH-BEAM PHOTOELECTRIC SENSOR 30

FIG. 3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100
120
50

FIG. 4

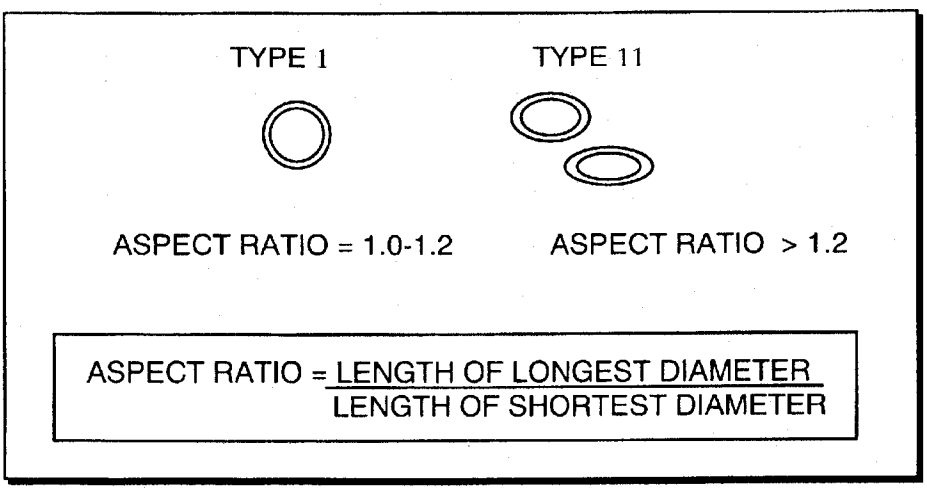

TYPE 1
TYPE 11
ASPECT RATIO = 1.0-1.2
ASPECT RATIO > 1.2
ASPECT RATIO = LENGTH OF LONGEST DIAMETER / LENGTH OF SHORTEST DIAMETER

FIG. 5

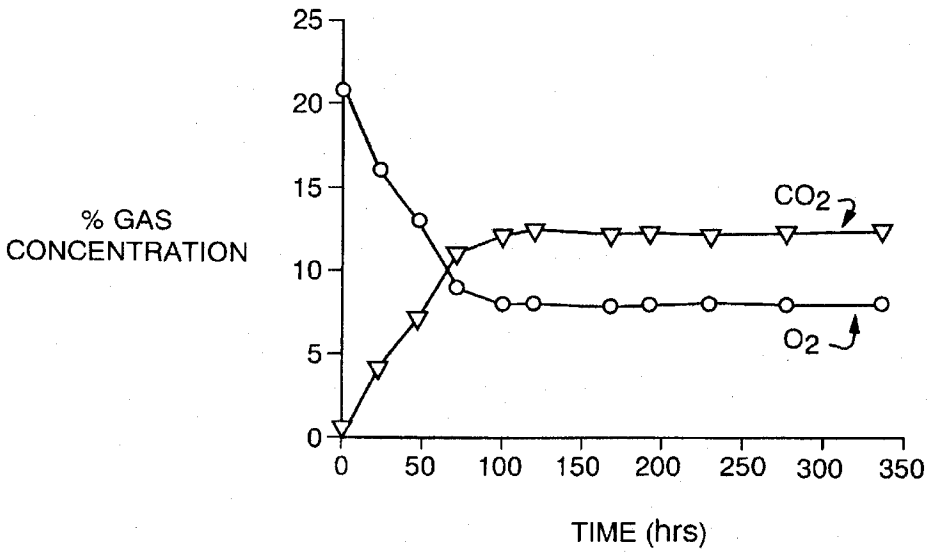

% GAS
CONCENTRATION
25
20
15
10
5
0
0
50
100
150
200
250
300
350
TIME (hrs)
CO2
O2

FIG. 6

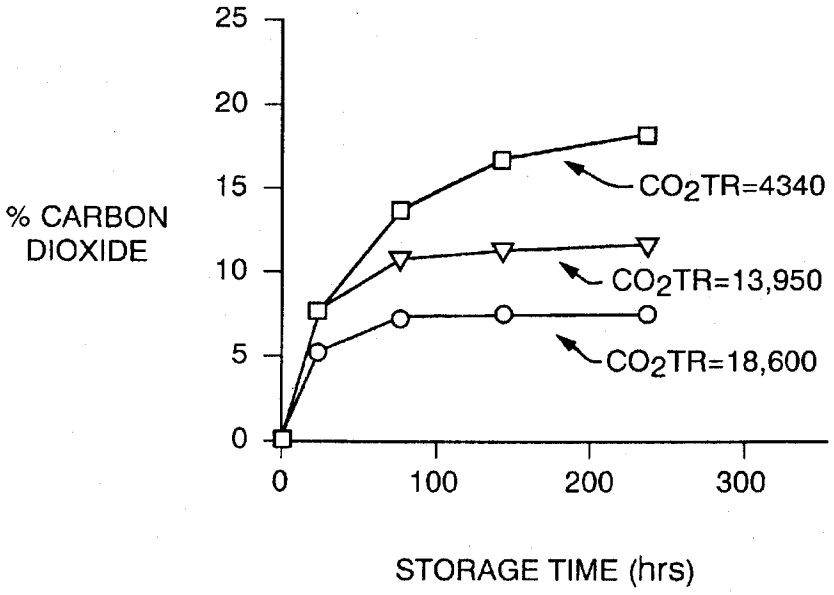

25
20
15
10
5
0
% CARBON DIOXIDE
0
100
200
300
STORAGE TIME (hrs)
CO_2TR=4340
CO_2TR=13,950
CO_2TR=18,600

FIG. 7

REGISTERED MICROPERFORATED FILMS FOR MODIFIED/CONTROLLED ATMOSPHERE PACKAGING

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. §119(e) from U.S. patent application Ser. No. 60/132,388 filed on May 4, 1999, which is incorporated herein by reference for all purposes.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to the field of packaging for respiring or biochemically active agricultural products such as fresh fruits, fresh vegetables, fresh herbs, and flowers (herein referred to collectively as fresh produce) and more particularly to registered microperforations in packaging materials for use in modifying or controlling the flow of oxygen and carbon dioxide into and/out of a fresh produce container.

BACKGROUND OF THE INVENTION

The quality and shelf life of many food products is enhanced by enclosing them in packaging that modifies or controls the atmosphere surrounding the product. Increased quality and longer shelf life result in fresher products for the consumer, less waste from spoiled produce, better inventory control, and appreciable overall savings for the food industry at both the retail and wholesale levels.

Modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) are often used interchangeably in the industry, and much confusion exists on their exact meanings. Both refer to methods to control the atmosphere in the package. In the processed foods area, MAP is considered a static method for controlling the atmosphere whereby an initial charge of a specific gas composition, e.g. 30% CO_2 and 70% N_2, is introduced into a barrier container before sealing.

The oxygen transmission rate (OTR) of a film is expressed as cc O_2/m^2-day-atmosphere, where one atmosphere is 101325 kg/ms^2. Generally, a barrier container is one that has an OTR of <70 cc/m^2-day-atm. The units describing the flow of a particular gas through a film are "flux", expressed as cc/day-atm.

For fresh produce, the primary means to extend quality and shelf life is temperature control. However, more than 50 years of evidence from industry practices on bulk storage of fresh fruits and vegetables in refrigerated controlled atmosphere storage rooms has shown that atmosphere control can contribute greatly to quality retention and shelf life. The use of MAP/CAP for fresh produce was a natural progression once packaging technology had advanced to include the production of non-barrier (often referred to in the industry as "breathable") materials.

The goal in fresh fruit and vegetable packaging is to use MAP/CAP to preserve produce quality by reducing the aerobic respiration rate but avoiding anaerobic processes that lead to adverse changes in texture, flavor, and aroma, as well as an increased public health concern. Aerobic respiration can be defined by the following equation:

$$(CH_2O)n+nO_2 \rightarrow nCO_2+nH_2O+heat$$

where O_2 from the air is used to metabolize carbohydrate ($(CH_2O)n$) reserves and in the process, CO_2, and H_2O are produced and heat is generated. For each respiring item, there is an optimum O_2 and CO_2 level that will reduce its respiration rate and thereby, slow aging and degradative processes. Different fresh produce items have different respiration rates and different optimum atmospheres for extending quality and shelf life.

The concept of passive MAP became common with the development of packaging materials with OTRs of 1085 to 7000 cc/m^2-day-atm for fresh-cut salads. In passive MAP, the produce is sealed in packages made from these low barrier materials and allowed to establish its own atmosphere over time through produce respiration processes. Sometimes the package is gas-flushed with N_2 or a combination of CO_2 and N_2, or O_2, CO_2, and N_2 before sealing to rapidly establish the desired gas composition inside the package. Alternately, a portion of the air may be removed from the pack, either by deflation or evacuation, before the package is sealed, to facilitate rapid establishment of the desired gas content.

In CAP, the atmosphere in the package is controlled at well-defined levels throughout storage. CAP can take many forms, and may even involve enclosing gas absorber packets inside processed food barrier packages. For example, CO_2 absorber sachets may be sealed inside coffee containers to absorb and control the level of CO_2 that continues to be generated by the ground coffee. Sachets containing iron oxides are enclosed in barrier packages of fresh refrigerated pasta to absorb low levels of O_2 entering the package through the plastic material.

CAP of fresh produce is just a more controlled version of MAP. It involves a precise matching of packaging material gas transmission rates with the respiration rates of the produce. For example, many fresh-cut salad packages use passive MAP as described herein. If the packages are temperature-abused (stored at 6–10° C. or higher), O_2 levels diminish to less than 1%, and CO_2 levels can exceed 20%. If these temperature-abused packages are then placed back into recommended 3–4° C. storage, the packaging material gas transmission rates may not be high enough to establish an aerobic atmosphere (<20% CO_2, >1–2% O_2) so fermentation reactions cause off-odors, off-flavors, and slimy product. If the salad was in a CAP package, the O_2 levels would decrease and CO_2 levels increase with temperature abuse, but would be re-established to desired levels within a short time after the product is returned to 4° C. storage temperatures.

Today, films made from polymer blends, coextrusions, and laminate materials with OTRs of 1085 to 14,000 cc/100 m^2-day-atm are being used for packaging various weights of low respiring produce items like lettuce and cabbage. These OTRs, however, are much too low to preserve the fresh quality of high respiring produce like broccoli, mushrooms, and asparagus. In addition, existing packaging material OTRs for bulk quantities (>1 kg) of some low respiring produce are not high enough to prevent sensory quality changes during storage. Therefore, several approaches have been patented describing methods to produce packaging materials to accommodate the higher respiration rate requirements and higher weights of a wide variety of fresh produce items.

U.S. Pat. No. 4,842,875, U.S. Pat. No. 4,923,703, U.S. Pat. No. 4,910,032, U.S. Pat. No. 4,879,078, and U.S. Pat. No. 4,923,650 describe the use of a breathable microporous patch placed over a opening in an essentially impermeable fresh produce container to control the flow of oxygen and carbon dioxide into and out of the container during storage. Although this method works effectively, the breathable

patch must be produced by normal plastic extrusion and orientation processes, whereby, a highly filled, molten plastic is extruded onto a chill roll and oriented in the machine direction using a series of rolls that decrease the thickness of the web. During orientation, micropores are created in the film at the site of the filler particles. Next, the microporous film must be converted into pressure sensitive adhesive patches or heat-seal coated patches using narrow web printing presses that apply a pattern of adhesive over the microporous web and die-cut the film into individual patches on a roll. These processes make the cost of each patch too expensive for the wide spread use of this technology in the marketplace. In addition, the food packer has to apply the adhesive-coated breathable patch over a hole made in the primary packaging material (bag or lidding film) during the food packaging operation. To do this, the packer must purchase hole-punching and label application equipment to install on each packaging equipment line. These extra steps not only increase packaging equipment costs, but also greatly reduce packaging speeds, increase packaging material waste, and therefore, increase total packaging costs.

An alternative to microporous patches for MAP/CAP of fresh fruits and vegetables is to microperforate polymeric packaging materials. Various methods can be used to microperforate packaging materials: cold or hot needle mechanical punches, electric spark and lasers. Mechanical punches are slow and often produce numerous large perforations (1 mm or larger) throughout the surface area of the packaging material, making it unlikely that the atmosphere inside the package will be modified below ambient air conditions (20.9% O_2, 0.03% CO_2).

Equipment for spark perforation of packaging materials is not practical for most plastic converting operations, because the packaging material must be submerged in either an oil or a water bath while the electrical pulses are generated to microperforate the material. The most efficient and practical method for making microperforated packaging materials is using lasers.

UK Patent Application No. 2 200 618 A and European Patent Application No. 88301303.9 describe the use of a mechanical perforating method to make perforations with diameters of 0.25 mm to 60 mm in PVC films for produce packaging. Rods with pins embedded into the surface of the cylinder are used to punch holes in the film. For each produce item to be packaged, the rod/pin configuration is manually changed so that the number of perforation rows in the film, the distance apart of the rows, the pitch of the pins used to make the holes, and the size of the holes are adjusted to meet the specific requirements of the produce. The produce requirements are determined by laboratory testing produce packed in a variety of perforated films. The invention does not disclose any mathematical method to determine the appropriate size or number of perforations to use with different produce items. In addition, the hole sizes, 20 mm to 60 mm, that are claimed would be too large to effectively control the atmosphere inside packages containing less than several kilograms of produce. Furthermore, the complicated perforation method would cause lost package production time due to equipment (perforation cylinder) change-overs for different perforation patterns. In addition the invention cautions that the produce should be placed in the package so that the perforations are not occluded and care should be taken to prevent taping over the perforations in the film. Since the perforations are not registered in a small area on the package, but are placed throughout the main body of the plastic film, the likelihood is high that perforations will be occluded by the produce inside the package or by pressure sensitive adhesive labels applied on packages for marketing purposes. When holes are blocked, the principal route for gas transmission through the film is blocked which leads to anaerobic conditions and fermentative reactions. The result is poor sensory properties, reduced shelf life and possible microbiological safety concerns. Therefore, it is important that perforations be registered in a well-defined area of the package where the likelihood of their occlusion during pack-out, storage, transportation, and retail display is minimized.

U.S. Pat. No. 5,832,699, UK Patent Application 2 221 692 A, and European Patent Application 0 351 116 describe a method of packaging plant material using perforated polymer films having 10 to 1000 perforations per m^2 (1550 in^2) with mean diameters of 40 to 60 microns but not greater than 100 microns. The patents recommend the use of lasers for creating the perforations, but do not describe the equipment or processes necessary to accomplish this task. The patents describe the limits of the gas transmission rates of the perforated film: OTR no greater than 200,000 cc/ m^2-day-atm (12,903 cc O_2/100 in^2-day-atm), and MVTR no greater than 800 g /m^2-day-atm (51.6 g /100 in^2-day-atm). However, the OTR of a film does not define the total O_2 Flux (cc O_2/day-atm) needed by a fresh produce package to maintain a desired O_2 and CO_2 internal atmosphere based on the respiration rate of the specific produce item, the weight of the produce enclosed in the package, the surface area of the package, and the storage temperature. A 50-micron perforation has a very small surface area (1.96×10^{-9} m^2) and a low O_2 Flux (about 80 cc/day-atm) compared to its very high OTR (>200,000 cc O_2/m^2-day-atm). Therefore, one 50-micron perforation would exceed the OTR limit of this invention. Furthermore, fresh produce items such as fresh spinach are very susceptible to moisture that accumulates inside packages so produce weights greater than 0.5 kg require 2–3 times more moisture vapor transmission than the upper limit described in this patent.

The above inventions do not address the issue of microperforation occlusion by produce inside the package when microperforations are placed throughout the length and width of the film. Since 20 to 100 micron holes cannot be readily seen with the naked eye, it is impossible to prevent occlusion of the microperforations either by the produce or by adhesive labels applied to the packages when microperforations are placed across and along the entire film. Finally, the size and location of the microperforations in the film also makes it impossible for the packaging user to quickly inspect the films for consistency of perforation size and number. These deficiencies have been roadblocks in the wide spread commercialization of films made according to this invention.

As indicated, the current practices of producing microperforated materials for modifying or controlling the atmosphere inside fresh produce packages are not satisfactory. There is a need for packaging in which the microperforations are registered in a small identifiable area that will not be blocked by adhesive labels or adjacent packages during package stacking or handling. The fresh produce should be placed in a product-specific package where the microperforation size, location, and number of microperforations are optimally selected to obtain the desired film gas transmission rates and gas flux for maintaining the quality of that specific produce item. In addition, a method is needed for accurately predicting the size and number of microperforations required by a particular weight of respiring produce at a specified temperature to maintain a pre-selected atmosphere inside the package during storage. And, there needs

to be a cost-effective method of manufacturing microperforated packaging materials according to the requirements of the present invention.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a registered microperforated polymeric packaging material with the microperforations situated in well-defined target areas of the packaging material.

Another object of the invention is to provide a means of calculating gas transmission requirements of respiring foods contained in registered microperforated polymeric packaging materials with microperforations having specific size, shape, location, and number in order to optimize the shelf life and quality of respiring foods.

A further object is to provide a packaging system, wherein registered microperforated polymeric packaging materials wherein specific size, type and location of the microperforations is matched to specific characteristics of respiring fresh produce to optimize storage life.

Another object of the invention is the method of manufacturing registered microperforated polymeric packaging materials, using a laser mounted above a stationary or moving polymer film web. The web-handling equipment can be a bagmaking machine, a slitter/rewinder, a printing press, a stand-alone web stopper, or a thermoforming unit. The system of the present invention employs a photoelectric sensor or other electrical means to signal the laser to ensure the microperforations are placed in a small identifiable area on the polymer web. There is a system controller, either a PLC (programmable logic controller), a PC (personal computer) or a combination of both, that takes the input from the sensor or other electrical signal and commands the laser to fire. The controller may also control the moving web.

This invention is directed to the specification, production, and use of product-specific, registered microperforated polymeric packaging materials selected from the group consisting of polyethylene, polypropylene, polyester, nylon, polystyrene, styrene butadiene copolymers, cellophane, and polyvinyl chloride, in monolayers, coextrusions, or laminates, for extending the quality and shelf life of respiring foods, particularly fresh fruits, fresh vegetables, fresh herbs, and fresh flowers, contained within the packaging.

Another object of the invention is a means of calculating the number of microperforations of a preferred size, for example, 120 to 160 microns, specified for the polymer packaging material to maintain pre-selected levels of O_2, CO_2, and H_2O inside packages containing respiring fresh produce. The calculations can establish the optimal number of microperforations required in the packaging material for each microperforation size and shape.

And yet a further object of the invention is to provide a packaging system for the industry, wherein there is a matching of the packaging material gas transmission rates and the respiration rates of the fresh produce to maintain preselected atmospheres inside the packages during storage. The packaging is optimized for a particular item, extending the freshness and quality of the produce.

The present invention is an improved packaging for establishing optimal atmospheric conditions for respiring fresh fruits, vegetables, herbs and flowers, comprising a polymeric material with a set of microperforations in the polymeric material to control the atmosphere within specified O_2 and CO_2 concentrations in the presence of the respiring fresh produce, wherein the set of microperforations are placed in a registered target area on the polymeric material. The improved packaging material can be used to form a bag or a lidding film or a semi-rigid container.

The present invention is susceptible to many variations, including where the polymeric material is a heat-sealable film. Or where the polymeric material is formed into a semi-rigid container with a thickness in the range of 0.025 cm to 0.076 cm. And, where the polymeric material is selected from the group consisting of polyethylene, polypropylene, polyester, nylon, polystyrene, styrene butadiene, cellophane, and polyvinyl chloride, their blends, coextrusions, and laminates.

The present invention also includes a means of calculating the total O_2 Flux (cc O_2/day-atm) required by a particular product based on produce weight, respiration rate, storage temperature, and desired gas composition inside the package. The total O_2 Flux of the package is satisfied by calculating the O_2 Flux provided by the breathable, non-perforated surface area of the packaging material and determining the size, shape, and number of microperforations required to meet the total O_2 Flux requirements of the package. In the preferred embodiment, the optimal size, shape and number of the set of microperforations for the particular product is used for the registered target area. In most cases, the target area is a small identifiable area in an upper third or quarter of the package. More preferably, the registered microperforations are placed in any area that will not be occluded by produce or other packages during shipping and storage.

Each of the microperforations has a preferred average diameter between 110 and 400 microns, and more preferably 120–160 microns. It is further desired that the polymeric material that is microperforated have a CO_2 transmission rate that is 2.4 to 5.0 times greater than the film OTR, preferably 3.4 to 4 times greater than the film OTR.

The aspects of the present invention include a system of packaging fresh produce comprising the steps of calculating the total O_2 Flux required for a given weight of respiring produce item, package surface area, storage temperature, and a pre-selected O_2 and CO_2 atmosphere. Next, determining an optimal packaging material with a desired CO_2,/ O_2 transmission rates wherein the packaging material contains registered microperforations designed for said O_2 Flux, placing the produce in the container derived from the packaging material, and hermetically sealing said container.

A further object of the invention is a microperforated packaging for a given quantity of respiring food produced by the process of calculating the number of microperforations for the given quantity of said respiring food, locating a target area for the microperforations, positioning laser over said target area, and drilling the microperforations in the target area.

Still another object is a microperforation system for making microperforations in a target area of packaging material, comprising a polymeric web, having a laser mounted over the web, a sensor means to identify the target area on the packaging material, and a means to control the laser to drill the microperforations in the target area. Laser drilling software is used to increase efficiency.

The microperforation system can be used on a stationary (stopped) web where the laser beam moves over the packaging material to drill the holes. The laser system is interconnected to a two-axis beam scanner, which directs the laser beam to drill holes in the desired location. Alternatively, the microperforation system can consist of a stationary laser beam and a moving polymer web. The laser

is a CO_2 laser in the preferred embodiment. In order to provide registration of perforations, a photoelectric sensor is used to find the eye mark on the polymeric film or an electrical signal from the web-handling equipment is used to signal the laser to fire at a preselected location on the film.

A basic intent of the present invention is to make a system for computing an optimal number and size of microperforations to control a package atmosphere within specified O_2 and CO_2 concentrations. This system also has a means of computing an optimal number of microperforations to control package moisture vapor transmission rates while maintaining pre-selected O_2 and CO_2 concentrations.

An object of the invention is an improved packaging for establishing optimum atmospheric conditions for respiring fresh fruits, vegetables, herbs and flowers, comprising a polymeric material, a set of microperforations on the polymeric material, wherein the set of microperforations are calculated to control the optimum atmospheric conditions within specified O_2 and CO_2 concentrations for the respiring fresh fruits, vegetables, herbs and flowers, and wherein the set of microperforations are placed in a registered target area on the polymeric material.

A further object is an improved packaging for establishing optimum atmospheric conditions for respiring fresh fruits, vegetables, herbs and flowers wherein the polymeric material is selected from the group consisting of polyethylene, polypropylene, polyester, nylon, polystyrene, styrene butadiene, cellophane, and polyvinyl chloride, in monolayers, coextrusions, and laminates. Furthermore, an improved packaging material wherein the polymeric material is heat-sealable.

Other objects include an improved packaging material wherein the polymeric material has a thickness in the range of 0.4 to 8 mil. An improved packaging material wherein the polymeric material provides a total O_2 Flux ranging from 150 cc/day-atm to 5,000,000 cc/day-atm. An improved packaging material wherein the polymeric material provides a total O_2 Flux ranging from 200 cc/day-atm to 1,500,000 cc/day-atm.

And yet another object of the invention is an improved packaging material wherein the polymeric material forms a bag. Also, an improved packaging material wherein the polymeric material is a heat sealable lidding film. An improved packaging material wherein the polymeric material is formed into a semi-rigid container with a thickness greater than 8 mil.

An object of the invention is an improved packaging material further comprising a means of calculating an optimal number of the set of microperforations in the registered target area. An improved packaging material further comprising a means of calculating an optimal size of the set of registered microperforations. Also including an improved packaging material wherein the registered target area is a small identifiable area in an upper quarter of the package. Further objects include an improved packaging material wherein the registered target area is a small identifiable area in an upper third of the package. An improved packaging material wherein the registered target area is located in an area that prevents occlusion of the microperforations by product or other packages. Additionally, an improved packaging material wherein each of the microperforations has an average diameter between 110 and 400 microns, preferably 120–160 microns. Finally, an improved packaging material wherein the polymeric material has a CO_2 transmission rate that is 2.5 to 5.0 times greater than the O_2 transmission rate, most preferably 3.4 to 4.0 times greater.

Yet a further object is a system of packaging fresh produce comprising the steps of calculating the total oxygen flux of the polymeric material required for a given weight of respiring produce item, package surface area, storage temperature, and a pre-selected O_2 and CO_2 atmosphere, determining an optimal packaging material, wherein the packaging material contains registered microperforations designed for the O_2 and CO_2 transmission, placing the produce in the container derived from the packaging material and closing the container.

An object of the invention is a process of producing a microperforated packaging system for a given quantity of respiring food comprising the steps of selecting a polymeric packaging material for optimal O_2 and CO_2 transmission rates, calculating a number of microperforations required in the packaging material for the given quantity of the respiring food, locating a target area for the microperforations, positioning a laser over the target area, and drilling the microperforations in the target area.

An object includes a microperforation system for making microperforations in a registered target area of packaging material, comprising, a polymeric web, a laser mounted over the web, a sensor means to identify the target area on the packaging material, a means to control the laser to drill the microperforations in the target area. Additionally, a microperforation system wherein the laser is a CO_2 laser. Also, a microperforation system wherein the sensor is selected from the group comprising a through-beam photoelectric sensor and a photoelectric proximity sensor.

And yet another object is a microperforation system wherein the laser is triggered to drill holes in the target area with the target area identified using an electrical signal from the web-handling equipment. And, a microperforation system wherein the web is moving and the laser is stationary. It being understood that the term laser refers to the laser beams eminating from the laser delivery head or similar delivery device, and the laser optical system controls the firing of the laser beams.

A final object of the invention is a microperforation system further comprising a means of computing an optimal number and size of microperforations to control a package atmosphere within specified O_2 and CO_2 concentrations. Also, a microperforation system further comprising a means of computing an optimal number of microperforations to control package moisture vapor transmission rates while maintaining pre-selected O_2 and CO_2 concentrations. A microperforation system wherein the web is stationary and the laser is moving. And also, a microperforation system wherein the laser comprises a two-axis beam scanner mounted over the web.

Still other objects and advantages of the present invention will become readily apparent to those skilled in this art from the following detailed description, wherein only a preferred embodiment of the invention is described, simply by way of illustration of the best mode contemplated for carrying out the invention. As will be realized, the invention is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

FIG. 1 depicts a microperforation system of a stationary film web wherein the moving laser beam drills the microperforations in the target area of what will be a finished bag.

FIG. **2** shows a bag produced by the stationary web microperforation process.

FIG. **3** depicts a microperforation system wherein the stationary laser beam drills the microperforations in the target area of the film as the web is moving.

FIG. **4** shows a bag produced by the moving web microperforation process.

FIG. **5** shows a Type I microperforation with an aspect ratio of 1 to 1.2, and shows Type II microperforations with an aspect ratio >1.2.

FIG. **6** depicts the oxygen and carbon dioxide contents inside 3-lb. packages of broccoli florets sealed in registered microperforated bags having 36, 150-micron perforations. Storage temperature was 4–5° C.

FIG. **7** depicts carbon dioxide content inside 3-lb. packages of broccoli florets sealed in registered microperforated bags having 36, 150-micron perforations with base packaging films having different carbon dioxide transmission rates. Storage temperature was 4–5° C.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description, the units applied to terms used in reference to the O_2, and CO_2 transmission rates of a packaging material, i. e., "OTR and CO_2TR", respectively, are expressed as cc/m^2 -day-atmosphere at 25° C., 75% RH. In the pressure units, one atmosphere (atm) is 101,325 kg/ms^2. The units describing the flow of a particular gas through a packaging material are "flux", expressed as cc/day-atm. The units applied to moisture vapor transmission ("MVTR") of a film are expressed as g H_2O/m^2-day-atm at 25° C., 75% RH.

As shown in FIG. **1**, a CO_2 laser drilling system can be used to drill microperforations in a stopped polymer web (hereafter called "stopped web method"). This is essentially a low speed (50–150 ft/min) method for microperforating packaging materials using lasers mounted over the web-handling equipment. A controller **20** operates with input from the through-beam photoelectric sensor **30** to position the polymer film sheeting or tubing **40** and locate the target area **50**. The polymer film **40** has an eye mark **60** which is detectable by the sensor **30**. Once the eye mark **60** is detected, the registration of the film **40** is determined and the controller **20** sends a signal to the laser/optics power supply **70** which directs the laser beam to the scan head **80** where the laser beam **90** is directed onto the film **40** creating microperforations **100** in a pre-selected array defined by a computer program. The registered microperforated film **40** is then **20** converted into bags using bagmaking machines known to the industry. As an example, a polymer bag **120** with side seals is shown in FIG. **2**, and the microperforations **100** are in a specific target area **50** of the bag **120**.

For example, a simple drilling system consists of a 10-watt sealed beam air-cooled CO_2 laser with a controller **20**, a power supply and focusing optics **70**, and a two-axis beam scanner **80** mounted horizontally above the packaging material **40** web on a bagmaking machine, a slitter/rewinder, a print station or a stand-alone web stopper. The horizontal position of the laser system mounted over the web can be adjusted by mechanical or electronic methods so that the laser beam **90** is positioned over the area of the web to be microperforated **50**. The laser system **70** is linked to a controller **20** which is also linked to a photosensor **30** or a mechanical timer on the web-handling equipment. In a preferred embodiment, all components are interfaced to a computer that uses laser drilling software to direct the laser to microperforate the packaging material in a pre-selected array.

Registered microperforations are produced by linking the laser drilling process to a signal from a photosensor **30** mounted on a bagmaking machine, a web stopper, a slitter/rewinder, or a printing press. When the photosensor **30** detects a printed eye mark **60** on the packaging material **40**, this signal is used to direct the controller **20** to fire the laser **70** to drill a specified number of perforations in the packaging material in a pre-determined array, e.g. in 1 cm^2 with 150-micron perforations at each comer of the square, at a specific location on the web. Microperforation arrays **100** are normally positioned near what will become the upper one-quarter or one-third of the bag, as shown in FIG. **2**, so when filled packages are placed in case cartons they are not occluded by adjacent packages in the carton. For heat-sealable lidding films used with rigid plastic trays, the perforations **100** are registered in areas of the lid that will not be occluded during stacking.

The photosensor detection process uses a printed eye mark on the packaging material. Photoelectric sensors detect an object when it interrupts the sensing path. For example, the edge of a film is printed with a colored eye mark (a small, solid rectangular bar, usually black in color) at defined locations along the web to designate where microperforations are to be drilled in the film. A photoelectric sensor is mounted on the web-handling equipment. When the sensor beam passes over the eye mark on the film, the eye mark interrupts the beam and therefore, it is sensed by the photoelectric sensor. This beam interruption is detected by the controller which then directs the laser to drill a specified number of perforations in the film directly acoss from the eye mark or at a defined distance from the eyemark in a location where the laser head is positioned above the plastic web. The location of the microperforations from the eye mark can be varied by moving the laser housing, either mechanically or electrically, over the target area of the plastic web.

For other photoelectric sensing modes, it is not necessary to have a printed eye mark to detect the object. In the photoelectric proximity mode, an object is sensed when the sensor's own transmitted energy is reflected back from the object's surface. If there is no object present, this reflection does not occur. Proximity sensors could be used to signal the laser to microperforate semi-rigid plastic trays for fresh produce packaging.

A wide range of polymer materials (monowebs, coextrusions, and laminates), can be microperforated with lasers, including polypropylene, polyethylene, polyester, polystyrene, styrene butadiene copolymers, nylon, cellophane, or polyvinyl chloride. The preferred drilling method uses CO_2 lasers mounted over stationary or moving polymer webs. Photoelectric sensor methods or other electrical signals can be used to register microperforations in polymer materials. The photoelectric sensor method is accurate and reliable and is the preferred method of this invention.

When the stopped web method is used on a bagmaking machine, the drilling can occur during the heat-sealing portion of the bagmaking cycle, because in this short time span (about 400 msec), the web is essentially stationary. In effect, the web is stopped, an electrical signal from the bagmaking machine timer directs the laser to commence the drilling. Alternatively, a stand alone web stopper can be used to stop the web (using a series of accumulator rolls) for the drilling operation.

From 1 to over 200 microperforations can be drilled into the packaging material during a single stop phase (stopped

web method) with the beam scanner perforating in a serpentine pattern to minimize total perforation time. The more holes that are drilled, the longer the drilling operation takes. For most applications 1–100 microperforations are needed with 1–7 msec drilling time for each microperforation. If drilling occurs through two thickness of material at the same time, as would be the case when microperforating plastic tubing, then the number of holes drilled per laser firing doubles.

For the stopped web method that uses a two-axis beam scanner, the microperforations can be drilled in a variety of different patterns or arrays, e.g., straight lines, rectangles, squares, and circles. The most time-efficient method is to place the microperforations in a straight line or square. If microperforations are placed in a square or a rectangular array, the most time-efficient drilling occurs when the laser follows a serpentine pattern. The size of the microperforations is determined by adjusting the laser power (30–100% of the maximum power) and drilling duration.

Higher power and longer duration give larger microperforations than lower power and shorter duration. Preferably, the laser should be set at 70% of maximum power and the duration should be varied to produce the desired perforation size. As the perforation size increases the OTR of the perforation also increases.

Registered microperforations **100** can be drilled in moving packaging material webs, as shown in FIG. **3**, using higher power CO_2 lasers. Hereafter this process will be referred to as "microperforating on the fly." A controller **20** for the moving web receives input from the photoelectric sensor **30**, and controls the power supply **200** to the laser optics. As the polymer film **40** moves through the web-handling equipment, the sensor **30** detects the eye mark **60**, and the signal is communicated to the controller **20**. The controller **20** operates the laser power supply and optics **200**, which, in turn, powers the laser and directs the laser beam to the stationary laser delivery head **210** to drill a specific number of microperforations **100** in the target area **50**. As an example, a polymer bag **120** with side seals is shown in FIG. **4**, and the microperforations **100** are in the specific target area **50** of the bag **120**.

The power requirements (25-watt to >700-watt) depend on the speed the web will be traveling, and the composition and the thickness of the materials to be drilled. Faster speeds and thicker packaging materials require higher power lasers than slower speeds and thinner packaging materials. For microperforating on the fly, a stationary laser beam delivery head mounted on a printing press, slitter/rewinder, or bag-making machine is used to produce a specified number of microperforations, usually one to 50, in a short line, generally 7 cm or less, running in the machine direction of the moving film web. When the photosensor **30** detects a printed eye mark on the packaging material, this signal is used to trigger the laser to drill a specified number of perforations **100** in a straight line on the material in the target area **50** of the impression. In this application, the laser power and the speed of the web determine the size and shape of the microperforations that are made. The faster the speed, the more elongated the microperforations become. If multiple segments of the same bag or package impression (boundaries of the package) must be microperforated to provide the necessary O_2 Flux, then multiple eye marks **60** are needed to signal the laser **200** to fire at each location in the bag or package impression.

If more than one lane of microperforations is needed for microperforating on the fly, as would be the case for microperforating two side-by-side printed impressions of a packaging material or two microperforation lanes in the same impression, multiple lasers can be mounted on the web handling equipment or a beam splitter can be used to split the beam from one laser to multiple delivery heads.

Various hole sizes and shapes are created when plastic materials are perforated with lasers. Whatever laser drilling method is used, either stopped web or microperforating on the fly, the packaging material composition, degree of orientation, and structure (monolayer, coextrusion, or laminate) affect the size, shape and O_2 Flux of the resulting microperforations. Computer software that directs the laser perforating process can affect the shape of the perforation, i.e., the time delay between each hole in the perforation. However, software factors can be easily changed to alter the perforation shape. In contrast, polymer materials have inherent physical/chemical characteristics that will impact the hole size and shape for any given power and pulse duration. For example, stationary monowebs of polyethylene films perforated with a beam from a 10-watt CO_2 laser (stopped web), produce perforations that are elongated, having -aspect ratios (ratio of the longest to the shortest diameter) greater than 1.2. In contrast, when heat-seal coated polyester films are perforated under identical conditions, the perforations are nearly spherical with aspect ratios of 1–1.2. When lasers drill moving polymer webs, faster speeds (>300 ft/min) may produce more elongated perforations, with aspect ratios of 1.8, depending on the polymer film composition and speed of the web. These differences in microperforation shape affect the O_2 Flux . Perforations with the same size long diameter but different size short diameters have different O_2 Flux. That is, microperforations with aspect ratios (ratio of the longest to the shortest diameter) of close to 1 have higher O_2 Flux than perforations with aspect ratios >1.

A wide range of microperforation sizes can be used to control the atmosphere inside fresh produce packaging. However, in the preferred embodiment, microperforations in the range of 110–400 microns (longest diameter), preferably, 120–160 microns, offer the most benefits in controlling desired O_2 and CO_2 levels inside the package. Based on our research with a wide range of polymer materials, microperforation shapes can be classified into two broad categories. Type I category consists of holes with an aspect ratio (the ratio of the longest diameter to the shortest diameter) of 1–1.2, as shown in FIG. **5**. This is typical for polyesters and polypropylene films with heat-seal coatings.

Type II category of microperforations, observed in polyethylene monowebs and polyethylene coextrusions, has an aspect ratio >1.2, illustrated in FIG. **5**. There is an elongation (slight to exaggerated) of the microperforation, often in the direction of the film orientation, forming an oval or elliptical shape.

An analytical method using an oxygen sensor was used to determine the O_2 Flux through microperforations of individual, 150-micron (longest diameter) perforations from the two categories of microperforations describe above. The average values for O_2 Flux for one, 150 micron perforation are as follows:

Type I microperforation (aspect ratio 1.0–1.2) is 250 cc/day-atm.

Type II microperforation (aspect ratio >1.2) is 200 cc/day-atm.

Experimental results showed that the range of O_2 Flux values for these microperforations varies by +/–6% of the stated value. The O_2 Flux of the microperforations is not dependent on the thickness of the film that is microperforated.

The range of O_2 Flux that can be created by registering microperforations, in polymer materials by the laser methods described above, is very broad. Although microperforated films, according to the present invention, can be made with an O_2 Flux ranging from 150 cc/day-atm to over 5,000,000 cc/day-atm, the preferred range is 200 to 1,500,000 cc/day-atm for controlling or modifying the atmosphere inside fresh produce packages varying in weights from 19 g to several thousand kg.

Knowing the O_2 Flux of individual microperforations makes it a relatively simple task to calculate the size and number of microperforations needed to establish a desired atmosphere inside a package containing fresh fruit, fresh vegetables, fresh herbs, fresh flowers or other biochemically active foods.

EXAMPLE 1

To determine the number and size of microperforations needed for each produce item in a particular package, the gas transmission requirements (O_2, CO_2, moisture vapor transmission rate—MVTR) for the total package is first determined. The contribution the microperforations must make to the total gas transmission properties of the package is affected by:

- produce respiration rate,
- weight of produce to be packaged,
- desired atmosphere in the package,
- breathable surface area of the package,
- gas transmission properties (O_2, CO_2, MVTR) of the packaging material to be microperforated, and
- expected storage temperatures during the life of the product.

Different fresh produce items, whether whole or fresh-cut, have different respiration rates. Cutting the produce item generally increases the respiration rate by 2-fold or more.

Equations (1), (2), and (3) below can be used to determine the total O_2 Flux ($Flux_{O2\text{-}Total}$) requirements of a fresh produce package, including the O_2 Flux of the breathable area of the packaging film ($Flux_{O2\text{-}film}$), and the O_2 Flux of the microperforations ($Flux_{O2\text{-}MP}$), required to maintain a desired atmosphere inside a package containing a specific fresh fruit, fresh vegetable, fresh herb or fresh flower.

$$OTR_T=[(M\times RR)/(A_s P(0.21-Int O_2))]\times 24 \text{ hrs/day} \quad (1)$$

where,

OTR_T = total OTR required for the package in cc O_2/m^2-day-atm

M = mass of produce (kg)

RR = respiration rate (cc O_2/kg/hr) @ the expected storage temperature

A_S = breathable surface area of the package (m^2)

P = atmospheric pressure (atm), assumed to be 1

$Int\ O_2$ = desired O_2 atmosphere inside the package stated as a volume fraction (*i.e.*, if the desired O_2 is 8%, the volume fraction is 0.08).

The value 0.21 represents the volume fraction of O_2 in ambient air.

For example: To establish an atmosphere at 5° C. of 8% O_2 and 10–15% CO_2 inside a 25.4 cm wide ×40.6 cm long ×50 micron thick polyethylene bag ($OTR_{base\text{-}film}$=3100 cc/m^2-day-atm) containing 1.36 kg of broccoli florets, with an O_2 respiration rate of 31 cc/kg/hr, the OTR_T required by the package would be:

$$OTR_T=[(1.36 \text{ kg}\times 31 \text{ cc/kg/hr})/(2(0.254 \text{ m}\times 0.356 \text{ m}))\times 1 \text{ atm}(0.21-0.08)]\times 24 \text{ hr/day}$$

$$=43{,}038 \text{ cc/m}^2\text{-day-atm}$$

Note that the breathable surface area is less than the total dimensions of the bag because the top seal and the film skirt beyond the seal are subtracted since they do not contribute to the OTR_T.

Once the OTR_T requirements for a particular item and package size are determined from equation (1), then the O_2 flow through the breathable surface area of the bag per day ($Flux_{O2\text{-}film}$ in cc/day-atm), is calculated using equation (2):

$$Flux_{O2\text{-}film}(\text{cc/day-atm})=OTR_{base\text{-}film}(\text{cc/m}^2\text{-day-atm})\times A_s(\text{m}^2) \quad (2)$$

For example: The dimensions of the breathable area of a plastic bag used to package 1.36 kg of fresh-cut broccoli are 25.4 cm ×35.6 cm (×2 for 2 sides), and the OTR of the base film is 3100 cc/m^2-day-atmosphere. The $Flux_{O2\text{-}film}$ (cc/day-atm) through the breathable area of the bag is:

$$Flux_{O2\text{-}film}\ (\text{cc/day-atm})=(3100 \text{ cc/m}^2\text{-day-atm})\times 0.181 \text{ m}^2$$

$$=561 \text{ cc/day-atm}$$

However, a total $Flux_{O2\text{-}Total}$ of 7790 cc/day-atm is needed for this package:

$$Flux_{O2\text{-}total}=OTR_T \text{ cc/m}^2\text{-day-atm}\times A_S(\text{m}^2)$$

$$Flux_{O2\text{-}total}=43{,}038 \text{ cc/m}^2\text{-day-atm}\times 0.181 \text{ m}^2=7790 \text{ cc/day-atm}$$

Therefore, the majority of $Flux_{O2\text{-}Total}$ must be supplied by the microperforations ($Flux_{O2\text{-}MP}$):

$$(3)\ Flux_{O2\text{-}MP}=Flux_{O2\text{-}Total}-Flux_{O2\text{-}film}$$

$$=7790 \text{ cc/day-atm}-561 \text{ cc/day-atm}=7229 \text{ cc/day-atm}$$

The number of 150 micron (longest diameter) perforations required in this 2 mil polyethylene package is equal to:

(7229 cc/day-atm)/(200 cc/day-atm per Type II microperforation)=36

For this film, if the longest diameter of the average microperforation is smaller or larger than 150 microns, the number of perforations can be adjusted to meet the required $Flux_{O2\text{-}Total}$ for the package. For example, if the microperforations made in the polyethylene film were 120 microns (Type II) in the longest diameter, then each 120 micron perforation would have a $Flux_{O2\text{-}120\mu}$ of 160 cc/day-atm:

$Flux_{O2\text{-}120\mu}$ perf=(120 micron×200 cc/day-atm)/(150 microns)=160 cc/day-atm

To maintain an 8% O_2 and 10–15% CO_2 atmosphere inside a 0.181 m^2 polyethylene bag containing 1.36 kg broccoli florets stored at 5° C., it would require 45, 120-micron perforations to give the same $Flux_{O2\text{-}MP}$ as 36, 150-micron perforations.

To test the accuracy of the method to predict the size and number of microperforations required to maintain a desired atmosphere inside a package containing a respiring produce

item, 50 micron polyethylene tubing was blown by standard extrusion methods and used to make 25.4 cm wide ×40.6 cm long bags which were microperforated in-line on a bagmaking machine using a 10-watt CO_2 laser and the stopped web method. Thirty-six, 150 micron perforations were registered in a 6.45 cm^2 (1 in^2) array located 7.6 cm from the open end of the bag and 5 cm from the side seal. An electrical signal from the bagmaking machine was used to trigger the laser to fire at the same time the heat sealing bar made the bag side seal.

Broccoli florets were prepared at 4° C. in a commercial processing plant and 1.36 kg was packaged into each bag (25.4 cm wide ×40.6 cm long, 50 micron thick). Filled bags were packed vertically into corrugated cartons with the registered microperforations at the top of the carton. Cartons were stored at 4–5° C. for 14 days. FIG. **6** represents the % headspace gas concentration over time, in microperforated bags (36 microperforations with an average size of 150 microns) containing 1.36 kg of broccoli florets. A steady state atmosphere of 8–10% O_2 and 8–12% CO_2 was reached after 60 hrs at 5° C. After 2 weeks at 5° C., floret color remained bright green, there was little or no evidence of browning at the cut ends, and no off-odors were observed on opening the bag.

EXAMPLE 2

Equations (1), (2), and (3) were used to determine the size and number of microperforations needed to maintain an atmosphere of 10–12% O_2 and 8–10% CO_2 inside a polyethylene pallet bag (125 cm wide×102 cm full gusset×203 cm long×100 micron thick) containing 217.9 kg of fresh sweet cherries at 1.1 C. The OTR_{base}=1085 cc/m^2-day-atm. Ninety-one cm of the bag length will be used to seal the bag by gathering the plastic at the top of the pallet, twisting it, doubling over the neck, and closed tightly with an electrical tie. Therefore, the breathable area of the bag will be 125 cm wide×102 cm gusset×112 cm long.

The equations for this package are:

$$(1)\ OTR_T\ (\text{cc/m}^2\text{-hr-atm}) = (217.9\ \text{kg} \times 5\ \text{cc/kg/hr}) / (2.54\ \text{m}^2 \times 1\ \text{atm}\ (0.21 - 0.11)$$

$$OTR_T\ (\text{cc/m}^2\text{-day-atm}) = 4289\ \text{cc/m}^2\text{-hr-atm} \times 24\ \text{hr/day} = 102{,}936\ \text{cc/m}^2\text{-day-atm}$$

$$(2)\ Flux_{O2\text{-}film}\ (\text{cc/day-atm}) = 1085\ \text{cc/m}^2\text{-day-atm} \times 2.54\ \text{m}^2 = 2756\ \text{cc/day-atm}$$

$$(3)\ Flux_{O2\text{-}MP} = (102{,}936\ \text{cc/m}^2\text{-day-atm} \times 2.54\ \text{m}^2) - 2756\ \text{cc/day-atm} = 258{,}701\ \text{cc/day-atm}$$

Microperforations were drilled into a 58 cm^2 area 86 cm up from the bottom seal and in the middle of the front panel of the bag (125 cm wide×102 cm gusset×203 cm long, 100 micron thick). Both sides of the bag were microperforated with a laser using the stopped web method. The total number of 300-micron microperforations drilled into each bag was 646 (323 in the front panel and 323 in the back panel):

(258,701 cc/day-atm)/(400 cc/day-atm for each 300 micron Type II microperforation)=647

Twenty four boxes of cold Bing cherries, each containing 9.1 kg of cherries, were stacked inside the microperforated pallet bag that was draped over a 102 cm×122 cm wooden pallet. The filled bag was pulled over the top of the cartons, it was hermetically sealed, and the pallet was stored at 1.1 C. After 8 weeks at 1.1 C, headspace gas analysis of the sealed pallet bag indicated that the cherries had established an atmosphere of 12% O_2 and 8% CO_2. Sensory evaluation of the cherries showed that flesh color was maintained, cherry stems were green and had not darkened during storage, there was no evidence of mold growth, and eating quality was good.

EXAMPLE 3

Equations (1), (2) and (3) were used to determine the size and number of microperforations needed to maintain an atmosphere of 10% O_2 and 10–15% CO_2 (at 5° C.) inside a 15-cm diameter semi-rigid bowl (0.056 cm thick polyester/PE laminate) containing 227 g fresh-cut cantaloupe and sealed with a flexible heat-sealable lidding film made from a laminate of oriented polypropylene and polyethylene (OTR_{base}=1550 cc/m^2-day-atm). The OTR of the bowl does not contribute significantly to the $Flux_{O2\text{-}Total}$.

The equations for this package are:

$$(1)\ OTR_T\ (\text{cc/m}^2\text{-hr-atm}) = (0.23\ \text{kg} \times 6\ \text{cc/kg/hr}) / (1.8 \times 10^{-2}\ \text{m}^2 \times 1\ \text{atm}\ (0.21 - 0.10))$$

$$OTR_T\ (\text{cc/m}^2\text{-day-atm}) = 697\ \text{cc/m}^2\text{-hr-atm} \times 24\ \text{hr/day} = 16{,}728\ \text{cc/m}^2\text{-day-atm}$$

$$(2)\ Flux_{O2\text{-}film}\ (\text{cc/day-atm}) = 1550\ \text{cc/m}^2\text{-day-atm} \times 1.8 \times 10^{-2}\ \text{m}^2 = 28\ \text{cc/day-atm}$$

$$(3)\ Flux_{O2\text{-}MP} = (16{,}728\ \text{cc/m}^2\text{-day-atm} \times 1.8 \times 10^{-2}\ \text{m}^2) - 28\ \text{cc/day-atm} = 273\ \text{cc/day-atm}$$

One, Type II 205-micron perforation (produced with a stationary laser beam and a moving polypropylene/polyethylene laminate film web) is needed to provide the necessary OTR for 227 g cantaloupe stored in a semi-rigid tray at 5° C.

Samples of polypropylene/polyethylene lidding film were microperforated using a stationary laser and a moving polymer film web (microperforating on the fly). One microperforation, with an average diameter of 200–210 micron, was drilled into each impression at the eye mark. The microperforated lidding film was used to seal fresh-cut cantaloupe inside the 15 cm diameter bowls. Bowls were stored at 5° C. for 10 days and evaluated for headspace gas contents and changes in quality.

Headspace analysis showed that, one, 200 to 210-micron perforation controlled the atmosphere inside 227 g packages of fresh-cut cantaloupe at desired O_2 and CO_2 levels and maintained satisfactory product quality for 10 days at 5° C. Having at least one microperforation in the package also prevented the package seals from rupturing due to changes in pressure when such packages were shipped over mountains in refrigerated trucks.

EXAMPLE 4

The moisture vapor transmission rate (MVTR) of a packaging material is also important in maintaining the quality of packaged produce. The relative humidity inside most produce packages is between 96 and 99%. High relative

humidity, in combination with excess free water in the package, can limit fresh produce shelf life by fostering microbial growth that leads to watery/slimy deterioration of plant tissues. Most non-perforated polyethylene or polypropylene films have a MVTR of less than 15 g/m^2-day. Microperforating the package can increase the MVTR range from 30 to >600 g/m^2-day. The increase in film MVTR caused by microperforations improves shelf life of water sensitive produce.

Packaged spinach deteriorates quickly if excess moisture accumulates in the package during storage. Therefore, the most important goal in spinach packaging is to use microperforations to increase the package MVTR without causing the leaves to dehydrate and lose their turgor. O_2 levels should be held just below ambient air (i.e., O_2=16–19%) and CO_2 levels slightly elevated above ambient air (CO_2=2–5%).

Equations (1), (2), and (3), were used to determine the size and number of microperforations needed to maintain an atmosphere of 17–19% O_2 and 2–3% CO_2 inside bags containing 284 g spinach and stored at 5° C. Bags size was 25.4 cm wide×40.6 cm long (breathable area=25.4 cm×35.6 cm×2 sides) and film composition was 76-micron polyethylene (OTR_{base}=3255 cc/m^2-day-atm):

$$(1)\ OTR_T\ (\text{cc/m}^2\text{-hr-atm}) = (0.284\ \text{kg} \times 46\ \text{cc/kg/hr}) / (0.181\ \text{m}^2 \times 1\ \text{atm}\ (0.21 - 0.17))$$

$$= 1804\ \text{cc/m}^2\text{-hr-atm}$$

$$OTR_T\ (\text{cc/m}^2\text{-day-atm}) = 1804\ \text{cc/m}^2\text{-hr-atm} \times 24\ \text{hr/day}$$

$$= 43{,}296\ \text{cc/m}^2\text{-day-atm}$$

$$(2)\ Flux_{O2\text{-}film}\ (\text{cc/day-atm}) = 3255\ \text{cc/m}^2\text{-day-atm} \times 0.181\ \text{m}^2 = 589\ \text{cc/day-atm}$$

$$(3)\ Flux_{O2\text{-}MP} = (43{,}296\ \text{cc/m}^2\text{-day-atm} \times 0.181\ \text{m}^2) - 589\ \text{cc/day-atm}$$

$$= 7248\ \text{cc/day-atm}$$

Lasers make Type II microperforations in polyethylene. Therefore, this 284 g bag requires 36, 150-micron perforations, i. e., (7248 cc/day-atm)/(200 cc/day-atm per 150-μ perforation).

Thirty-six laser microperforations, with an average diameter of 150 microns, were registered in a 6.45 cm^2 area, 7.6 cm from the bag open end and 7.6 cm from the side seal of the 25.4 cm wide ×40.6 cm long bags using the stopped web method. Bags were filled with freshly washed and spun-dried spinach in a commercial 4° C. processing room before heat-sealing and storing at 5° C. for 14 days. After 3 days, the headspace O_2 and CO_2 ranged from 17–20% and 3%, respectively, which was maintained throughout the 14-day storage study. Spinach leaves maintained their bright green color and turgor and did not show signs of dehydration or watery deterioration. Water loss from the package was about 2–3% after 14 days at 5° C.

EXAMPLE 5

The OTR and MVTR of packaging material are not the only important gas transmission rates in maintaining produce quality in MAP/CAP packages. CO_2TR determines the internal CO_2 atmosphere in the package and also affects package appearance. A low CO_2TR and a low CO_2/O_2 ratio film may cause package puffing (distention). If CO_2TR is too high, a collapsed package may result. The CO_2/O_2 ratio of microperforations is 1. However, the following example shows the importance of selecting base polymer films for microperforating that have sufficient CO_2TR to maintain an acceptable package appearance and internal CO_2 concentration.

Three polymer films with similar base film OTRs and different CO_2TRs were microperforated by the stopped web method, registering 36 microperforations in a 6.45 cc^2 area in the top quarter of the formed bag. Fresh-cut broccoli florets (1.36 kg) were sealed in the bags and stored at 5° C. As shown in FIG. 7, the O_2 atmosphere inside packages made from the different polymers equilibrated at 8–10% after 48 hrs and maintained that level throughout storage. However, the content of CO_2 inside the packages varied with the CO_2TR of the film. Packages with the lowest CO_2TR became distended during storage, and those with the highest CO_2TR collapsed, looking more like a vacuum package than a pillow pack. The base polymer film with a CO_2TR of 13,950 cc/m^2-day-atm and a CO_2TR/OTR of 3.6 to 4.0 was optimum for preventing discoloration of broccoli cut ends and off-odors and for maintaining an acceptable package appearance.

EXAMPLE 6

Polymeric packaging materials used to make semi-rigid containers, range in thickness from 0.025 cm to 0.076 cm. Delicate fruits like strawberries, raspberries, and blueberries are routinely packaged in containers having two semi-rigid parts: a rigid tray and a rigid lid. We tested the hypothesis that a semi-rigid container with registered microperforations in the semi-rigid lid could be used to control the atmosphere within a fresh produce package, thereby extending shelf life.

Polyvinyl chloride sheeting was thermoformed into a tray (0.143 m wide×0.197 m long×0.057 m deep, 0.056 cm thick) and rigid lid (0.143 m wide×0.197 m long×0.013 m deep) for packaging 0.454 kg sliced strawberries. This 0.056 cm thick package is essentially impermeable, having an OTR of <7 cc/m^2-day-atm. Therefore, all the O_2 Flux for maintaining a desired atmosphere of 8 to 10% O_2 and 10 to 15% CO_2 at 4° C. must come from the microperforations. The microperforations will be placed in a 1 cm^2 (0.0001 m^2) area on the lid, essentially the only breathable portion of the package. Equations (1) and (3) were used to determine the size and number of microperforations needed in the lid to maintain the desired atmosphere inside the package:

$$(1)\ OTR_T\ (\text{cc/m}^2\text{-hr-atm}) = (0.454\ \text{kg} \times 22\ \text{cc/kg/hr}) / (0.0001\ \text{m}^2 \times 1\ \text{atm}\ (0.21 - 0.10))$$

$$= 908{,}000\ \text{cc/m}^2\text{-hr-atm}$$

$$OTR_T\ (\text{cc/m}^2\text{-day-atm}) = 908{,}000\ \text{cc/m}^2\text{-hr-atm} \times 24\ \text{hr/day}$$

$$= 21{,}792{,}000\ \text{cc/m}^2\text{-day-atm}$$

$$(3)\ Flux_{O2\text{-}MP} = 21{,}792{,}000\ \text{cc/m}^2\text{-day-atm} \times 0.0001\ \text{m}^2 = 2179\ \text{cc/day-atm}$$

Laser drilling of polyvinyl chloride sheet produces Type I microperforations. Therefore, 9, 150-micron perforations, each with a $Flux_{O2}$ of 250 cc/ day-atm, are needed to maintain the desired atmosphere in the package at 4° C.:

2179 cc/day-atm /250 cc/day-atm for each Type I microperforation=9 microperforations

Rigid polyvinyl chloride lids were microperforated using a 10-watt laboratory laser with a scan head (stopped web method). Nine, 150-micron perforations were drilled into each lid. Freshly sliced strawberries (0.454 kg) were placed in containers, microperforated lids were applied, and a band of shrink tape was applied over the flange area to achieve a hermetic seal. Packages were stored at 4° C. for 14 days.

Within 48 hrs, the atmosphere inside the packages had equilibrated to the desired O_2 and CO_2 levels. The strawberries maintained their color and turgor, and there was no obvious mold growth on the fruit during a 14 day storage period at 4° C.

The present invention has been particularly shown and described with respect to certain preferred embodiments of features. However, it should be readily apparent to those of ordinary skill in the art that various changes and modifications in form and details may be made without departing from the spirit and scope of the invention as set forth in the following claims. The objects and advantages of the present invention may be further realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims. Accordingly, the drawing and description are to be regarded as illustrative in nature, and not as restrictive.

What is claimed is:

1. A microperforation system for making microperforations in a registered target area of packaging material, comprising:

a polymeric web;

a laser mounted over said web;

a sensor to identify said target area on said packaging material;

a laser controller to drill said microperforations in said target area; and

a processor coupled to said laser controller and said sensor, said processor performing calculations, wherein said calculations control a fresh produce package atmosphere within specified O_2 and CO_2 concentrations and wherein said calculations determine an optimal number and size of said microperforations of said target area.

2. The microperforation system according to claim **1**, wherein said laser is a CO_2 laser.

3. The microperforation system according to claim **1**, wherein said sensor is selected from the group comprising a through-beam photoelectric sensor, a photoelectric proximity sensor, and a timer.

4. The microperforation system according to claim **1**, wherein said laser is triggered to drill holes in said target area wherein said target area is identified by said sensor.

5. The microperforation system according to claim **1**, wherein said web is moving and said laser is stationary.

6. The microperforation system according to claim **1**, further comprising a means for computing an optimal number of said microperforations to control package moisture vapor transmission rates while maintaining said O_2 and CO_2 concentrations.

7. The microperforation system according to claim **1**, wherein said web is stationary and said laser is moving.

8. The microperforation system according to claims **7**, wherein said laser comprises a two-axis beam scanner mounted over said web.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,441,340 B1
DATED : August 27, 2002
INVENTOR(S) : Verriano-Marston, Elizabeth

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9,
Line 48, deleted "**20**"

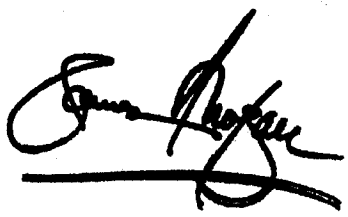
Column 10,
Line 9, delete "comer", insert -- corner --

Column 12,
Line 21, delete "-aspect", insert -- aspect --

Column 17,
Line 55, "3%", insert -- 1-3% --

Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office