requiring storage temperatures that are different from typical storage conditions are deficient in some cases as they do not allow the food system to be under storage temperatures that are relevant for retail storage. Furthermore, such higher storage temperatures may cause changes to the food (e.g., phase changes in the food system, changes to the conformations of molecules in this food) that limit the utility of such methods to provide accurate predictions in an accelerated time frame.

Given the above, a robust scientific method to rapidly quantify photoprotective performance of packaging concepts in a way that allows relative comparisons between the packaging concepts and is relevant to the conditions used for such packaging concepts in their targeted real-world applications is needed. These methods are needed to allow for the creation of performance design models for packaging concepts, and to allow for efficient design of photoprotective packages that achieve the required balance of performance attributes for a given package cost, weight, material usage, or other design requirements.

SUMMARY OF INVENTION

In one aspect, ~~the present invention relates to~~there is provided a method for producing packaging designs comprising: (a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations; (b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C; (c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2; (d)placing the sample into the cell, rendering a sample cell; (e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative property; (f) exposing the shielded

sample cell to one or more light beam intensities for one or more durations; (g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points; (h) using the data points to determine a photoprotective performance value of the first test material; (i) repeating steps (a)-(h) with one or more additional test materials under the same conditions to generate one or more additional photoprotective performance values; (j) utilizing the two or more photoprotective performance values, more preferably more than two, to generate a model for a class of materials that relates that known qualitative or quantitative property to the photoprotective performance; and either (k) using the model of step (j) to identify a photoprotective performance value of a packaging material; and optionally (l) using the packaging material in step (k) to design a package; or (k') using using the model of step (j), for materials of the same class; predicting the unknown qualitative or quantitative property of a material based upon a known photoprotective performance value or predicting an unknown photoprotective performance value based upon a known qualitative or quantitative property of the material.

~~In another repect the~~ The present ~~invention~~ disclosure relates to a method of predicting the photoprotective performance of a material, the method comprising: (a) providing a sample comprising one or more photosensitive entities; (b) providing a cell having controlled optical properties to contain the sample at a pre-determined temperature between about -20°C and about 100°C; (c) providing a light source that generates a light beam with a spectral signature between about 290 and about 1000 nm and an intensity between about 0.01 and about 5 W/cm^2 as measured at a defined monitoring position; (d) placing the photosensitive entity into the cell, rendering a sample cell; (e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test

material comprises a known quantitative or qualitative property; (f) exposing the shielded sample cell to one or more light beam intensities for one or more durations; (g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points either by studying the sample while it is contained within said cell or by removing a sample for measurement by external

methods; (h) using the data points to determine a photoprotective performance value of the first test material; (i) repeating steps (a)-(h) with one or more additional test materials to generate one or more additional photoprotective performance values; (j) utilizing the two or more photoprotective performance values to generate a model for a class of materials with the known qualitative or quantitative property that predicts the photoprotective performance of an untested material within the same class based upon the known quantitative or qualitative property of the untested material; (k) using the model of step (j), for materials of the same class, predicting the unknown qualitative or quantitative property of a material based upon a known photoprotective performance value or predicting an unknown photoprotective performance value based upon a known qualitative or quantitative property of the material; (l) optionally using one or more values from step (h) or one or more models of step (j) to create a library of data which includes the photoprotective performance values as well one or more values describing the qualitative or quantitative properties of the material; (m) optionally using the library from step (l) to identify, describe, and/or predict properties of materials.

In another aspect, there is provided a method for predicting the photoprotective performance of a package material for a liquid milk product, the method comprising: (a) providing a sample comprising an aqueous solution of riboflavin at about 30 ppm and test materials derived from a series of HDPE packages with differing loadings of titanium dioxide; (b) utilizing the method as disclosed herein to generate riboflavin degradation rate constant data for each test material; (c) exposing a liquid milk product in test packages constructed of the test materials described in (a) to retail storage conditions and measuring the riboflavin content of said product for each test package as a function of exposure time; (d) reducing the data from (c) to a riboflavin degradation rate constant for each test package; (e) relating the rate constant values from step (b) to the rate constant values from step (d) to develop a functional correlation; (f) testing a packaging test material comprised of HDPE and TiO_2 using steps (a) and (b) and

applying the obtained data to the model of step (e) to predict the photoprotective performance under retail storage conditions of a package comprised of the test material and containing the given liquid milk product.

~~In still another respect, t~~The present ~~invention~~ disclosure also relates to a method for predicting the photoprotective performance of a material, the method comprising:(a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations; (b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C; (c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2;(d) placing the sample into the cell, rendering a sample cell; (e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative

CLAIMS

What is claimed is:

1. A method for producing a packaging design comprising:

(a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations;

(b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C;

(c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2;

(d) placing the sample into the cell, rendering a sample cell;

(e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative property;

(f) exposing the shielded sample cell to one or more light beam intensities for one or more durations;

(g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points;

(h) using the data points to determine a photoprotective performance value of the first test material;

(i) repeating steps (a)-(h) with one or more additional test materials under the same conditions to generate one or more additional photoprotective performance values;

(j) utilizing the two or more photoprotective performance values, more preferably more than two, to generate a model for a class of

materials that relates that known qualitative or quantitative property to the photoprotective performance; and either

(k) using the model of step (j) to identify a photoprotective performance value of a packaging material; and optionally

(l) using the packaging material in step (k) to design a package; or

(k') using the model of step (j), for materials of the same class; predicting the unknown qualitative or quantitative property of a material based upon a known photoprotective performance value or predicting an unknown photoprotective performance value based upon a known qualitative or quantitative property of the material.

2. The method of claim 1 further comprising the step:

(l) optionally using one or more values from step (h) or one or more models of step (j) to create a library of data which includes the photoprotective performance values as well one or more values describing the qualitative or quantitative properties of the material.

3. The method of claim 1 further comprising the step:

(m) optionally using the library from step (l) to identify, describe, and/or predict properties of materials.

4. The method of claim 1, wherein the quantitative or qualitative property comprises one or more of the following : whiteness index ASTM E313; brightness index ASTM D985; CIE L*a*b* tri-stimulus data ASTM designation of E313 -10, D2244, E 1347, E1349, E1477, E2214, E284, E308, E805, E991, E1331, E275, D2616, D2745, D3134, D3964, D4877, D6290; DuPont Appearance Analyzer data; Diffuse Brightness of Paper and Paperboard (d/0) ASTM D2470; Standard test for haze for plastics ASTM D1003; Brightness, Directional (TAPPI) (T452); Brightness Directional; Brightness, Diffuse (T525); Brightness with Color (Diffuse(Micro TB1C) or Directional/ TAPPI(MicroS-5)); Printing & calculated TAPPI Opacity, Scattering & Absorption Coefficients, Sheet

Brightness (T519); Directional / TAPPI Opacity, Scattering Coefficient, Absorption Coefficient (T425); T/dyne Micro TB-1C: Diffuse brightness, opacity, color, color difference, ASTM Index, & tristimulus; T/dyne Micro S-5 BOC:Dir/TAPPI brightness, opacity, color, color difference, ASTM Index, & tristimulus; Color, Hunter or CIE L*A*B* (State Directional or Diffuse Values), opacifying agent composition(s), and/or opacifying agent(s) loading as a design parameter.

5. The method of claim 1, wherein the predictive models are used to facilitate the design of packages that provide targeted photoprotection appropriate for the package contents.

6. The method of claim 5, wherein the package contents include food, beverages, drugs, pharmaceuticals, and/or other photosensitive products.

7. The method of claim 1, wherein the predictive models are used to assess sustainability metrics for a package design.

8. The method of claim 1, wherein the method further comprises correlating the changes to the one or more photosensitive entities in step (g) with one or more sensory evaluation criteria values and utilizing said predicted photoprotective performance to further predict one or more sensory evaluation criteria values of an untested material.

9. The method of claim 1, wherein the sample is maintained under controlled atmosphere conditions.

10. The method of claim 1, wherein the measuring of step (g) comprises evaluating the changes to the one or more photosensitive entities while the sample is contained within the cell; or wherein the measuring of step (g) comprises removing a sample from the cell and

evaluating the changes to the one or more photosensitive entities externally.

11. The method of claim 1, wherein the one or more photosensitive entities are constituents of food, beverages, drugs, pharmaceuticals, or other photosensitive products.

12. The method of claim 1, wherein said sample comprises one or more photosensitive entities selected from one or more of the following classes:

i. natural and synthetic food additives, dyes, and pigments;
ii. chlorophyll;
iii. myoglobin, oxymyoglobin, and other hemeproteins;
iv. water and fat soluble essential nutrients, minerals, and vitamins;
v. food components containing fatty acids;
vi. oils;
vii. proteins;
viii. pharmaceutical compounds;
ix. personal care and cosmetic formulation compounds;
x. household chemicals and their components; and
xi. agricultural chemicals and their components.

13. The method of claim 12, wherein said sample comprises one or more photosensitive entities selected from two or more of the classes, three or more of the classes, four or more of the classes, five or more of the classes, six or more of the classes, seven or more of the classes, eight or more of the classes, nine or more of the classes, or ten or more of the classes.

14. The method of claim 1, wherein said measuring comprises a test method selected from the group consisting of HPLC, GC, IR spectroscopy, NMR spectroscopy, UV-VIS spectroscopy, GC-MS, LC-MS,

fluorescence spectroscopy, ion chromatography, thin layer chromatography, analytical wet chemistry, and electrochemical analysis.

15. A method for predicting the photoprotective performance of a package material for a liquid milk product, the method comprising:

(a) providing a sample comprising an aqueous solution of riboflavin at about 30 ppm and test materials derived from a series of HDPE packages with differing loadings of titanium dioxide;

(b) utilizing the method of Claim 2 to generate riboflavin degradation rate constant data for each test material;

(c) exposing a liquid milk product in test packages constructed of the test materials described in (a) to retail storage conditions and measuring the riboflavin content of said product for each test package as a function of exposure time;

(d) reducing the data from (c) to a riboflavin degradation rate constant for each test package;

(e) relating the rate constant values from step (b) to the rate constant values from step (d) to develop a functional correlation;

(f) testing a packaging test material comprised of HDPE and TiO2 using steps (a) and (b) and applying the obtained data to the model of step (e) to predict the photoprotective performance under retail storage conditions of a package comprised of the test material and containing the given liquid milk product.

CLAIMS

What is claimed is:

1. A method for producing a packaging design comprising:

(a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations;

(b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C;

(c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2;

(d) placing the sample into the cell, rendering a sample cell;

(e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative property;

(f) exposing the shielded sample cell to one or more light beam intensities for one or more durations;

(g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points;

(h) using the data points to determine a photoprotective performance value of the first test material;

(i) repeating steps (a)-(h) with one or more additional test materials under the same conditions to generate one or more additional photoprotective performance values;

(j) utilizing the two or more photoprotective performance values, more preferably more than two, to generate a model for a class of materials that relates that known qualitative or quantitative property to the photoprotective performance;

(k) using the model of step (j) to identify a photoprotective performance value of a packaging material; and

(l) using the packaging material in step (k) to design a package.

2. A method for predicting the photoprotective performance of a material, the method comprising:

(a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations;

(b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C;

(c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2;

(d) placing the sample into the cell, rendering a sample cell;

(e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative property;

(f) exposing the shielded sample cell to one or more light beam intensities for one or more durations;

(g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points;

(h) using the data points to determine a photoprotective performance value of the first test material;

(i) repeating steps (a)-(h) with one or more additional test materials under the same conditions to generate one or more additional photoprotective performance values;

(j) utilizing the two or more photoprotective performance values, more preferably more than two, to generate a model for a class of materials that relates that known qualitative or quantitative property to the photoprotective performance; and

(k) using the model of step (j), for materials of the same class, predicting the unknown qualitative or quantitative property of a material based upon a known photoprotective performance value or predicting an unknown photoprotective performance value based upon a known qualitative or quantitative property of the material.

3. The method of Claim 2 further comprising the step:

(l) optionally using one or more values from step (h) or one or more models of step (j) to create a library of data which includes the photoprotective performance values as well one or more values describing the qualitative or quantitative properties of the material;

4. The method of Claim 3 further comprising the step:

(m) optionally using the library from step (l) to identify, describe, and/or predict properties of materials.

5. The method of claim 2, wherein the quantitative or qualitative property comprises one or more of the following : whiteness index ASTM E313; brightness index ASTM D985; CIE L*a*b* tri-stimulus data ASTM designation of E313 -10, D2244, E 1347, E1349, E1477, E2214, E284,

E308, E805, E991, E1331, E275, D2616, D2745, D3134, D3964, D4877, D6290; DuPont Appearance Analyzer data; Diffuse Brightness of Paper and Paperboard (d/0) ASTM D2470; Standard test for haze for plastics ASTM D1003; Brightness, Directional (TAPPI) (T452); Brightness Directional; Brightness, Diffuse (T525); Brightness with Color (Diffuse(Micro TB1C) or Directional/ TAPPI(MicroS-5)); Printing & calculated TAPPI Opacity, Scattering & Absorption Coefficients, Sheet Brightness (T519); Directional / TAPPI Opacity, Scattering Coefficient, Absorption Coefficient (T425); T/dyne Micro TB-1C: Diffuse brightness, opacity, color, color difference, ASTM Index, & tristimulus; T/dyne Micro S-5 BOC:Dir/TAPPI brightness, opacity, color, color difference, ASTM Index, & tristimulus; Color, Hunter or CIE L*A*B* (State Directional or Diffuse Values), opacifying agent composition(s), and/or opacifying agent(s) loading as a design parameter.

6. The method of claim 2, wherein the predictive models are used to facilitate the design of packages that provide targeted photoprotection appropriate for the package contents.

7. The method of claim 6, wherein the package contents include food, beverages, drugs, pharmaceuticals, and/or other photosensitive products.

8. The method of claim 2, wherein the predictive models are used to assess sustainability metrics for a package design.

9. The method of claim 2, wherein the method further comprises correlating the changes to the one or more photosensitive entities in step (g) with one or more sensory evaluation criteria values and utilizing said predicted photoprotective performance to further predict one or more sensory evaluation criteria values of an untested material.

10. The method of claim 2, wherein the sample is maintained under controlled atmosphere conditions.

11. The method of claim 2, wherein the measuring of step (g) comprises evaluating the changes to the one or more photosensitive entities while the sample is contained within the cell.

12. The method of claim 2, wherein the measuring of step (g) comprises removing a sample from the cell and evaluating the changes to the one or more photosensitive entities externally.

13. The method of claim 2, wherein the one or more photosensitive entities are constituents of food, beverages, drugs, pharmaceuticals, or other photosensitive products.

14. The method of claim 2, wherein said sample comprises one or more photosensitive entities selected from one or more of the following classes:

i. natural and synthetic food additives, dyes, and pigments;
ii. chlorophyll;
iii. myoglobin, oxymyoglobin, and other hemeproteins;
iv. water and fat soluble essential nutrients, minerals, and vitamins;
v. food components containing fatty acids;
vi. oils;
vii. proteins;
viii. pharmaceutical compounds;
ix. personal care and cosmetic formulation compounds;
x. household chemicals and their components; and
xi. agricultural chemicals and their components.

15. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from two or more of the classes.

16. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from three or more of the classes.

17. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from four or more of the classes.

18. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from five or more of the classes.

19. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from six or more of the classes.

20. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from seven or more of the classes.

21. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from eight or more of the classes.

22. The method of claim 14 wherein said sample comprises one or more photosensitive entities selected from nine or more of the classes.

23. The method of claim 14, wherein said sample comprises one or more photosensitive entities selected from ten or more of the classes.

24. The method of claim 2, wherein said measuring comprises a test method selected from the group consisting of HPLC, GC, IR spectroscopy, NMR spectroscopy, UV-VIS spectroscopy, GC-MS, LC-MS, fluorescence spectroscopy, ion chromatography, thin layer chromatography, analytical wet chemistry, and electrochemical analysis.

25. A method for predicting the photoprotective performance of a package material for a liquid milk product, the method comprising:

(a) providing a sample comprising an aqueous solution of riboflavin at about 30 ppm and test materials derived from a series of HDPE packages with differing loadings of titanium dioxide;

(b) utilizing the method of Claim 2 to generate riboflavin degradation rate constant data for each test material;

(c) exposing a liquid milk product in test packages constructed of the test materials described in (a) to retail storage conditions and measuring the riboflavin content of said product for each test package as a function of exposure time;

(d) reducing the data from (c) to a riboflavin degradation rate constant for each test package;

(e) relating the rate constant values from step (b) to the rate constant values from step (d) to develop a functional correlation;

(f) testing a packaging test material comprised of HDPE and TiO2 using steps (a) and (b) and applying the obtained data to the model of step (e) to predict the photoprotective performance under retail storage conditions of a package comprised of the test material and containing the given liquid milk product.

26. The method of claim 25 where the time required to obtain predictive photoprotective performance data of a package under retail storage conditions is accelerated by at least 100 times.

27. A method for predicting the photoprotective performance of a material, the method comprising:

(a) providing a known homogeneous liquid sample comprising one or more known photosensitive entities at appropriate concentrations;

(b) providing a cell having controlled optical properties to contain the sample at a controlled temperature between about -20°C and about 100°C;

(c) providing a light source that generates a light beam with a controlled spectral signature between about 290 and about 1000 nm and a controlled intensity between about 0.01 and about 5 W/cm^2;

(d) placing the sample into the cell, rendering a sample cell;

(e) placing a first test material between the light source and the sample cell, rendering a shielded sample cell, wherein the light beam impinges upon the first test material and any penetrating light impinges upon the sample cell, and wherein the first test material comprises a known quantitative or qualitative property;

(f) exposing the shielded sample cell to one or more light beam intensities for one or more durations;

(g) measuring the changes to the one or more photosensitive entities contained within the shielded sample cell at one or more durations to generate data points;

(h) using the data points to determine a photoprotective performance value of the first test material;

(i) repeating steps (a)-(h) with one or more additional test materials under the same conditions to generate one or more additional photoprotective performance values;

(j) utilizing the two or more photoprotective performance values, more preferably more than two, to generate a model for a class of materials that relates that known qualitative or quantitative property to the photoprotective performance; and

(k) using the model of step (j), to identify a photoprotective p erformance value of a packaging material.