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VALIDATION OF A NUMERICAL MODEL FOR PREDICTION OF MOISTURE CONTENT FOR BINARY MIXTURES OF CORN, OATS AND WHEAT CEREALS IN SEMIPERMEABLE PACKAGING

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By

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ABSTRACT

VALIDATION OF A NUMERICAL MODEL FOR PREDICTION OF MOISTURE CONTENT FOR BINARY MIXTURES OF CORN, OATS AND WHEAT CEREALS IN SEMIPERMEABLE PACKAGING

By

Carlos G. Castro

The application of mathematical modeling, which correlates the products' moisture sorption characteristics, the packaging properties, and the storage conditions, to two-component products was used to develop a computer program. The experimental validation of the model was carried out with corn-wheat, corn-oats and oats-wheat mixtures and with individually packaged products. The mixtures were prepared at 1/2, 1/1 and 2/1 ratios and packaged in LDPE and HDPE pouches.

The model estimates the components' moisture contents with reasonable accuracy for systems where the components have similar water activities. The mixtures of components with very different water activity (corn-oats and oats-wheat) presented an initial moisture exchange. During this early stage of the storage, the moisture exchange was more important than the permeability. The determination of the components' moisture content after this moisture exchange was critical to the successfully application of the computer model. The correlation coefficient (>90%), obtained from a regression analysis, shows that model can be used to determine moisture gain of binary mixtures.

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INTRODUCTION

Packaging of multi-component products where components have different water activities has challenged food scientists and packaging engineers for years. The difference in water activities is responsible for the moisture exchange among the components and also controls the moisture transfer across the package.

Mathematical models that relate these mass transfer mechanisms have been created to facilitate package-product development and to replace tedious actual testing. These shelf life models are desirable to reduce cost, diminish labor, increase versatility and shorten the time of the product development process.

This thesis worked with a general shelf life model developed by Pocas (1995) who also prepared a DOS computer program with the proposed model. A new windows program based on the model develop by Pocas (1995) was produced to predict the time and moisture content of two-component products. The program was designed for single and two-component products and included linear and non-linear (GAB and Cubic) isotherms for its calculations. This new software was validated with binary mixtures of corn, oats and wheat breakfast cereals at different load ratios.

The corn, oats and wheat cereals were selected for this study because cereals are an excellent example of consumers' demand for variety, superior quality and great taste.

The objectives of this study were:

A) To obtain moisture sorption isotherms for corn, wheat and oat cereals at 23°C.

B) To apply shelf life models; based on the linear, GAB, and cubic polynomial moisture sorption isotherm equations; to flexible packaging containing two cereals.

C) To validate the shelf life model at 23°C.

D) To prepare a windows-based program that performs the models' calculations for shelf life and moisture content.

Chapter 1

LITERATURE REVIEW

1.1. Definition of Water Activity

Water activity is defined as the ratio of the vapor pressures of solution and solvent. In food science terms, water activity describes the availability of the water in the food to participate in reactions. Water activity is used for characterization of the state of water in foods and its availability for biological, physical and chemical changes. It is a critical factor in physical, chemical and biochemical phenomena taking place in the product. Therefore, water activity is connected to the quality or shelf life of most foods. Water plays an important part in the textural properties of several food products and also influences the activity of microorganisms during the storage of food products under various conditions. Water activity affects the rate of microbial growth, enzymatic reaction, non-enzymatic browning, lipid oxidation, textural changes, aroma retention, and it induces structural changes. (Troller and Christian, 1978; Iglesias and Chirife, 1982)

Three different binding mechanisms for water are found in food. Water is bound to polar sites with ionic bonds at low water activities (Le Maguer, 1986). This water is tightly bound and is unavailable to solvate reactants. The upper limit of this first binding mechanism is referred as the monolayer moisture (Le Maguer, 1986). The second mechanism observed is the adsorption at the multilayer. Hydrogen bonding governs the water adsorption in the multilayer zone. The last mechanism present is the condensed water in capillaries. The multilayer and the capillary mechanisms are observed at higher activities where the mobility of water increases (Le Maguer, 1986; Labuza, 1975 cited by Nelson and Labuza, 1994; Hernandez, 1999; and Pocas, 1995).

When water availability increases, the reaction rates also increase because water acts as a reaction medium in which sufficient reactant mobility occurs to allow reactant interactions. Some reaction rates decrease as water activity increases because some reaction species are diluted in the aqueous phase. A main exception to this minimum-maximum relationship involves the oxidation of unsaturated lipids where the reaction rate increases below the monolayer due to the increased catalytic activity of metal ions when sufficient water is removed from the hydration sphere around these ions. (Nelson and Labuza, 1994).

Labuza (1971; cited by Nelson and Labuza, 1994) summarized in a plot the reaction rate of various reactions and the moisture content as a function of water activity. The plot is presented on the next page in Figure 1.

Nelson and Labuza (1994) made a comparison between the role of water activity and the glass transition theory on physical, chemical and biochemical reactions. The researchers stated that water activity essentially considers the state of water in a food while glass transition theory generally considers the state of a food matrix. This glass transition theory suggests that chemical reactions are slower or do not occur at the glassy state, but will increase substantially at the rubbery state. Finally the researchers stated that both approaches help to understand the influence of water on rates of chemical reactions.

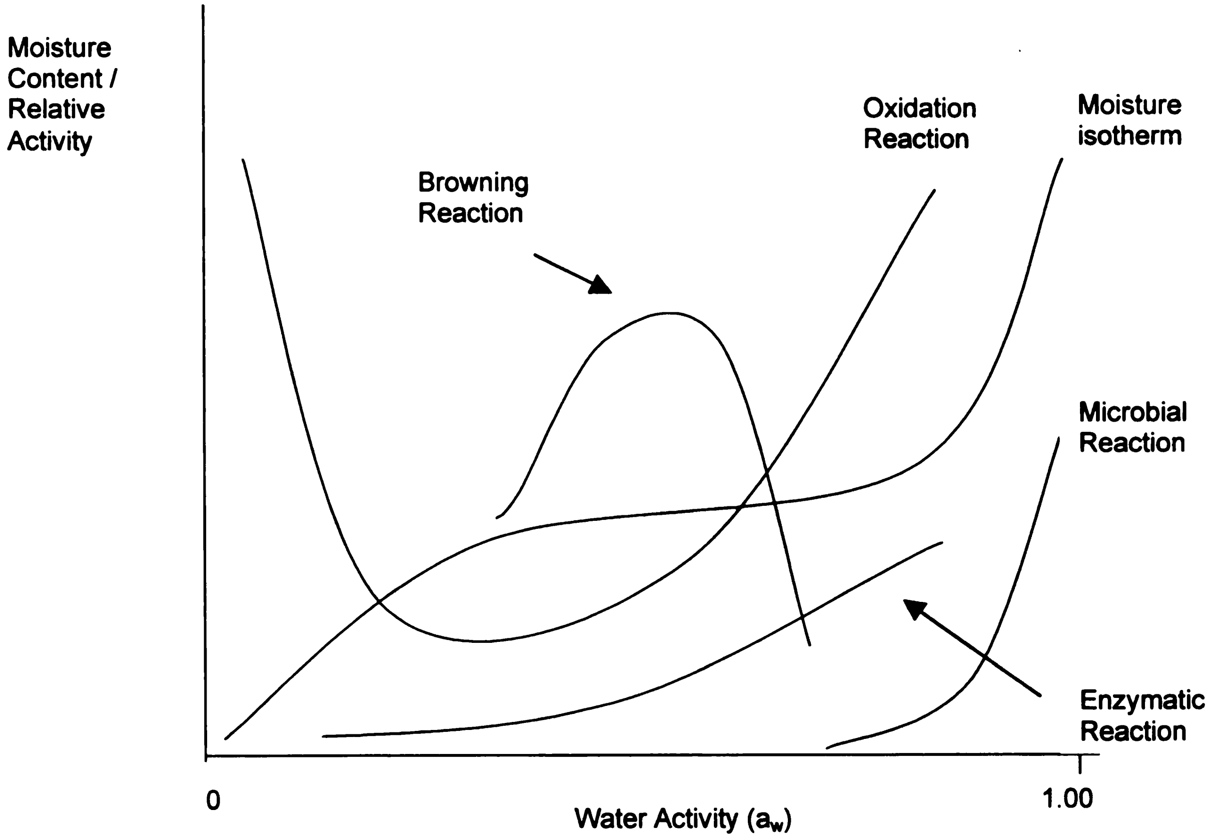

Figure 1 – Water Activity – Stability Diagram

Source: Le Maguer (1986)

1.2. Sorption Isotherms

The water sorption isotherms of foods show the equilibrium relationship between the moisture content of foods and the water activity (a_w) at constant temperatures and pressures (Troller and Christian, 1978; Iglesias and Chirife, 1982). Water sorption isotherms are usually described as a plot of the amount of water sorbed as a function of the water activity. The plot has generally, but not in all cases, a sigmoid shape (Iglesias and Chirife, 1982).

An important phenomenon present in most food's sorption isotherms is hysteresis. Kapsalis (1987) defined hysteresis as the phenomenon where two different paths exist between the adsorption and desorption isotherms. Due to hysteresis, a much lower vapor pressure is required to reach a certain amount of water by desorption than by adsorption. Hysteresis phenomenon is critical in food stability because some foods are fitted to a chosen a_w by desorption while others are fitted to the desired a_w by adsorption. (Labuza, 1984; Troller and Christian, 1978; Kapsalis, 1987). A representation of the hysteresis phenomenon is shown by Figure 2.

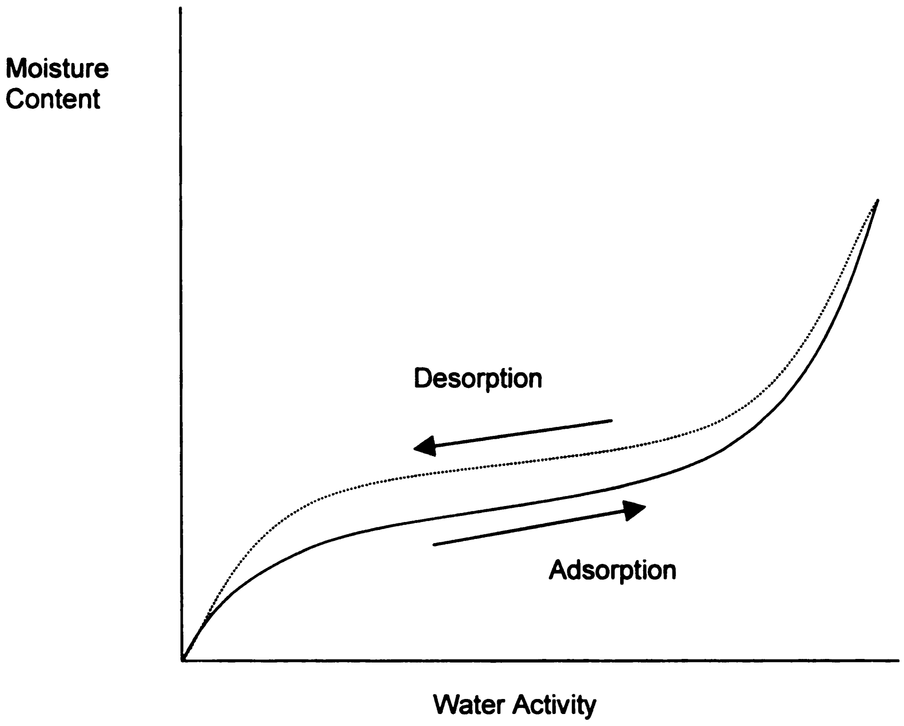

Figure 2 – Schematic Representation of a Moisture Sorption Hysteresis

Source: Kapsalis, 1987

1.3. Use of Moisture Sorption Isotherms

The sorption data has numerous theoretical and practical applications in food science and technology. Among the theoretical uses of sorption isotherms are thermodynamics (sorption-desorption enthalpies and bound water), structure investigations (specific surface area, pore volume/size distribution and crystallinity). The practical applications of sorption data in food processing are in drying, mixing, packaging, and storage (Gal, 1983).

In 1982, Iglesias and Chirife presented a handbook of food isotherms that compiled more than a thousand water vapor sorption isotherms of foods and their components. The researchers also included a brief description of the techniques for the use and calculation of isotherms. Among the uses mentioned are prediction of microbial and physicochemical stability of foods, engineering purposes related to concentration and dehydration, predicting sorption values, determination of net heat of sorption and analyzing the behavior of food mixtures.

1.4. Equations for Sorption Isotherms

Attempts to classify the several available sorption models have been made by various researchers (Van Den Berg and Bruin, 1981; Iglesias and Chirife, 1978, Boquet et al, 1978 and Boquet et al 1979). Van Den Berg and Bruin (1981) compiled and classified sorption models in four groups according to their origins. The researchers presented the following categories:

(1) Monolayer sorption models

(2) Multilayer sorption and condensed film models

(3) Sorption models from polymer science

(4) Empirical sorption models

Chirife and Iglesias (1978) compiled and reviewed twenty three equations for fitting water sorption isotherms of food and food products. They used the origin, range of applicability and use of the sorption isotherms as the criteria for their analysis. The researchers not only found that some theoretical, semi-empirical and empirical models are not equivalent, but that they also were limited to specific ranges of water activity or types of food.

Boquet et al (1978) and Boquet et al (1979) continued the work started by Chirife and Iglesias (1978) selecting for their study eight two-parameter and four three-parameter models to describe the sorption isotherms of various foods. They grouped the food products as fruits, meats, milk products, proteins, starchy foods and vegetables. The researchers concluded, based on its versatility and excellent ability to fit the experimental data for most types of foods, that the Hailwood and Horrobin equation should be considered as the "universal" isotherm. This three-parameter equation is mathematically equivalent to the Guggenheim-Anderson-de Boer (GAB) equation and it works well on a wide range of water activity (0.10-0.80). They also mentioned that some two-parameter equations have equal or better fitting abilities than the three-parameter ones and the use of a third parameter might not be useful. The recommended two-parameter equations were the Halsey and the Oswin models.

The use of the GAB equation to construct sorption isotherms has been also supported by Bizot (1991). The researcher prepared a computer program capable of fitting and plotting the isotherms from the experimental data and used the transformed GAB equation to prepare it. The researcher also emphasized that the GAB equation is the best alternative to determine primary adsorption sites and to fit an equation to experimental data. Spiess (Bizot, 1991) presented a discussion about Bizot's article and pointed out that D'arcy-

Watt developed a five-parameter equation with application over the entire water activity range (from zero to one), but for the application range, 0.2-0.8, the model will be very difficult to use and will not have any advantage over other models.

Peleg (1993) took a different approach from the previous workers by proposing an empirical double power law four-parameter equation. An equal or slightly better fit than the GAB model was obtained with the model proposed when the model was validated with the following products: agar-agar, carrageenan, gelatin, low methoxyl pectin, raisins, casein, potato starch, dextrin, and coffee. Peleg used the Mean Square Error magnitudes of the GAB and his empirical model to make his comparison. It is important to remark that like the GAB model, Peleg's model is only applicable up to an a_w level about 0.90 and beyond this range ($a_w > 0.95$) it can only be applied if a_w is replaced by a transform such as $-\ln(1-a_w)$.

The relative percent root mean square (%RMS) is widely used and accepted to evaluate the fitting goodness of the experimental data. Bizot (1991) proposed the use of this relative per cent root mean square (%RMS) to judge the quality of the fit of the experimental data. The %RMS is expressed as:

$$\%RMS = \sqrt{\frac{\sum_{i}^{N}\left[\frac{W_i - W_i^*}{W_i}\right]^2}{N}} \times 100 \qquad (1)$$

Where N is the number of experimental points, W_i is the experimental water content, and W_i^* is the calculated water content.

1.5. Equations for Multicomponent Isotherms

When two or more products are packaged together in a permeable package, a moisture transfer from the component with a lower water activity to the component with a higher water activity is observed. A moisture flow between the package and the environment is also observed. The moisture exchange among the products continues until an equilibrium water activity is reached. This exchange causes the product with the lower water activity to gain moisture while the component with the higher activity loses moisture. (Salwin and Slawson, 1959; Gal, 1983; Labuza, 1984; Hong et al, 1986; and Kim et al, 1999). Therefore, it is critical to predict the equilibrium water activity in multicomponent products.

A weighted-average hypothesis has been widely used by various researchers to predict the water sorption behavior of a mixture from the knowledge of its individual components.

$$M_{cal} = \frac{\Sigma W_i * M_i}{\Sigma W_i} \qquad (2)$$

Where M_{cal} is the moisture content if the mix, M_i is the moisture content of the product i before mixing and W_i is the dry weight of component i.

This equation based in a mass balance assumes that water is independently bounded to each product. In other words, at a given water activity the moisture content of a mixture is equal to a weighted average of the moisture content of each component at that water activity.

Attempts to predict water sorption behavior of a mixture from its individual components has been researched by various investigators: Salwin and Slawson (1959), Chuang and Toledo (1976), Iglesias et al. (1980), Lang and Steingberg (1980), Lang and Steinberg (1981), Lang et al.(1981), Hardy and Steinberg (1984), Chinachoti and Steinberg (1985), Chinachoti and Steinberg (1988), Nieto and Toledo (1989), Chinachoti, P. (1990), Leiras and Iglesias (1991), and Bakhit, R.M. and Schmidt, S.J. (1992).

The shelf life studies mentioned above considered that no moisture transfer occurred between the products and the environment and they used linear sorption isotherm equations or equations with limited water activity range of applicability (Iglesias, et al, 1979).

Lang and Steinberg (1981) studied hand-mixed mixtures of starch, casein, sucrose, salt propylene glycol, and ground beef in binary and ternary combinations. They concluded that each component sorbs water independently of the others. In other words, the predicted and measured values of moisture content have shown good agreement because there are no interactions present. The referred interactions are the ones that occurred at the molecular level (e.g. modifications of molecular bonds).

For multicomponent products obtained by physical mixing, it may be assumed that mixtures sorb an amount of water equal to the weighed average of the amount that components would sorb alone. This assumption implies that water is independently bound to each product (weighed average basis) as described by equation (2).

It has been proven that interactions among the mixture components affect the moisture sorption of mixtures, creating an increase or decrease of moisture content as compared to moisture content predicted by the weighed average basis equation (Iglesias et al, 1980; Hardy and Steinberg, 1984; Chinachoti and Steinberg, 1985; Chinachoti and Steinberg, 1988; Leiras and Iglesias, 1991; Bakhit and Schmidt, 1992). The interactions observed are caused by different mixing methods rather than simple physical mixing. Examples of these mixing procedures are wet mixing followed by freeze-drying and the order of the drying, before or after mixing.

Iglesias et al (1980) worked with mixtures of non water soluble biopolymers (proteins and carbohydrates) and found that the predicted values of the moisture content of the mixtures were higher than the measured ones for most of the samples that were run. The investigators proposed that the polymer-polymer H-bonds that compete with polymer-water H-bonds are responsible for decreasing the water sorption. Chinachoti and Steinberg (1985) found the same type of interaction in mixtures of sodium chloride and starch above water activities of 0.75.

Chinachoti and Steinberg (1988) worked with sucrose-protein mixtures and found that the mixtures sorbed more water than calculated due to the water binding with the proteins. Leiras and Iglesias (1991) found that at high water activities (a_w>0.75) the experimental moisture contents were greater than predicted and granted this difference to the solubilization of the salt and sugar in cake mixtures.

Salwin and Slawson (1959) developed a model to predict moisture transfer in combinations of dehydrated foods, from the knowledge of the sorption isotherm of the individual components, dry weight of the components and the relative humidity of each component. They assumed linear isotherms between the initial and the equilibrium relative humidity. They worked over a narrow range of relative humidity and found good agreement. Lang and Steinberg (1981) reviewed and criticized Salwin and Slawson work and stated that their linear approach over a narrow a_w range ($a_w \leq 0.11$) is not convenient. They also emphasized that at higher relative humidities, the normal s-shaped isotherms show more curvature and the assumption of a linear isotherm is no longer valid. Iglesias et al (1979) pointed out another major limitation in the work done by Salwin and Slawson (1959). It does not allow the prediction of equilibrium a_w when there is simultaneous moisture exchange with the environment.

Iglesias et al. (1979) used the concept of additivity of isotherms. The additivity of isotherms proposes that the amount of water sorbed at any given water activity is derived by the weight percentage of each component times the amount it would sorb alone. The researchers substituted the linear equation for the BET equation and the range of work was 0.05-0.40 for the dehydrated products tested. A very good agreement was obtained between samples of the additive isotherm and the computer calculated values.

1.6. Shelf Life Definition

Marsh (Brody and Marsh, 1997) defined shelf life as the time after the production and packaging of the product for which it remains acceptable under defined environmental conditions. He emphasized that shelf life is a function of the product, the package, and the environment through which the product is transported, stored, and sold.

Product, package and environment are critical factors that affect shelf life. While companies desire a shelf life that matches the distribution and use of the company's inventory, the consumers expect a shelf life that allows them to fully use the product.

An overestimated shelf life requirement will increase costs due to overpackaging. An underestimated shelf life requirement will increase costs in wasted or discarded products, increased liability, or consumer dissatisfaction. Therefore it is critical to define a reasonable shelf life which could be met with a proper packaging design (Pocas, 1995; Marsh, 1997)

1.7. Shelf Life Models

1.7.1. Generalities

A moisture transfer between the food product and the external environment is observed in moisture-permeable packages and its rate is controlled by the water vapor pressure difference between the package headspace and the environment. When the product exhibits moisture diffusion much faster than the diffusion across the packaging barrier, the food product equilibrates with the headspace vapor pressure and the product's moisture content may be described by its isotherm. (Pocas, 1995)

An adequate shelf life can be achieved by controlling the moisture exchange between the product and the storage environment with the proper packaging material. Therefore, the shelf life determinations help to develop and to optimize the packaging-product system. (Pocas, 1995)

The mathematical models connect the product's characteristics, the package properties and the environmental conditions. When a model is validated and proven to be reliable, its use is preferred over other shelf life estimation methods. Mathematical modeling is the most preferred shelf life estimation due to its short time, low cost and as a package design tool. (Pocas, 1995; and Marsh, 1997).

1.7.2. Single Products

Shelf life modeling of single products was first studied by Heiss (1958). This researcher established a relationship between moisture sorption properties of foods, the permeability of the film and the shelf life of the product. Heiss (1958) used Fick's law of diffusion to develop his solution.

Heiss (1958) introduced basic concepts that served to calculate the shelf life for moisture sensitive products. Further studies increased the complexity and applicability of the models, but these studies were still focused on packages of single products. For example, Labuza et al (1972) introduced Oswin, Kuhn and Mizrahi, non-linear isotherms, into the model. Lee (1987) and Lee et al (1996) developed a mathematical model for predicting the changes in the moisture content of a packaged solid dosage form that takes into consideration the effect of fluctuating temperature and relative humidity during prolonged storage. The model combines the sorption characteristics of the product and the water vapor permeability of the package system as a function of temperature.

Cardoso and Labuza (1983) worked with a single product, but they developed a dynamic model to predict moisture transfer in packaged pasta. They created a controlled unsteady state conditions (varying as sine wave) of temperature and relative humidity.

1.7.3. Multicomponent Products

For food mixtures, the moisture transfer from the component with the higher to the lower water activity occurs until equilibrium of water activity is reached. This equilibrium of water activity is responsible for the final moisture content of each component that directly influence the quality and shelf life of the mixture (Hong et al, 1986; Gal, 1983; Labuza, 1984 and Pocas, 1995). In consequence, predicting the equilibrium water activity of a mixture is critical to formulate a mixed product.

When the diffusion coefficient of the water in the packaging material is much smaller than the diffusion of water within the product the transport through the film barrier controls the shelf life of the mixture (Pocas, 1995).

It is assumed that the water transferred through the package at any water activity is distributed proportionally to each component as predicted by their respective sorption isotherms. This weighted isotherm has been combined with the shelf life models for single products (Iglesias, 1979 and Pocas, 1995). Iglesias et al (1979) used a BET equation to describe the mixture sorption isotherm in the water activity range of 0.05-0.40.

Hong et al (1986) predicted the moisture change of each component of a mixture by using finite element modeling. They considered the moisture transfer across the packaging material negligible. The researchers used the GAB equation to describe the products' isotherm. Salwin and Slawson (1959) used linear isotherm and also did not consider moisture transfer through the packaging. Shelf life studies of multicomponent moisture sensitive products in permeable packaging have been conducted primarily using linear and BET isotherms.

Shelf life modeling of multicomponent foods has only focused on the prediction of mixture sorption behavior from the sorption characteristics of individual components and assumed no moisture transfer across the packaging barrier. These studies reported the use of a linear sorption isotherm equation or equations with limited range of activity.

Pocas (1995) developed a mathematical model and a computer program to calculate the shelf life and to predict the change in moisture content over storage time of a two component mixture packaged in flexible packages. The model used GAB (Bizot, 1983), Oswin (Oswin, 1946 in Pocas, 1995), Halsey (Halsey, 1948 in Pocas, 1995), Henderson (Henderson, 1952 in Pocas, 1995) and Chen (Chen, 1971 in Pocas, 1995) equations to fit the experimental sorption isotherm and the computer program included them. The importance of this model is the consideration of the whole isotherm and not only the linear part. The previous models mentioned considered only the linear part.

Pocas (1995) validated the program with mixtures at different weight ratios of breakfast cereal and powder chocolate packaged in Oriented Polypropylene (OPP) and Polyethylene (PE). It was reported that the model tended to overestimate the component moisture content, especially the cereal after longer storage periods. It was proposed that deviations are dependent on the packaging material barrier, which affected the relative tendency of the components to absorb moisture simultaneously. It was suggested that the package introduced deviations because the model assumption of fast equilibrium between the product's moisture content and the package's headspace relative humidity is not met. Another proposed cause of this difference was that the equilibrium moisture content of each component may be affected by the presence of the other component (Pocas, 1995).

Pocas (1995) developed a more general mathematical model to calculate the change in moisture content over storage time and the shelf life of a two-component packaged mixture, using the GAB, Halsey, Henderson, Oswin or the Chen equations, maintaining the individuality of each component and not using one "weighed sorption isotherm". This researcher also wrote a computer program where simulation runs were carried out.

1.8. Mathematical Model Development

Labuza (1972) expressed the rate of water transport through a permeable film with the following equation:

$$\frac{dW}{dt} = \frac{P}{l} A (p_o - p_i) \qquad (3)$$

Where:

W is the weight of water transported across the film, in g.

t is time, in days

P is the film permeability coefficient, in g-μm/m^2-day-mm Hg

l is the film thickness, in μm

po, pi are the vapor pressure of the water outside and inside of the package, respectively, in mm Hg.

It is assumed that the packaging material controls the moisture exchange between the product and environment. To consider this assumption valid the condition of having a water diffusion coefficient through the packaging material much smaller than the water diffusion coefficient in the air and within the product must be met. It is also assumed the following: (1) the products' moisture content is in equilibrium with the internal pressure, (2) there is a rapid equilibrium between water and the food, (3) the internal pressure is determined by the product equilibrium moisture content and the storage temperature.

For mixtures of binary products, the amount of moisture permeating through the package is equal to the sum of the moisture changes in each component.

Pocas (1995) developed a general equation for mixtures of two products from the equations presented above. The researcher used the Henderson, Chen, Oswin, Halsey linear and the GAB non-linear sorption isotherm equations. A complete summary of the derivation for each component based on moisture sorption data by linear regression and by second order polynomial regression proposed by Pocas (1995) is presented in Appendix A.

To determine the shelf life of mixed products using the linear isotherm, Pocas (1995) derived the following equation.

$$t_A = \frac{1}{P.A.p_s}\left(W_A + W_B\frac{b_B}{b_A}\right)\int_{M_A^1}^{M_A^2}\frac{dM_A}{a_{WO} - a_W(M_A)} \qquad (4)$$

$$t_B = \frac{1}{P.A.p_s}\left(W_A\frac{b_A}{b_B} + W_B\right)\int_{M_B^1}^{M_B^2}\frac{dM_B}{a_{WO} - a_W(M_B)} \qquad (5)$$

Where:

M_A^1 and M_B^1 are the initial moisture content of component A and B, respectively

t_A, and t_B represents the time required to achieve the moisture content M_A^2 and M_B^2, respectively.

a_A, a_B, b_A and b_B are coefficients of the linear equation.

To determine the shelf life of mixed products using the non-linear isotherm, the following equation was derivated by Pocas (1995).

$$t_A = \frac{1}{P.A.p_s} . \int_{M_A^1}^{M_A^2} \frac{W_A + W_B . D(M_A)}{a_{WO} - a_W \left(M_A\right)} dM_A \qquad (6)$$

$$t_B = \frac{1}{P.A.p_s} . \int_{M_B^1}^{M_B^2} \frac{W_B + WA_B . D(M_B)}{a_{WO} - a_W \left(M_B\right)} dM_B \qquad (7)$$

The relative percent root mean square of the difference between the experimental and the calculated moisture content (R) was used to evaluate the goodness of the fit. The equation, previously presented is written below.

$$\%RMS = \sqrt{\frac{\sum_{i}^{n} \left[\frac{M_i - M_i^*}{M_i} \right]^2}{n}} \text{ x } 100 \qquad (8)$$

where Mi is the experimental moisture content Mi* is the calculated moisture content and n is the number of experimental data points.

Chapter 2

MATERIALS AND METHODS

2.1. Product – Package System

2.1.1. Food Product Samples

Three common breakfast cereals were obtained from a local store. The following cereals were chosen, Corn Flakes, Shredded Wheat and Oats due to their low sugar and salt contents.

The main ingredients in corn flakes cereal are milled corn, sugar, salt, malt flavoring, and high fructose corn syrup. It was packaged in a polyethylene bag which was placed into a carton. Shredded wheat has no salt or sugar added and it also was packaged in a carton with an inner plastic bag. Oats also has no salt or sugar added and it also was packaged in a carton cylinder with a plastic cap.

Products were preconditioned before experiments. Products were stored in a control environment at 23°C and 50% relative humidity for 48 hours. Then a single product was stored in a glass container with nitrogen flush.

2.1.2. Package

High Density Polyethylene and Low Density Polyethylene with 1.0 and 1.9 mil thickness, were supplied by a local converter. Materials were conditioned at 23°C, 50% RH for 72 hours prior to testing. The characterization of the packaging materials includes thickness and water permeability of the films. The characteristics are presented in Appendix B.

For the validation experiments three-side-seal pouches of these materials were sealed using an impulse sealer. The dimensions of the pouches were 17 cm x 10 cm. The integrity of the pouches was checked with a polariscope and with manual tensile test. A quality seal was obtained when a uniform and consistent color band was observed when placing the sample between two polarized lenses. In the manual tensile test, the seals were slowly pulled apart while holding the two sides of the sealed sample. Ripping of the material before the seal suggests a quality seal.

2.2. Moisture Content Determination

Moisture content of cereals was determined by Gravimetric Method: 5 g of product was placed in an aluminum dish and dried in vacuum oven (Precision Scientific Model 524) at 75°C and 30 mm Hg until constant weight. The moisture content was reported on percent wet basis, M_w. The percent moisture content (dry basis), M, was determined as

$$M = \frac{M_w}{1 - M_w} \tag{9}$$

This method was developed at School of Packaging (Michigan State University) and is used on the Permeability and Shelf Life Lab Manual. For more information see the Bibliography.

2.3. Moisture Sorption Isotherms

Moisture sorption isotherms were determined gravimetrically at 72°C by equilibrating cereal samples (3 replicates) at nine different relative humidity values, ranging from 5% to 88% RH. The relative humidity was created inside closed containers with saturated solutions and was monitored with a calibrated hygrometer (Hydrodynamics, Inc., Silver Spring, MD) at the beginning and end of the experiment. Table 1 presents the saturated salt solutions and their corresponding measured relative humidity.

Table 1: Saturated salt solutions and their corresponding relative humidities at 23°C

Saturated Salt Solution	Relative Humidity, %	Source
Lithium Bromide	5.3	Sigma, MO
Lithium Chloride	11.2	J,T. Baker, NJ
Potassium Acetate	25.1	J,T. Baker, NJ
Magnesium Chloride	33.0	J,T. Baker, NJ
Potassium Nitrite	47.8	Columbus Chemical Industries, Inc., WI
Sodium Nitrate	61.5	J,T. Baker, NJ
Sodium Chloride	76.0	Columbus Chemical Industries, Inc., WI
Ammonium Sulfate	80.8	EM Science, NJ
Potassium Nitrate	87.8	Columbus Chemical Industries, Inc., WI

Water activity can be easily calculated from the relative humidity values presented on Table 1 by

$$a_w = \frac{RH}{100} \tag{10}$$

About 4 grams of cereal were weighed into a Petri dish (55 mm diameter). Three replicates and two controls (empty Petri dish) were placed into the closed containers (specific relative humidity). Samples were weighed on AE 160 Meter Analytical Balance at pre-determined time intervals. This procedure was performed until a constant weight was found. The equilibrium moisture content, expressed as dry basis, was calculated based on moisture change of a sample at equilibrium.

The equilibrium moisture content (dry basis), M, was calculated by equation 11.

$$M = \left[\frac{W_e(M_i - 1)}{W_i} - 1 \right] x\,100 \tag{11}$$

where M = equilibrium moisture content, % dry basis

M_i = initial moisture content, % dry basis

W_e = weight at equilibrium, g

W_i = initial weight, g

Experimental moisture sorption isotherm was fit with GAB, and cubic polynomial equations. Parameters in equation were estimated as the following:

GAB Equation

$$\frac{M}{W_m} = \frac{CKa_w}{(1 - ka_w)(1 - ka_w + Cka_w)} \qquad (12)$$

Where:

W_m = water content corresponding to saturation of all primary adsorption sites by one water molecule (formerly called the monolayer in BET theory)

C = Guggenheim Constant = c' $\exp[(H_l - H_m)/RT]$

k = factor correcting properties of the multilayer molecules with respect to the bulk liquid: k =k' exp $[(H_l - H_q)/RT]$

H_l = heat of condensation of pure water vapor

H_m = total heat of sorption of the first layer on primary sites

H_q = total heat of sorption of the multilayer water molecules

In order to estimate parameters, the equation was transformed into a quadratic form as

$$\frac{a_w}{M} = \alpha a_w^2 + \beta a_w + \gamma \qquad (13)$$

where

$$\alpha = \frac{k}{W_m}\left(\frac{1}{C} - 1\right) = \frac{1}{W_m C}(1 - C) \qquad (14)$$

$$\beta = \frac{1}{W_m}\left(1-\frac{2}{C}\right) = \frac{1}{W_m C}(C-2) \qquad (15)$$

$$\gamma = \frac{1}{W_m Ck} \qquad (16)$$

The quadratic regression was performed by MS Excel. GAB constants C, W_m, and k were calculated by equations 17, 19, and 20, respectively. The details for obtaining these equations are presented in Appendix C.

$$C = \frac{\theta \pm \sqrt{\theta^2 - 4\theta}}{2} \qquad (17)$$

where

$$\theta = 4+\frac{\beta^2}{(-\alpha)\gamma} \qquad (18)$$

$$W_m = -\frac{1}{\beta C}(C-2) \qquad (19)$$

$$k = \frac{1}{W_m Ck} \qquad (20)$$

Cubic Polynomial Equation

$M = k_1 a_w^3 + k_2 a_w^2 + k_3 a_w + D_c$

The polynomial regression was performed by Microsoft Excel 97-SR1.

The goodness of fit for each isotherm was evaluated based on the minimum value of percent root mean square, RMS.

$$\mathrm{RMS} = \sqrt{\frac{\sum_{i=1}^{n}\left[\frac{M_{\mathrm{exp}} - M_{\mathrm{calc}}}{M_{\mathrm{exp}}}\right]}{N}} \times 100$$

where M_{exp} = experimental moisture content, % dry basis, M_{calc} = calculated moisture content, %dry basis, and N =number of data point.

2.4. Permeability of Packaging Material

Water vapor transmission rate of packaging films was determined by an infrared sensor method (based on ASTM F1249-90), using a PERMATRAN W3/31 (Mocon Inc, Minneapolis, USA). Six replicates per material were tested at 23°C with 50% of relative humidity as the driving force. The relative humidity was obtained with water vapor in one side chamber of the cell and nitrogen flush in the other side chamber. The actual value of permeability was found by dividing the transmission rates of the material by the driving force as indicated in Appendix B.

Water vapor transmission rate of the pouches was also determined by the gravimetric method (ASTM D3079). Three pouches of each material (17 cm x 10 cm) filled with desiccant, were stored at 23°C and 50%relative humidity and weighed every 4 days, until there was a constant increase of weight. Three empty pouches were also stored to evaluate the moisture sorption on the material.

2.5. Model Validation Experiments

To validate the model, two experiments were carried out. For the first experiment, mixtures of two cereals (corn-oats, oats-wheat; and corn-wheat) were packaged in 17 cm x 10 cm pouches of HDPE and stored at 23°C and 50% relative humidity. Mixtures of different ratios of cereal to cereal were prepared: 1/2, 1/1 and 2/1. Pouches were weighed daily during the first week and then weekly during the following 8 weeks, two of those pouches of each mixture were tested for moisture content determination of each product. A similar procedure was employed for pouches with single product.

For the second validation experiment, mixtures of cereals in a ratio of 1/1 were packaged in LDPE pouches (17 cm x 10 cm) and stored at the same conditions. Pouches were weighed daily during the first week and afterwards weekly for the following 8 weeks. Pouches with a single product were also treated with same procedure.

Initial moisture content was determined for each experiment with the procedure described above.

Chapter 3

RESULTS AND DISCUSSION

3.1. Initial Moisture Content

The initial moisture content (dry basis) of corn, oats and wheat determined and used for plotting the moisture sorption isotherms were:

Corn: 3.18 ± 0.07 g H_2O/ g 100 dry product

Oats: 10.68 ± 0.08 g H_2O/ g 100 dry product

Wheat: 4.95 ± 0.107 g H_2O/ g 100 dry product

3.2. Moisture Sorption Isotherms

The plot of the moisture sorption isotherms for corn, oats and wheat cereals at 23°C isotherms are presented in Figures 3, 4 and 5 respectively.

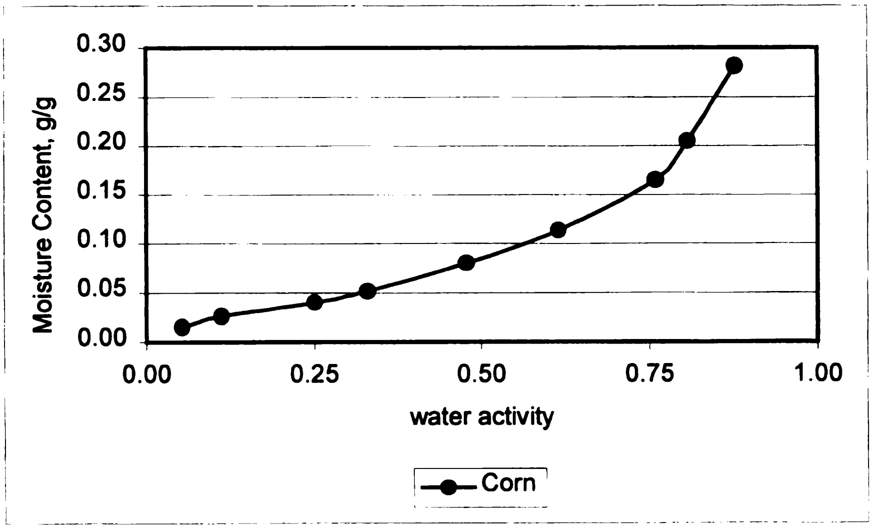

Figure 3 – Moisture Sorption Isotherm of Corn Cereal at 23°C.

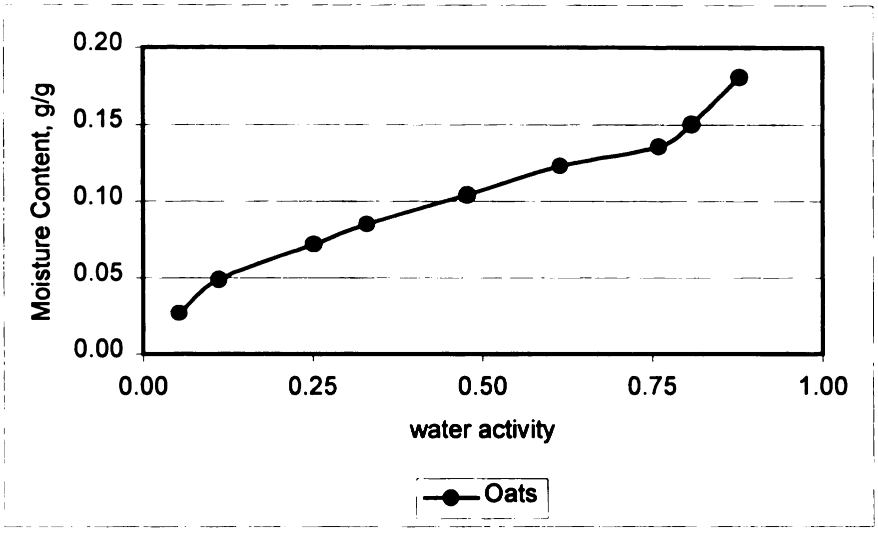

Figure 4 - Moisture Sorption Isotherm of Oats at 23°C.

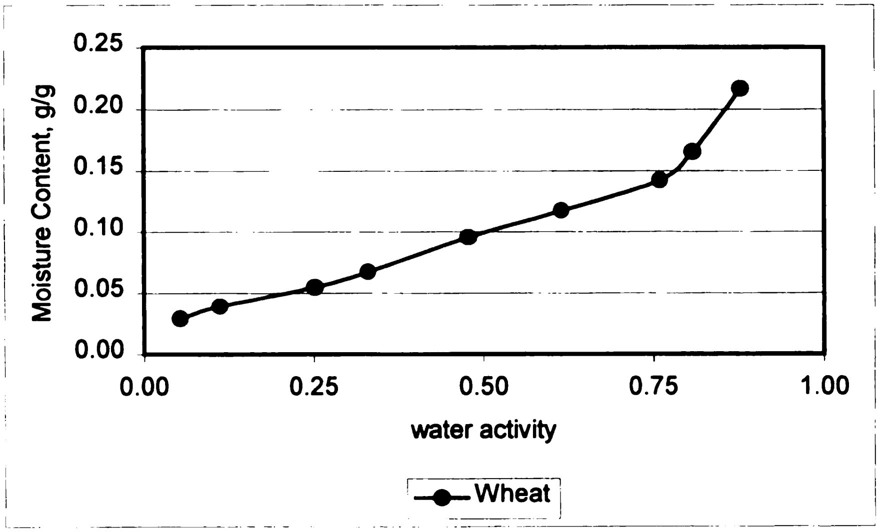

Figure 5 - Moisture Sorption Isotherm of Wheat Cereal at 23°C.

The data used to construct the graphs are presented in Appendix E. The same data was used to calculate the Linear, GAB and Cubic Sorption Isotherm Equations. The equations for the cereals tested were calculated with MS Excel and they are presented in Table 2.

Table 2 – Linear, GAB and Cubic Sorption Isotherm Equations of Corn, Oats and Wheat Determined at 23°C.

Equation	Corn	Oats	Wheat
Linear (*)	$M = 0.1450a_w + 0.0073$ (1) $R^2 = 0.9807$	$M = 0.1456a_w + 0.0346$ (2) $R^2 = 0.9960$	$M = 0.1566a_w + 0.0191$ (3) $R^2 = 0.9933$
GAB	$a_w /M = -17.74a_w^2 +15.70a_w$ $+2.86$ $R^2 = 0.9353$	$a_w /M = -6.50a_w^2 +10.07a_w$ $+1.34$ $R^2 = 0.9786$	$a_w /M = -13.20a_w^2 +14.94a_w$ $+1.29$ $R^2 = 0.9484$
Cubic	$M = 0.9330a_w^3 -0.8738a_w^2$ $+0.3633a_w -0.0042$ $R^2 = 0.9931$	$M = 0.5018a_w^3 - 0.6938a_w^2$ $+0.4146a_w + 0.0074$ $R^2 = 0.9927$	$M = 0.5342a_w^3 -0.5594a_w^2$ $+0.3020a_w + 0.0119$ $R^2 = 0.9866$

(*) The linear equation for Corn, Oats and Wheat did not use all the experimental points. (1) Corn used 5 points (1-5 from table 5); (2) Oats used 5 points (2-6 from Table 5); (3) Wheat used 6 points (1-6 from table 5)

3.3. Film Permeability

The permeability of four HDPE and four LDPE film samples was determined with ASTM F-1249-90. The conditions were set at: 50%RH and 23 °C. Permeability results, obtained from 4 repetitions, are presented below and the details are presented in Appendix B.

LDPE Film: 9.54E-05 ± 7.85E-06 g.mil/in^2.day.mmHg

HDPE Film: 5.31E-05 ± 4.91E-07 g.mil/in^2.day.mmHg

3.4. Package Permeability

Package permeability was also measured to see the effect of the seals. The permeability values obtained from the LDPE and HDPE samples' transmission rates by the Gravimetric Method are presented below.

LDPE Film: 6.34E-05 ± 6.05E-06 g.mil/in^2.day.mmHg

HDPE Film: 4.20E-05 ± 1.16E-06 g.mil/in^2.day.mmHg

The package permeability values of LDPE and HDPE were approximately 33% and 21% lower than the ones obtained from the film samples. This difference between the film-sample and pouch permeability is within reasonable range. An explanation for this difference lies on a higher film permeability determination due to a higher vapor pressure differential, a higher temperature or a miscalibrated sensor in the Permatran. A lower storage relative humidity or a lower storage temperature could be responsible for the lower pouch-permeability values reported. The storage relative humidity and temperature were monitored and they were in the range ± 3%. The Moisture Gain vs Time plot for the pouches (Appendix B) showed straight lines, indicating good agreement. The pouch-permeability values also indicate that good seals were achieved because the pouches' permeability values were always lower than the film samples. Due to this difference in permeability value between the film (also known as flat-film) and gravimetric method, the latter value was selected and used in the calculation carried by the computer program.

3.5. Validation 1 – Moisture Change in Cereal Packaged in HDPE 1.9 mil

The experimental validation for the computer model was carried out by monitoring the change in moisture content over time of each component of the packaged mixtures. Table 3 summarizes the combinations used for the Experimental Validation 1.

Table 3 - Combinations of cereals used for the Experimental Validation 1

Experiment	33/67	50/50	67/33	100
1	corn/wheat	corn/wheat	corn/wheat	corn
2	corn/oats	corn/oats	corn/oats	oats
3	oats/wheat	oats/wheat	oats/wheat	wheat

Because oats presented an initial water activity of approximately 0.47-0.49 and the values for corn and wheat ranged near 0.17-0.20; it was expected that moisture exchange between oats and corn or oats and wheat would be more important than the permeability through the package during the early phase of he experiment. Therefore, in addition to the mixtures described in the table above, a 30-gram mixture (ratio 1:1) of corn (14.63 g dry product) and oats (13.50 g dry product) was placed in a glass jar to determine the time required until moisture equilibrium is reached in the absence of permeability.

Equilibrium, the time when the hygrometer sensor attached to the metal lid did not report any further change, was reached in 48 hours. The readings of this closed environment were performed every 12 hours. After forty-eight hours the sensor showed a constant reading (38.5 ± 1.0 %RH).

Corn at an initial moisture content of 0.0284 g H_2O/g dry product and oats at 0.1206 g H_2O/g were placed in the glass jar. The glass jar was opened after 192 hours (8 days), and corn and oats were separated. Then their moisture content was determined. The final moisture content of corn and oats were 0.0491 g H_2O/g dry product and 0.1027 g H_2O/g dry product respectively.

A mass balance was performed to corroborate the numbers obtained. The mass balance was as follows:

Initial Water Mass: 0.0284 g H_2O/g dry corn * 14.63 g dry corn + 0.1206 g H_2O/g dry oats * 13.50 g dry oats = **2.04 g H_2O**

Final Water Mass: 0.0491 g H_2O/g dry corn * 14.63 g dry corn + 0.1027 g H_2O/g dry oats * 13.50 g dry oats = **2.10 g H_2O**

The most important conclusion from this ancillary experiment is that in closed systems moisture exchange takes approximately 48 hours. This consideration will be helpful to support the discussion of the following experiments and in the application of the computer model.

Figures 6, 7 and 8 show the percent moisture change profile of 33/67, 50/50 and 67/33 corn/wheat samples. Figures 9, 10 and 11 present the percent moisture change profile of 33/67, 50/50 and 67/33 corn/oats pouches. Figures 12, 13 and 14 plot the percent moisture change profile of 33/67, 50/50 and

67/33 oats/wheat samples. Finally, the percent moisture change profile for corn, oats and wheat is presented in Figures 15, 16 and 17.

The experimental and predicted values of the percent moisture content as a function of storage time for the cereal combinations (Table 3) are presented in Appendix F. Detailed tables of the individual pouches' weight gain values for all these combinations are presented in Appendix G.

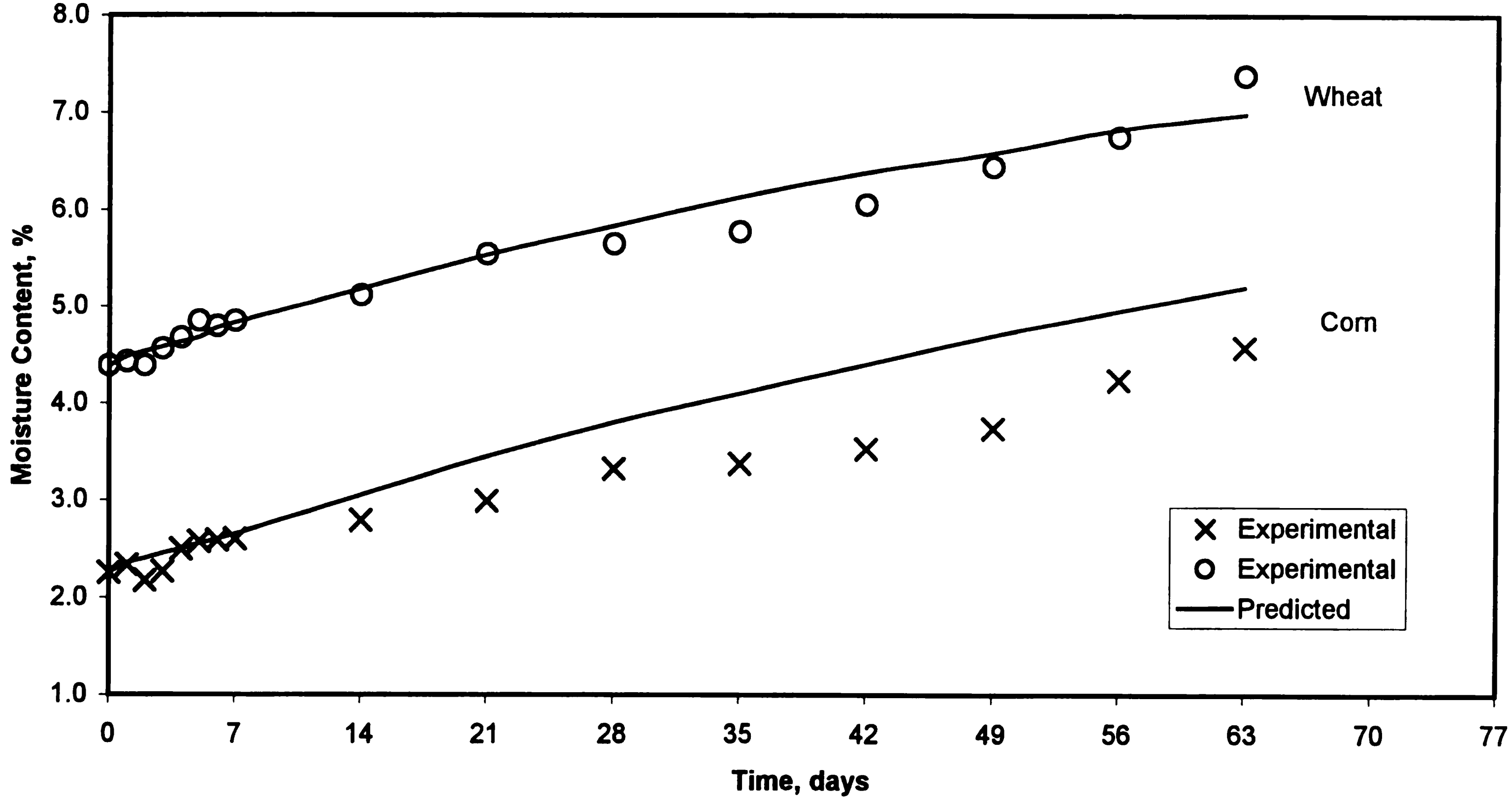

Figure 6: Experimental and Predicted Moisture Content Profile of 33/67 Corn-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

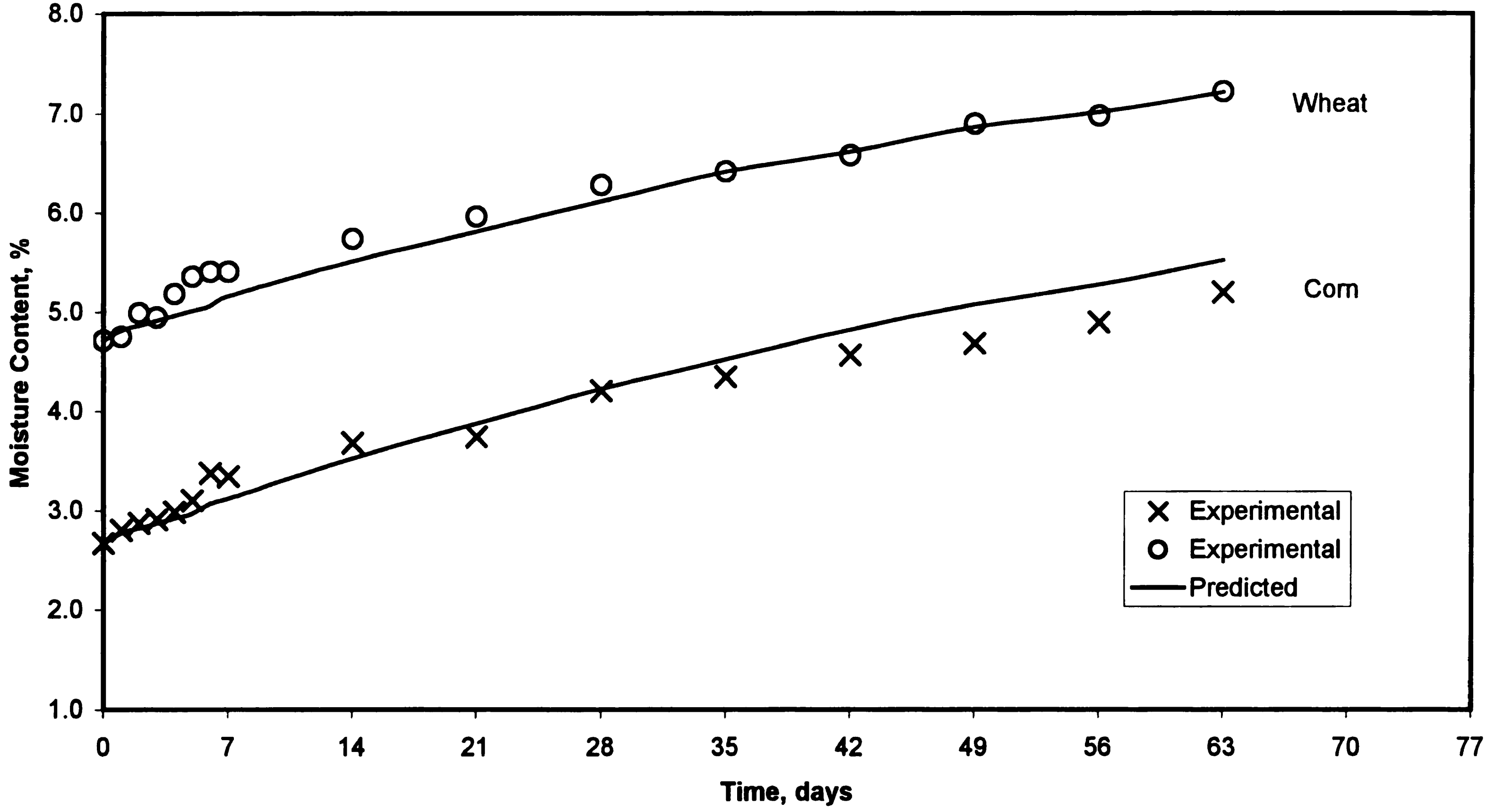

Figure 7: Experimental and Predicted Moisture Content Profile of 50/50 Corn-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

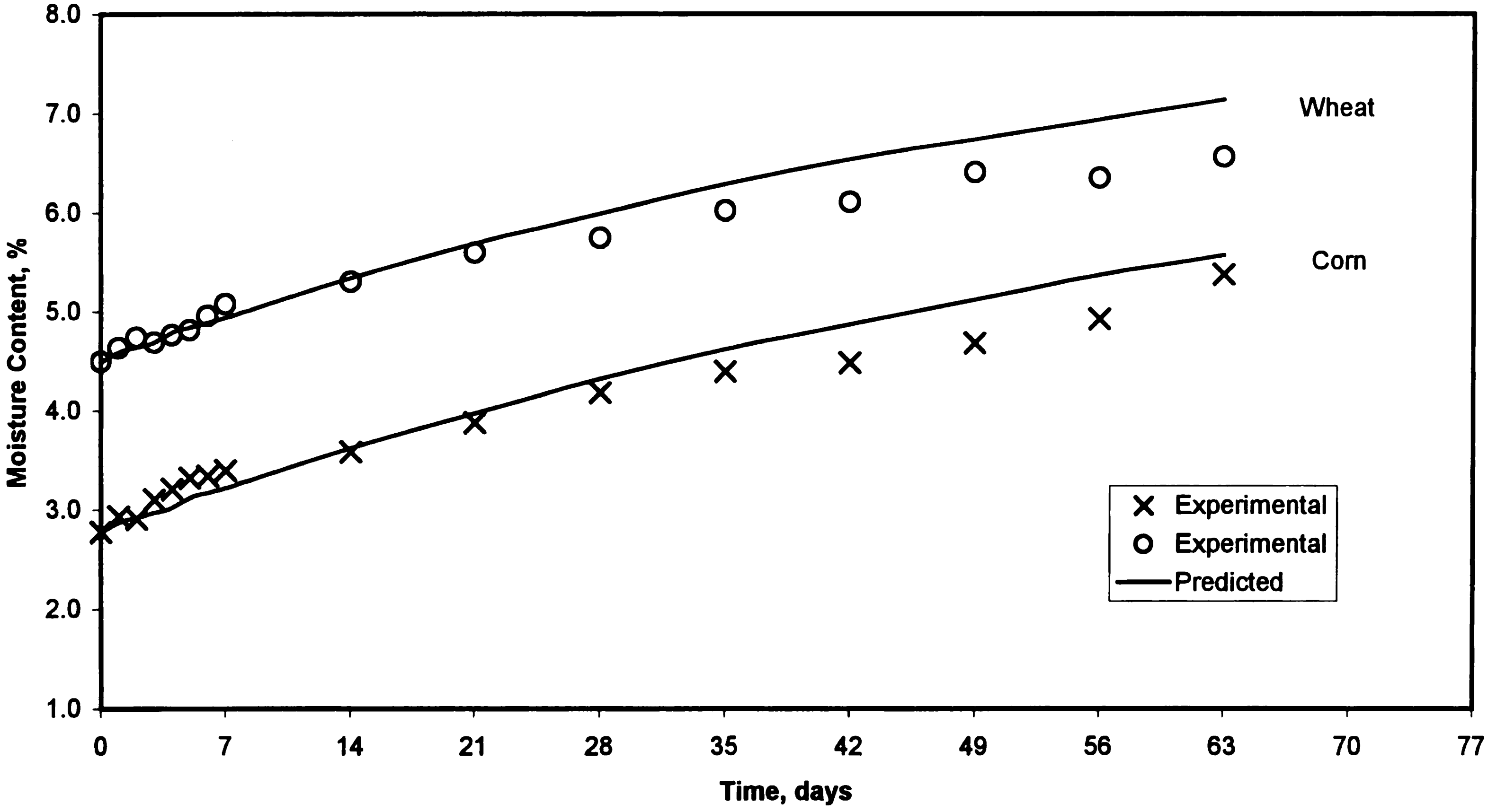

Figure 8: Experimental and Predicted Moisture Content Profile of 67/33 Corn-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE mil - 50%RH).

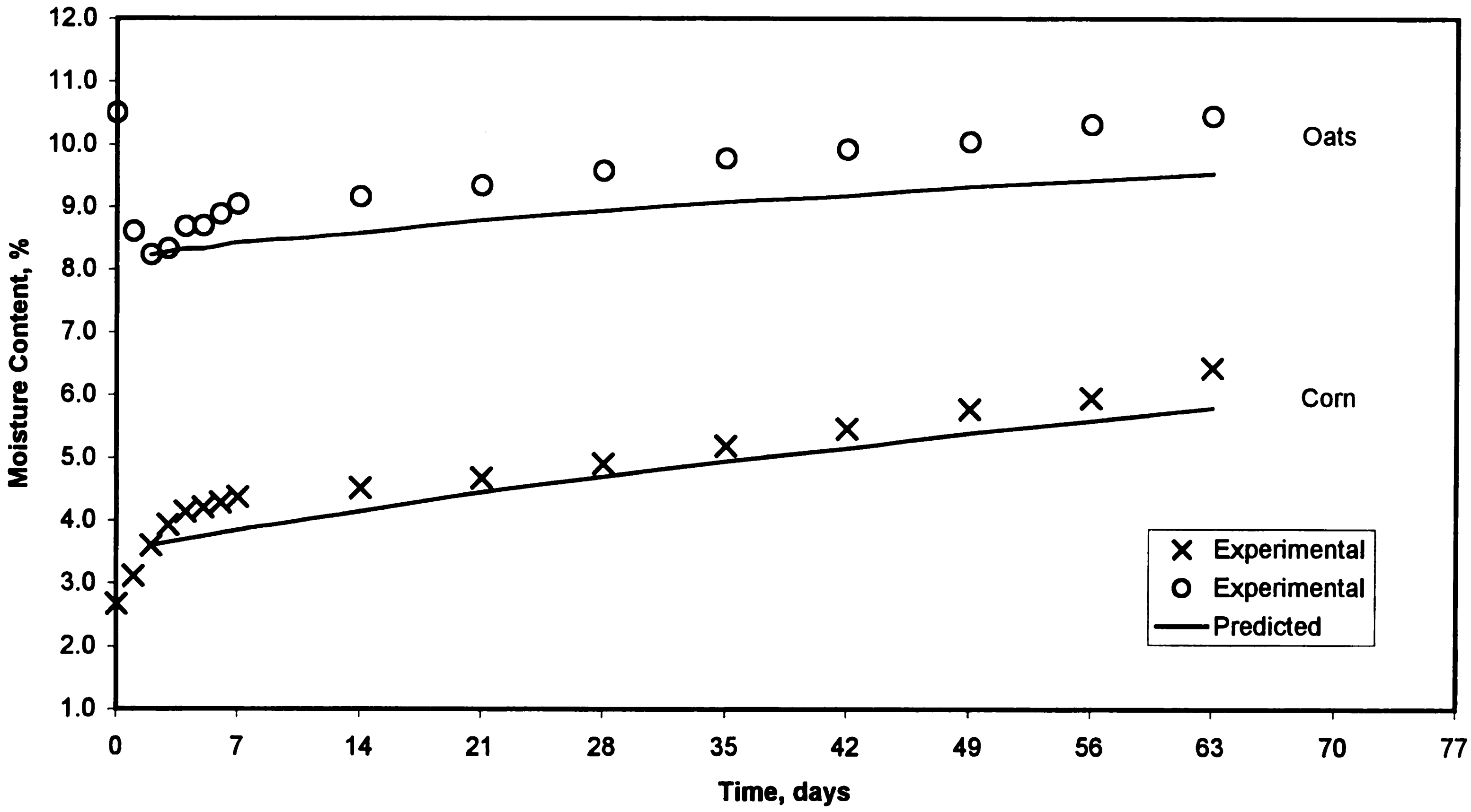

Figure 9: Experimental and Predicted Moisture Content Profile of 33/67 Corn-Oats Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

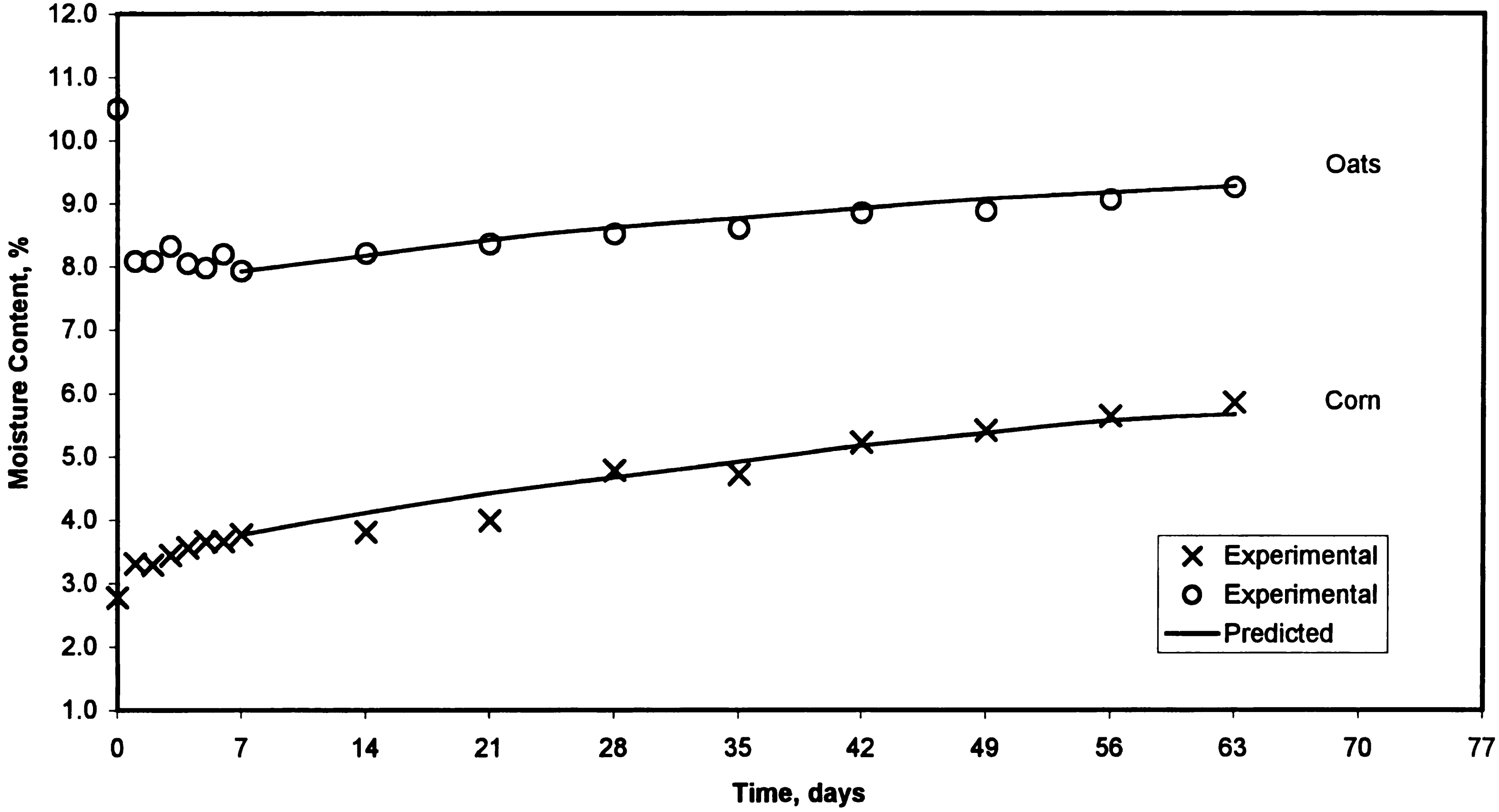

Figure 10: Experimental and Predicted Moisture Content Profile of 50/50 Corn-Oats Mixtures for Validation 1 (Conditions; 23°C - HDPE 1.9 mil - 50%RH).

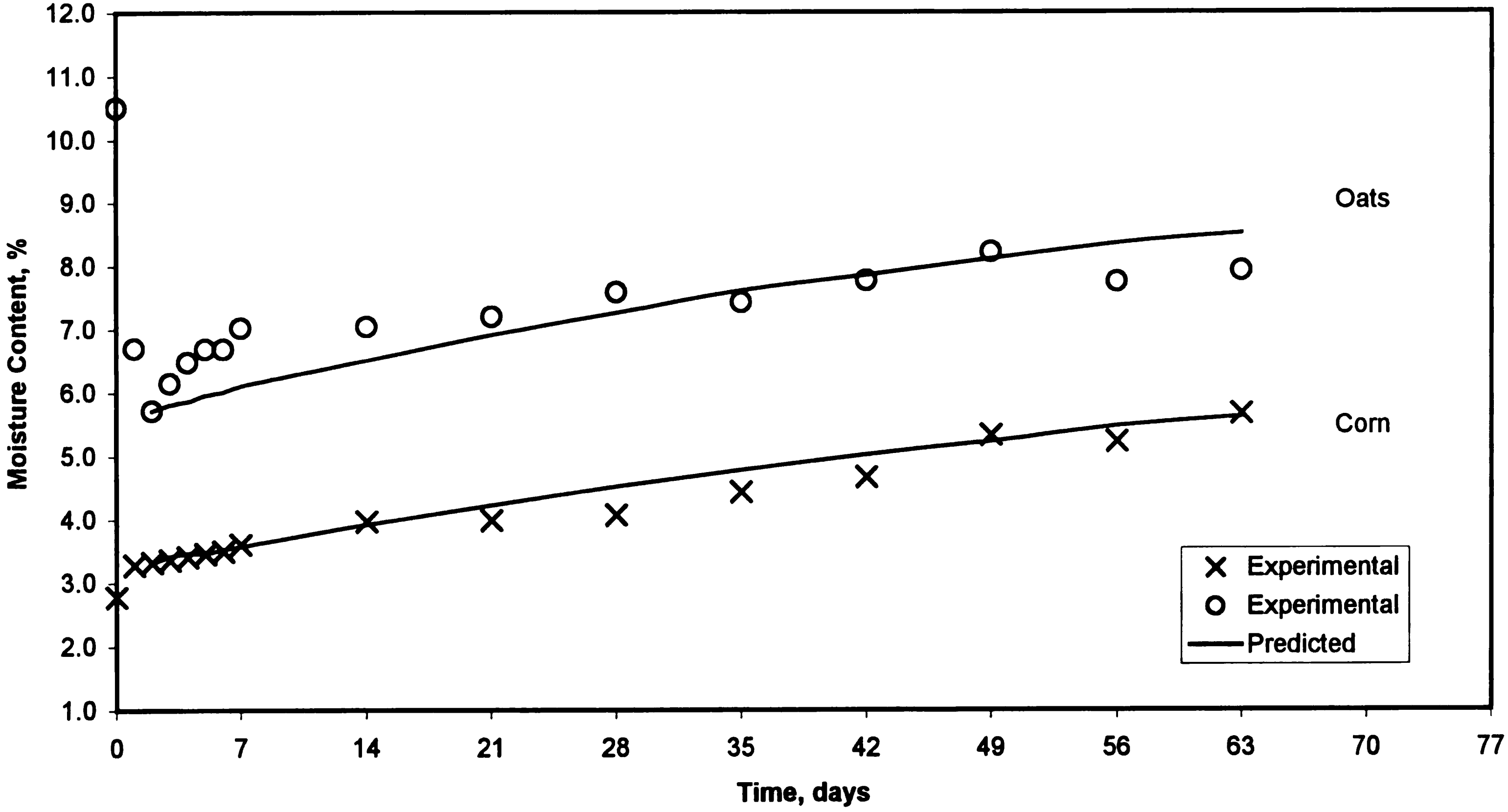

Figure 11: Experimental and Predicted Moisture Content Profile of 67/33 Corn-Oats Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

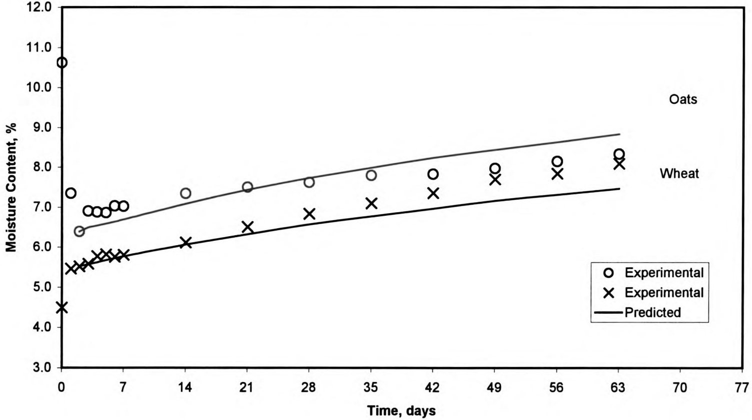

Figure 12: Experimental and Predicted Moisture Content Profile of 33/67 Oats-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

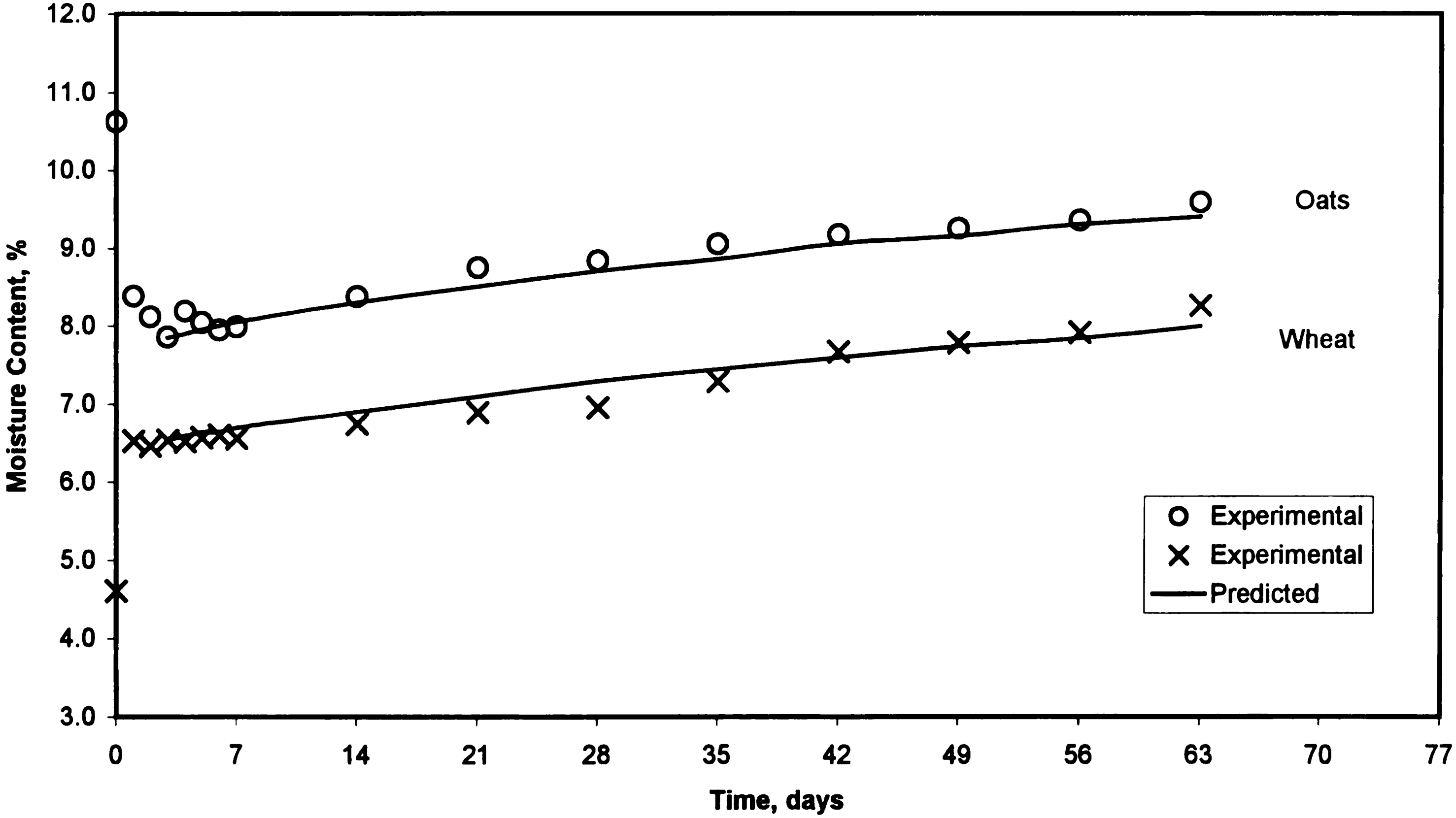

Figure 13: Experimental and Predicted Moisture Content Profile of 50/50 Oats-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

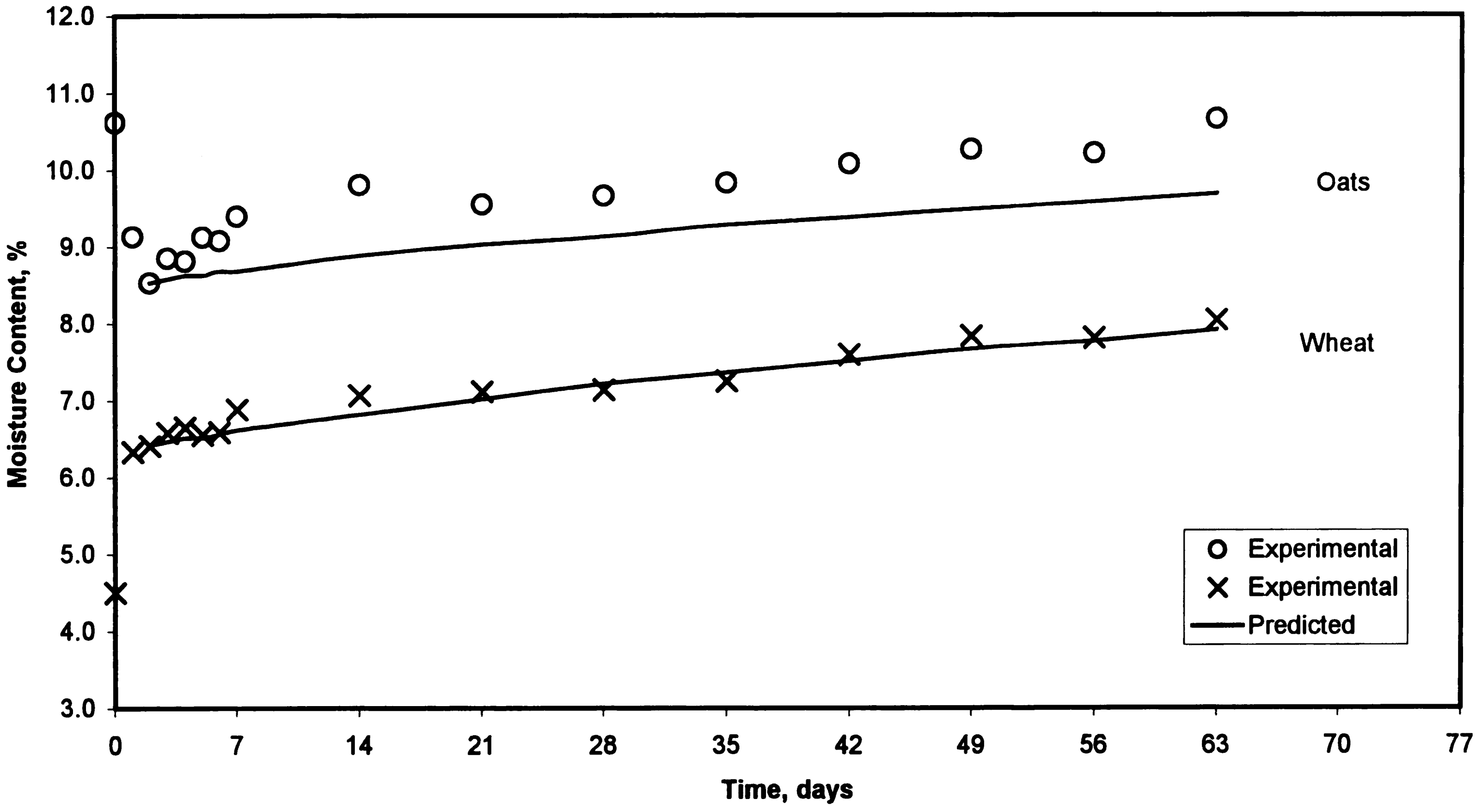

Figure 14: Experimental and Predicted Moisture Content Profile of 67/33 Oats-Wheat Mixtures for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

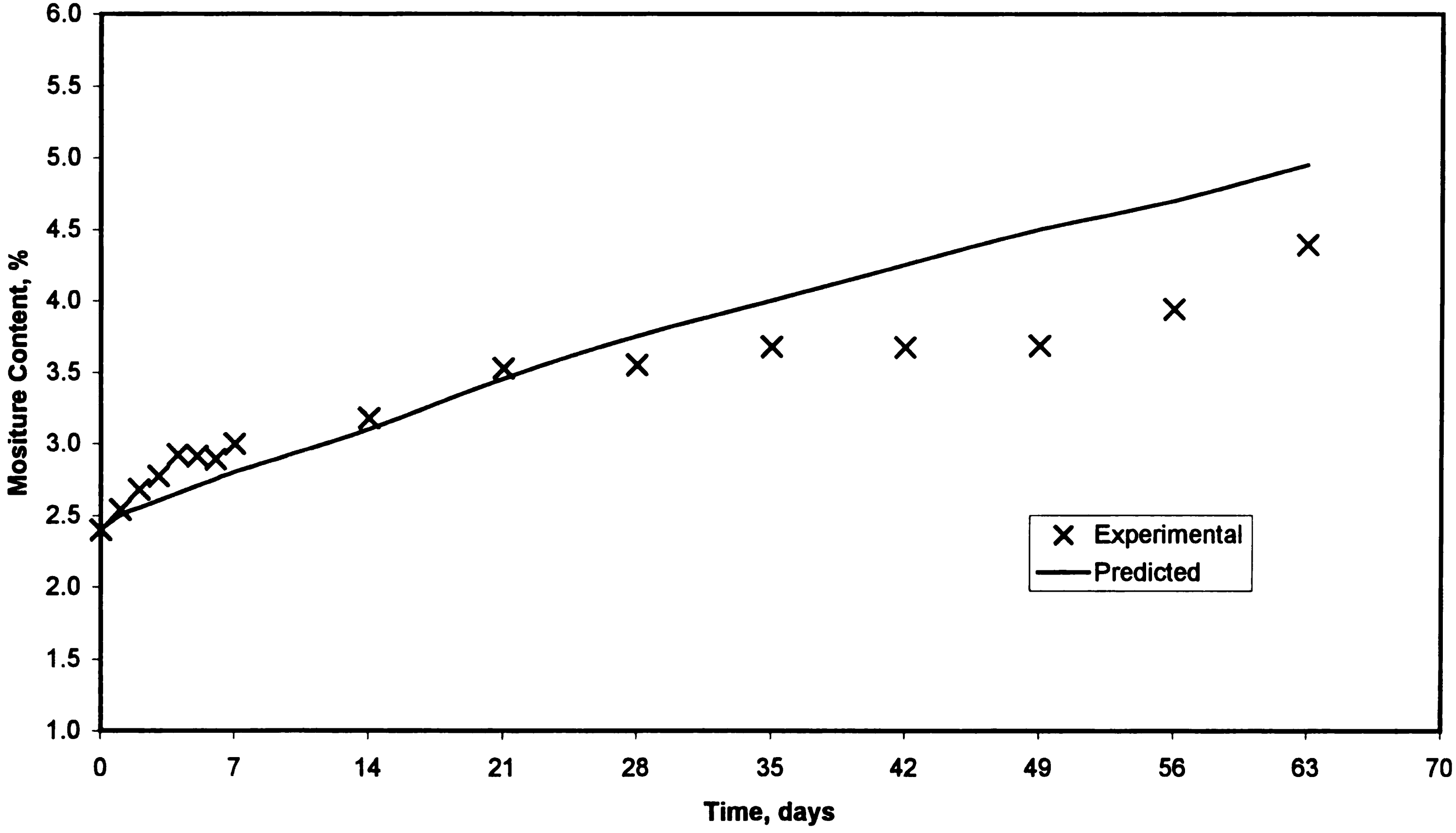

Figure 15: Experimental and Predicted Moisture Content Profile of 100/0 Corn for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

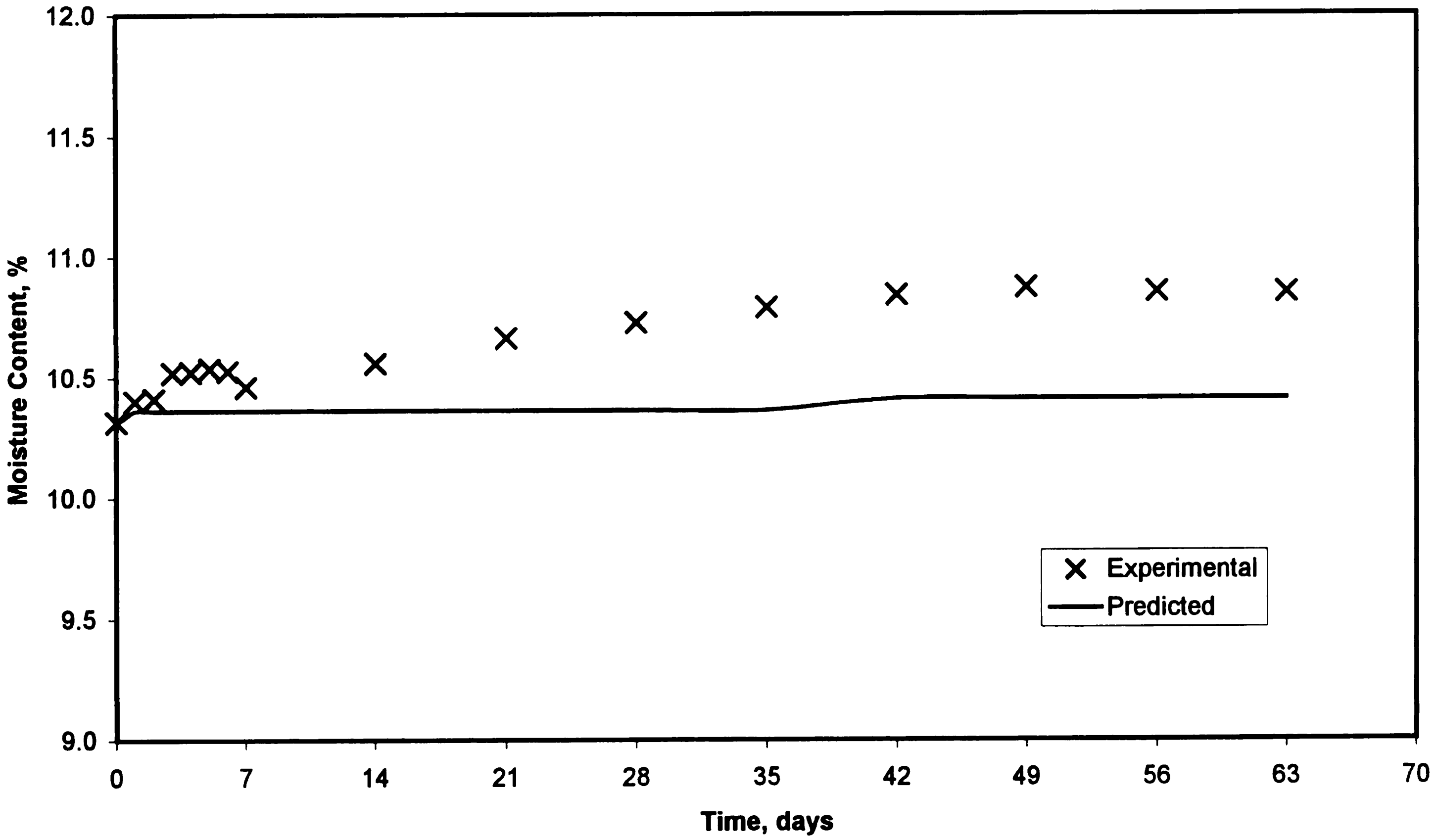

Figure 16: Experimental and Predicted Moisture Content Profile of 100/0 Oats for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

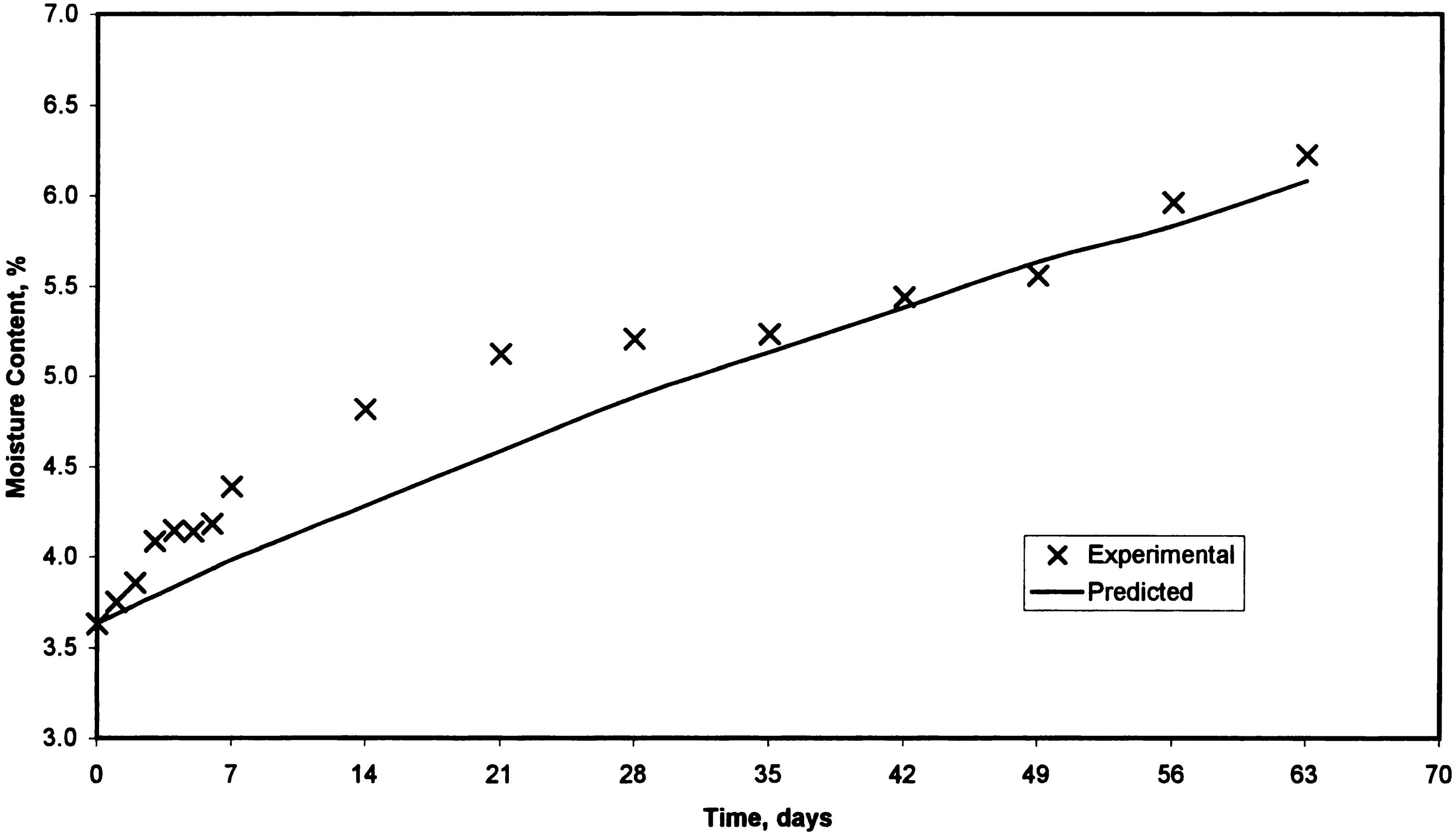

Figure 17: Experimental and Predicted Moisture Content Profile of 100/0 Wheat for Validation 1 (Conditions: 23°C - HDPE 1.9 mil - 50%RH).

In the corn and wheat mixtures, it was observed that both cereals started to pick up moisture immediately because the cereals had lower initial water activity (0.17-0.20) in comparison with storage relative humidity (50%RH). The moisture transfer between corn and wheat was expected to be small because their initial water activities taken from their respective isotherms were close (corn = 0.17, oats = 0.20).

The experimental and predicted values showed good agreement for the corn and wheat mixtures (Figures 6-8). The percent difference between these values was lower than 10% with the exception of mixture of 33/67 corn-wheat (Figure 6). A difference in the order of 10-26% was noticed from the third week. It is important to mention that the difference was above 20% (20-26%) only during weeks 5-7 (Figure 6). The experimental values for the 33/67 corn/wheat samples were slightly lower than the predicted ones for most of the samples. The 50/50 and 67/33 corn/wheat samples also show this behavior.

In the individually packaged products (Figures 15-17), single packaged corn (Figure 15) showed a difference between the experimental and predicted values greater than 10% from the sixth week of storage. The difference range for weeks 6-9 was 10-23%. Again, the experimental values were lower than the predicted ones. The difference in the single packaged oats and wheat (Figures 16 and 17) was lower than 4% and 12%, respectively.

The difference (greater than 10%) found in the samples of corn-wheat (33/67) and corn could be caused by errors in the moisture content determination of those samples. The corn samples were mixed in a large plastic bag and then immediately nitrogen-flush packaged in glass jars. The initial moisture content was determined from samples before placing the cereal in the jars and perhaps the batch did not have homogenous moisture content.

The lower rate on the moisture transfer could possibly attributed to a lower storage relative humidity, to the pouches' lower transmission rate or to the pouches' lower surface available for moisture transfer. It is proposed that samples of individually packaged corn and 33/67 corn-wheat showed the deviation because of a lower storage relative humidity or lower temperature during the storage.

Experimental errors associated with the weighing, component separation, moisture determination or modification of the corn (e.g. oxidation) could also be responsible for the higher values of moisture content predicted by the model as compared to the values that were experimentally determined.

Pocas (1995) pointed out that the relative resistance to moisture transfer within the food components to the packaging material plays an important role to the effectiveness of the model. The researcher used corn cereal and chocolate powder and found that corn alone or packaged (in PP and PE) with the powder presented similar deviations in the order of 20-30%. The researcher remarked that the corn moisture content when packaged together with the powder chocolate reached equilibrium at lower values than the predicted at longer storage periods. Individually packaged corn as well as the powder chocolate did not reach equilibrium during the storage period.

In the corn-oats and oats-wheat, oats was selected because it had a much higher initial water activity (about 0.45-0.48), which was close to the storage relative humidity. It was expected that oats would gain moisture from the storage environment very slowly as shown by the oats isotherm (Figure 4) and the individually packaged oats samples (Figure 16).

Oats would also transfer moisture to the other component (corn or wheat) much faster during the first days as demonstrated in the glass-jar experiment. After this time of dramatic moisture exchange, a temporal equilibrium will be reached and oats will present lower moisture contents while the other cereal (corn or wheat) will have higher moisture content values. For most of the cases the transitory equilibrium was reached in one or two days.

To account for this moisture exchange event ("temporal equilibrium"), the lowest experimental moisture content (from oats) was used to define the initial point where permeation through the package became more important than the components' moisture exchange.

After making the corrections, it was observed that the predicted and experimental moisture content values for corn-oats and oats-wheat presented a good agreement. The difference between these values was less than 13% for all the combinations of corn-oats and oats-wheat.

In addition to the percent difference between the experimental and predicted values, a regression analysis was performed to determine the positive relationship between the predicted and experimental values. The regression analysis was selected because it is the most suitable statistical method to compare observed and predicted values. The regression analysis was done by plotting the experimental values in the X-axis and the predicted values in the Y-axis. If the model predicts perfectly the experimental data a straight line should be expected and its correlation coefficient will be 1, but this hypothetical condition does not occur. Therefore, the correlation coefficient is a good indicator of the relationship between the experimental and predicted values.

All combinations used on the validation with HDPE, with the exception of the oats individually packaged (84%), presented correlation values greater than 90%. This indicates that the model described accurately the systems used.

3.6. Validation 2 – Moisture Change in Cereals Packaged in LDPE 1 mil

An additional experimental validation for the computer model was carried out with a lower barrier packaging material. Monitoring the moisture content change of each component of the packaged mixtures over time was performed similarly to Validation 1. Table 4 summarizes the combinations used for the Experimental Validation 2.

Table 4 – Cereal combinations used for the Validation 2

Experiment	50/50	0/100
1	corn/wheat	/corn
2	corn/oats	/oats
3	oats/wheat	/wheat

Figures 18, 19 and 20 show the percent moisture change profile of 50/50 corn/wheat, corn/oats and oats/wheat samples. The percent moisture change profile for corn, oats and wheat is presented in Figures 21, 22 and 23.

The experimental and predicted values of the percent moisture content as a function of storage time for the cereal combinations (Table 4) are presented in Appendix F. Detailed tables of the individual pouches' weight gain values for all these combinations are presented in Appendix G.

For the validation with LDPE, the predicted and experimental moisture content values for individually packaged cereals present good agreement. All the samples showed a difference smaller than 10% with the exception of individually packaged wheat where the difference range was 6-13%.

The combinations of corn-oats and oats-wheat also present good agreement between the experimental and predicted values. The samples also showed the initial moisture exchange. Therefore, a similar treatment was applied to determine the initial moisture content to be entered into the computer program.

A regression analysis was also performed to determine the relationship between the predicted and experimental values. All combinations used on the validation with LDPE, with the exception of the oats individually packaged, presented correlation values greater than 90%. This indicates that the model has a high and significant relationship with what is observed in the experiments. A correlation value was not available for oats because the predicted moisture content value was constant during the storage. This reflect that the software did not account for the relative humidity variation in the storage room.

Both sets (validation with HDPE and LDPE) clearly indicate the importance of the consideration of initial moisture exchange in the application of the model. The time required for moisture exchange seems to be less important than the internal moisture equilibrium reached.

The moisture content can be calculated from the products' isotherms or determined experimentally in a glass jar. The resulting moisture content (from the above experiment) for the component with the lower water activity will be the lowest moisture content to be used in the computer program. For the component with the higher water activity, the outcoming moisture content will be the lowest moisture content to be entered in the computer program.

To find the resulting moisture content after the internal moisture exchange from the components' isotherms, the isotherms need to be expressed as water activity as a function of moisture content. The resulting water activity range is defined by the water activities of the components. The components also reach an equilibrium condition where the water activity is the same for each component. Therefore, selecting a moisture content for each component and replacing in its isotherms. This procedure is done until the moisture content values give the same water activity value.

Another way to find the resulting moisture content is to place the components in a glass jar and monitor the moisture headspace until equilibrium is reached. Then open the jara determined the moisture content of each component. This procedure was used and described earlier in this chapter.

Permeation through the package is present at all times, but the approximation discussed in the above paragraph could be used as a good approximation. Defining what is the minimum water activity difference between the components that will make the moisture exchange between products predominant over the permeation through the package is important.

In multicomponent products packaged in low-permeability packaging, the moisture exchange between the products is more noticeable than if they were packaged in high-permeability materials. This is because a low permeability packaging material will simulate glass.

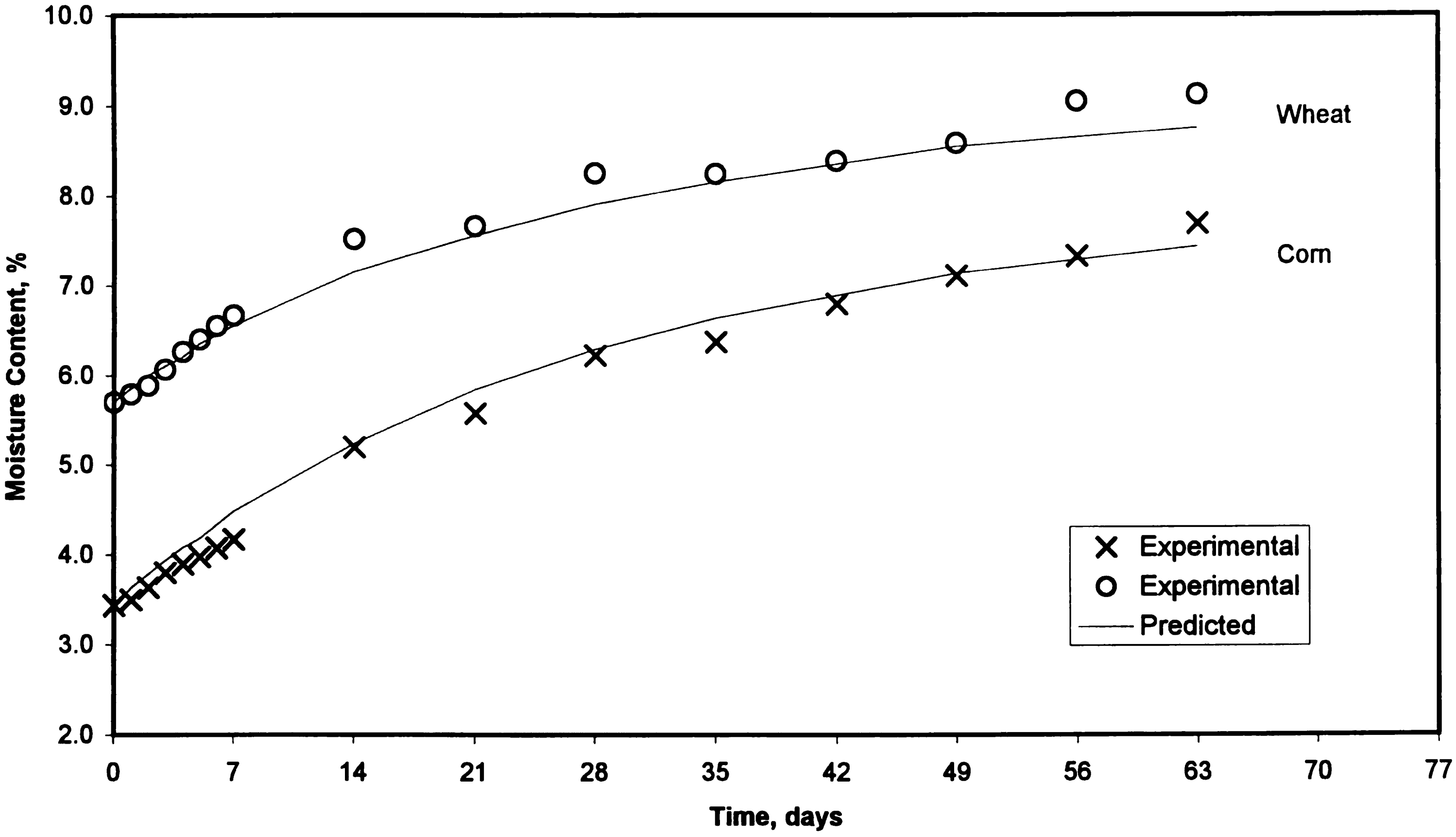

Figure 18: Experimental and Predicted Moisture Content Profile of 50/50 Corn-Wheat Mixtures for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

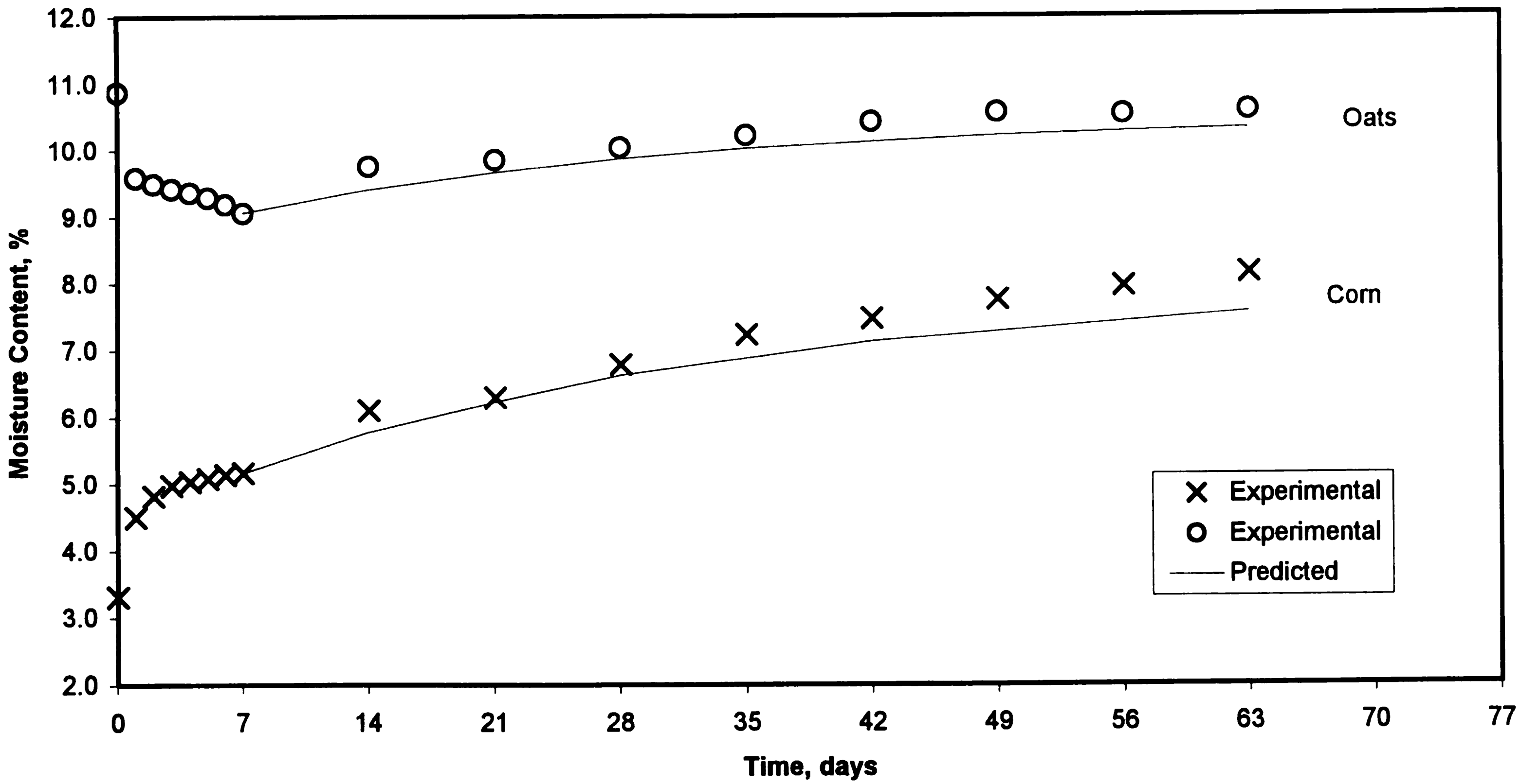

Figure 19: Experimental and Predicted Moisture Content Profile of 50/50 Corn-Oats Mixtures for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

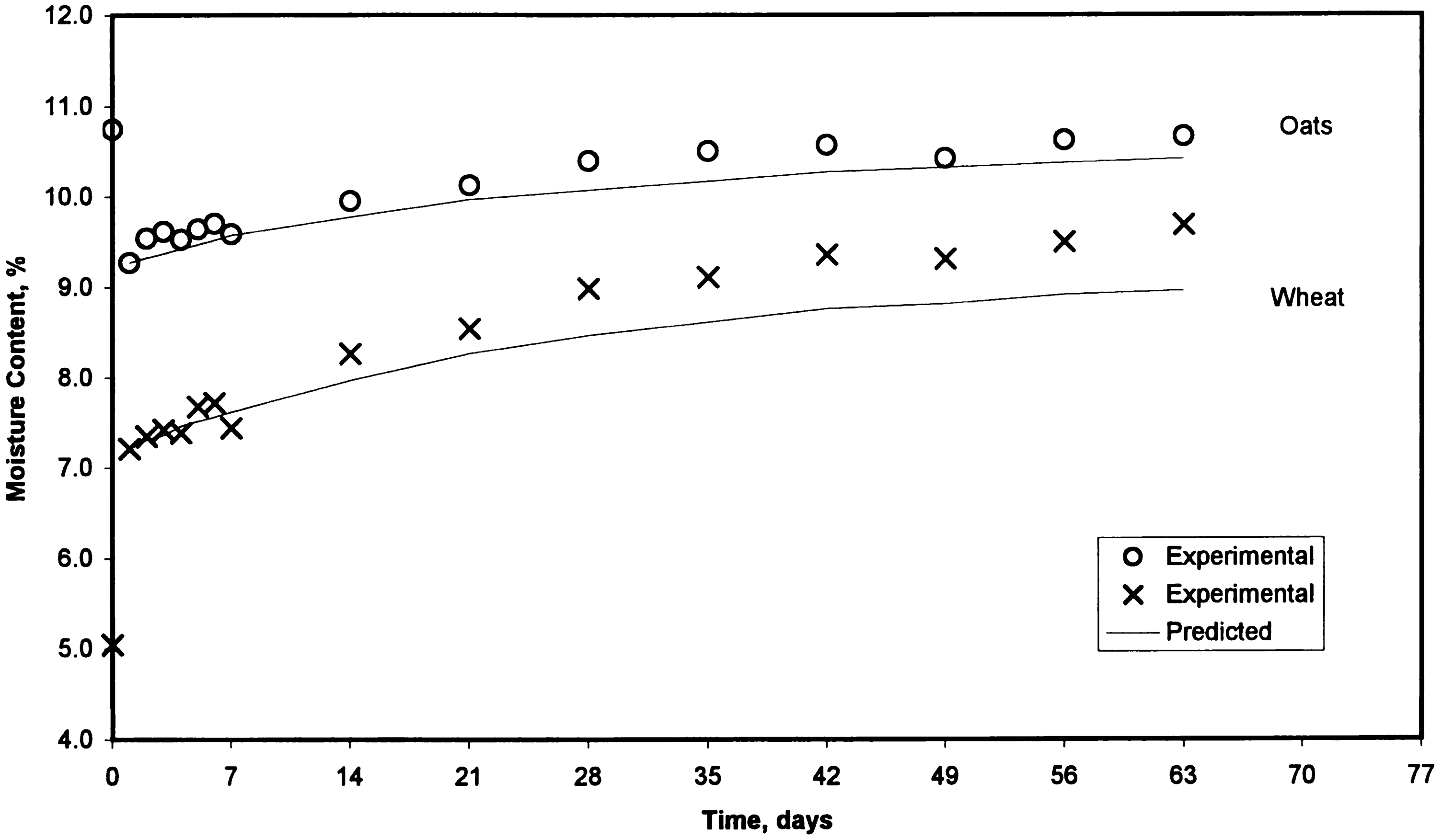

Figure 20: Experimental and Predicted Moisture Content Profile of 50/50 Oats-Wheat Mixtures for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

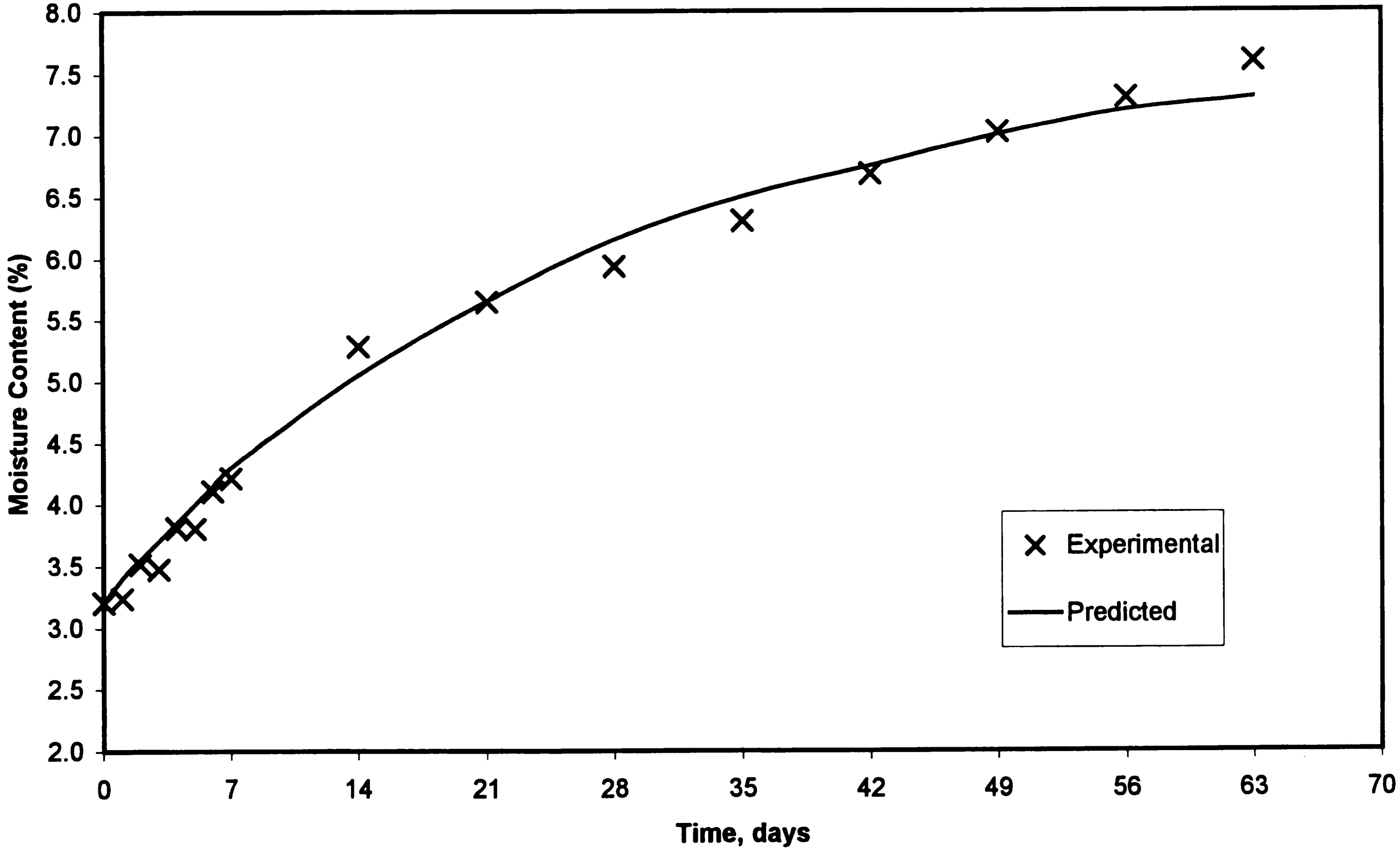

Figure 21: Experimental and Predicted Moisture Content Profile of 100/0 Corn for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

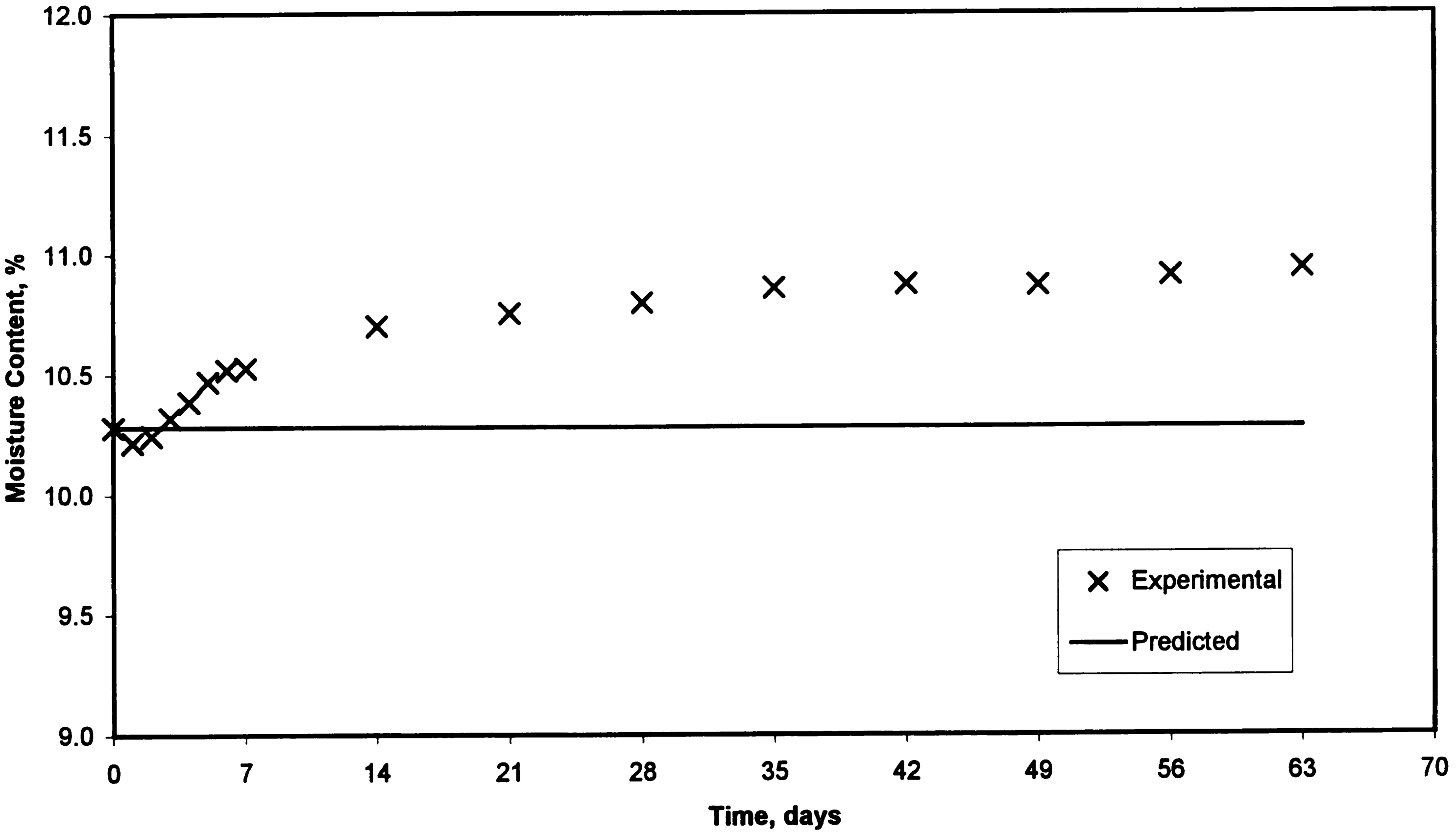

Figure 22: Experimental and Predicted Moisture Content Profile of 100/0 Oats for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

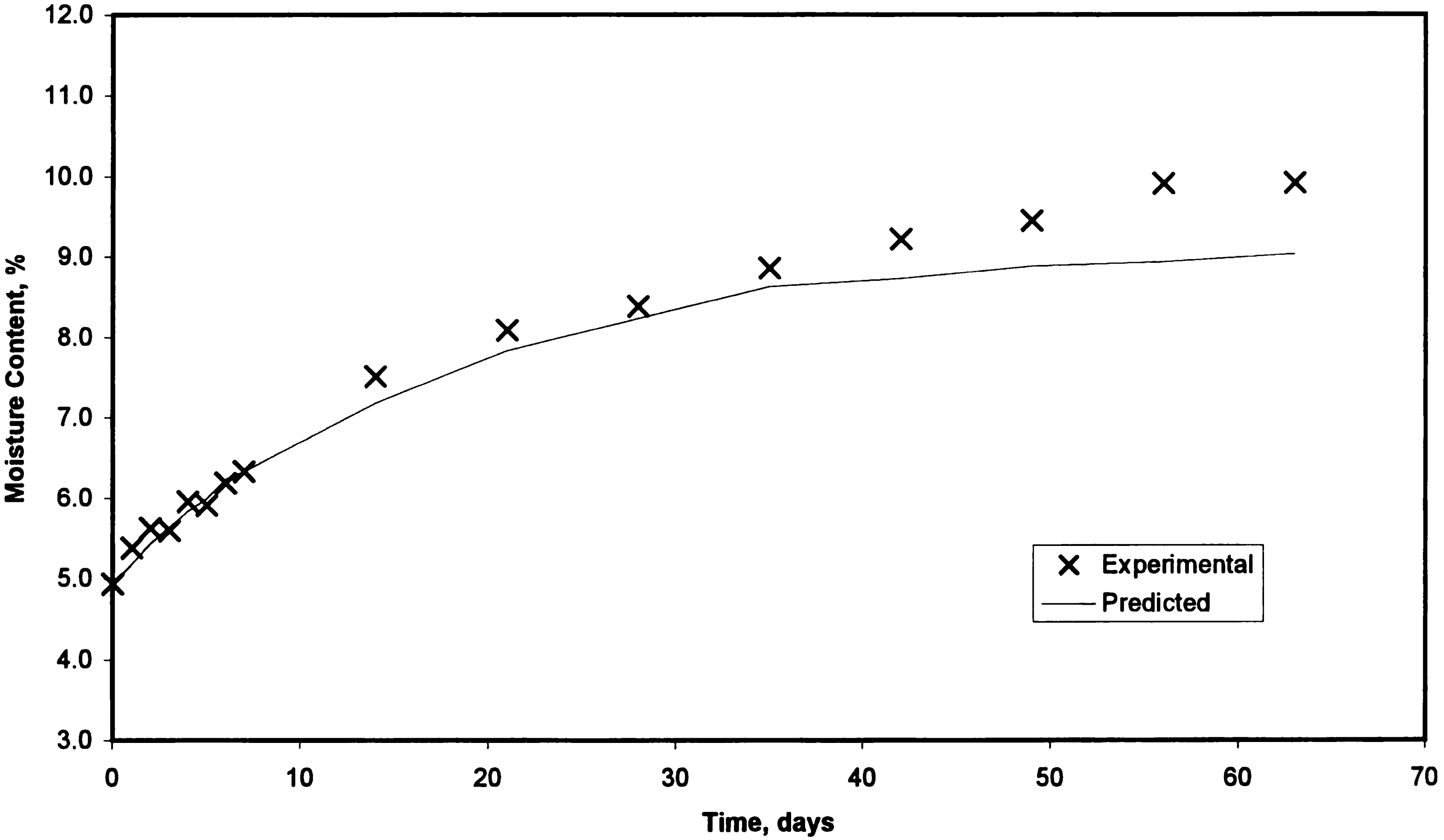

Figure 23: Experimental and Predicted Moisture Content Profile of 100/0 Wheat for Validation 2 (Conditions: 23°C - LDPE 1 mil - 50%RH).

CONCLUSIONS

1. A model developed using the GAB (Guggenheim-Anderson-deBoer) equation to predict moisture content in binary mixtures was validated
2. For products with a large difference in water activity, the internal moisture exchange is more important than the permeability during the first days of storage.
3. The model accuracy was greatly improved when the initial moisture exchange is accounted.

RECOMENDATIONS

Further refinement of the model should focus on the following:

1. Determining the minimum water activity difference between components that makes the moisture exchange between products predominant over the permeation through the package
2. Incorporating the moisture exchange between the components in the model for a more accurate prediction when they present very different water activity,
3. Studying the effect of the temperature on the moisture exchange as well as the moisture permeated during the storage.

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APPENDICES

APPENDIX A

DETERMINATION OF SHELF LIFE EQUATIONS USING A LINEAR AND NON-LINEAR SORPTION ISOTHERM

Pocas (1995) presented the following procedure to deduce the shelf life equation for mixed products packaged in permeable packages using linear and non-linear isotherms.

Moisture exchange is governed by the following equation.

$$\frac{dW}{dt} = \frac{P}{l} A \left(p_o - p_i\right) \qquad \text{(I)}$$

Where:

W: is the weight of water transported across the film

t: is time

P is the film permeability coefficient

l is the film thickness

p_o, p_i are the vapor pressure of the water outside and inside of the package, respectively

Moisture distribution in two products is controlled by the following equation.

$$dW = W_A\, dM_A + W_B\, dM_B \qquad \text{(II)}$$

Where:

W_A, W_B are the dry weights of components A and B, respectively

dM_A, dM_B are the change in moisture content of component A and B respectively, in g/g dry weight.

Combining the equations (I) and (II)

$$W_A\, dM_A + W_B\, dM_B = \frac{P}{l} A\, ps\, (a_{wo} - a_w)\, dt \qquad \text{(III)}$$

Where:

p_s is the water vapor pressure at the storage temperature

a_{wo}, a_w are the external and internal water activity, respectively

M_A and M_B are products' equilibrium moisture content at a_w

M_A and M_B are related to the a_w through the sorption isotherm equations.

Integrating equation (III) gives a relationship between time and moisture content of each component.

Linear sorption isotherms

The simplified case is when the moisture sorption isotherms of the components are represented by a linear equation within the water activity range under consideration:

$$M_A = a_A + b_A\, a_w \qquad \text{(IV)}$$

$$M_B = a_B + b_B\, a_w \qquad \text{(V)}$$

Where a_A, a_B, b_A and b_B are coefficients if the linear equation.

Derivating

$$dM_A = da_w\, .b_A \qquad \text{(VI)}$$

$$dM_B = da_w\, .\, b_B \qquad \text{(VII)}$$

Dividing equations (7) and (8) and rearranging the terms:

$$dM_A\, .\, b_B = dM_B .\, b_A \qquad \text{(VIII)}$$

Combining equation (8) with equation (3) and integrating gives:

$$t_A = \frac{1}{P.A.p_s}\left(W_A + W_B \frac{b_B}{b_A}\right)\int_{M_A^1}^{M_A^2} \frac{dM_A}{a_{WO} - a_W\left(M_A\right)} \qquad \text{(IX)}$$

$$t_B = \frac{1}{P.A.p_s}\left(W_A \frac{b_A}{b_B} + W_B\right)\int_{M_B^1}^{M_B^2} \frac{dM_B}{a_{WO} - a_W\left(M_B\right)} \qquad \text{(X)}$$

Where:

M_A^1 and M_B^1 are the initial moisture content of component A and B, respectively

t_A, and t_B represents the time required to achieve the moisture content M_A^2 and M_B^2, respectively.

The analytical integration of equations 9 and 10 gives:

$$t_A = \frac{1}{P.A.p_s}\left(W_A . b_A + W_B . b_B\right)\ln\left[\frac{a_{WO} - a_W\left(M_A^1\right)}{a_{WO} - a_W\left(M_A^2\right)}\right] \qquad \text{(XI)}$$

$$t_B = \frac{1}{P.A.p_s}\left(W_A . b_A + W_B . b_B\right)\ln\left[\frac{a_{WO} - a_W\left(M_B^1\right)}{a_{WO} - a_W\left(M_B^2\right)}\right] \qquad \text{(XII)}$$

Where:

$a_w(M_A)$ and $a_w(M_B)$ represent the head-space water activity, in equilibrium with the components' moisture content. Superscripts 1 and 2 refer respectively for initial and final moisture content conditions.

Non-linear sorption isotherm

When the linear equation does not represent accurately the sorption isotherm, the whole isotherm needs to be considered in the model and a numerical integration of equation (3) will be necessary.

Assuming that the sorption isotherm equations of components A and B are described by,

$$M_A = f(a_w) \qquad \text{(XIII)}$$

$$M_B = f(a_w) \qquad \text{(XIV)}$$

Where $f(a_w)$ and $g(a_w)$ are the sorption equations for component A and B, respectively.

Considering the inverse functions of the isotherms, a_w can be expressed as a function of the components' equilibrium moisture content, M_A and M_B, respectively:

$$a_w = f^{-1}(M_A) \qquad \text{(XV)}$$

$$a_w = g^{-1}(M_B) \qquad \text{(XVI)}$$

It is assumed that the moisture content between the two products is in equilibrium and therefore:

$$M_A = f\,[\,g^{-1}(M_B)] \qquad \text{(XVII)}$$

and

$$M_B = g\,[\,f^{-1}(M_A)] \qquad \text{(XVII)}$$

Therefore dM_B can be expressed as a function of dM_A:

$$dM_B = D\,dM_A \qquad \text{(XIX)}$$

Where the function D is defined as:

$$D(M_A) \equiv \frac{dM_B}{dM_A} = \frac{d[g[f^{-1}(M_A)]]}{dM_A} \qquad \text{(XX)}$$

The expression of dM_A as a function of dM_B gives:

$$D(M_B) \equiv \frac{dM_A}{dM_B} = \frac{d[f[g^{-1}(M_B)]]}{dM_B} \qquad \text{(XXI)}$$

The function D can be obtained analytically or numerically.

Equation (III) rearranged can then be integrated to calculate the shelf life or to predict the moisture content over storage time.

$$t_A = \frac{1}{P.A.p_s} \cdot \int_{M_A^1}^{M_A^2} \frac{W_A + W_B . D(M_A)}{a_{WO} - a_W(M_A)} dM_A \qquad \text{(XXII)}$$

$$t_B = \frac{1}{P.A.p_s} \cdot \int_{M_B^1}^{M_B^2} \frac{W_B + W_A . D(M_B)}{a_{WO} - a_W(M_B)} dM_B \qquad \text{(XXIII)}$$

where:

P = film permeability coefficient

l = film thickness

A = package surface area available for the moisture transfer

p_s = water vapor pressure at the storage temperature

W_A, W_B = dry weights of components A and B

dM_A, dM_B = change in moisture content of component A and B respectively

a_{wo} = external water activity

$a_w(M_A)$, $a_w(M_B)$ = head-space water activity, in equilibrium with the moisture content of component A and B, respectively

$M_A{}^1$, $M_A{}^2$, $M_B{}^1$ and $M_B{}^2$ = initial and final moisture content of component A and B respectively

t_A, t_B = time required to component A and B to achieve the moisture content $M_A{}^2$, $M_B{}^2$ respectively

$D(M_A)$, $D(M_B)$ = functions of M_A ,M_B relating the slopes of the components isotherms at each a_w.

Pocas stated also the following assumptions for the model that she developed:

(1) The shelf life of the mixture depends solely on the moisture content change of the components

(2) The storage temperature and relative humidity are constant

(3) The amount of water vapor in the package head-space is negligible compared with the products' moisture content

(4) Both components of the mixture reach fast equilibrium with the package's head space relative humidity

(5) The components do not show hysterisis behavior on moisture sorption isotherms

(6) The transfer of water through the package is always at a steady state

(7) The packaging material controls the rate of water transfer

(8) Moisture is independently bonded to each component according to its sorption isotherm.

APPENDIX B

PACKAGING MATERIALS CHARACTERIZATION

1. Film Thickness

Ten measurements of film thickness were performed to verify the value provided by the manufacturer. The average values are presented below.

LDPE Film: 1.15 ± 0.09 mil

HDPE Film: 1.85 ± 0.09 mil

2. Materials water vapor transmission rate (g/m2.day) and permeability (g.mil/m^2.day.mmHg) at 23°C. Infrared Sensor Method.

Four flat samples were tested to determine the permeance and permeability of the films. Results are compiled below.

Table B1 – Permeance (g/m^2.day) and Permeability (g.mil/m^2.day.mmHg) at 23°C for flat LDPE samples.

Sample	Permeance, g/m^2.day	Permeability, g.mil/m^2.day.mmHg
1	1.350	8.80E-05
2	1.531	1.02E-04
3	1.536	9.80E-05
4	1.395	9.29E-05
Average	**1.453**	**9.52E-05**
Std. Dev.	9.48E-02	6.08E-06

Table B2 – Permeance (g/m^2.day) and Permeability (g.mil/m^2.day.mmHg) at 23°C for flat HDPE samples.

Sample	Permeance, g/m^2.day	Permeability, g.mil/m^2.day.mmHg
1	1.350	8.80E-05
2	1.531	1.02E-04
3	1.536	9.80E-05
4	1.395	9.29E-05
Average	**1.453**	**9.52E-05**
Std. Dev.	9.48E-02	6.08E-06

3. Materials water vapor transmission rate (g/m2.day) and permeability (g.mil/m^2.day.mmHg) at 23°C. Gravimetric Method.

Four pouch samples were tested to determine the transmission rate and permeability of the films. The results are compiled in the next page.

Table B3 – Water Vapor Transmission Rate (g/day) and Permeability ($g.mil/m^2.day.mmHg$) at 23°C for LDPE pouches.

Sample	Transmission Rate, g/ day	Permeability, $g.mil/m^2.day.mmHg$
1	0.0324	6.15E-05
2	0.0286	5.44E-05
3	0.0370	6.64E-05
4	0.0396	7.13E-05
Average	**0.0327**	**6.34E-05**
Std. Dev.	0.0042	6.05E-06

Table B4 – Water Vapor Transmission Rate (g/day) and Permeability ($g.mil/m^2.day.mmHg$) at 23°C for HDPE pouches.

Sample	Permeance, $g/m^2.day$	Permeability, $g.mil/m^2.day.mmHg$
1	0.0115	4.15E-05
2	0.0120	4.34E-05
3	0.0121	4.13E-05
4	0.0119	3.87E-05
Average	**0.0119**	**4.20E-05**
Std. Dev.	0.0003	1.16E-06

Experimental data for packaging permeance determination by the gravimetric method.

APPENDIX C

PARAMETER ESTIMATION OF GAB EQUATION

The Guggenheim-Anderson-deBoer (GAB) equation (Eq. C1) was transformed into quadratic form to easily estimate GAB parameters.

$$\frac{M}{W_m} = \frac{C K a_w}{(1 - k a_w)(1 - k a_w + C k a_w)} \qquad \text{(C1)}$$

$$\frac{W_m C K a_w}{M} = 1 - k a_w + C k a_w - k a_w + k^2 a_w{}^2 - C k^2 a_w{}^2 \qquad \text{(C2)}$$

$$\frac{a_w}{M} = \frac{k}{W_m}\left(\frac{1}{C} - 1\right) a_w{}^2 + \frac{1}{W_m}\left(1 - \frac{2}{C}\right) a_w + \frac{1}{W_m C k} \qquad \text{(C3)}$$

Assigning

$$\alpha = \frac{k}{W_m}\left(\frac{1}{C} - 1\right) = \frac{1}{W_m C}(1 - C) \qquad \text{(C4)}$$

$$\beta = \frac{1}{W_m}\left(1 - \frac{2}{C}\right) = \frac{1}{W_m C}(C - 2) \qquad \text{(C5)}$$

$$\gamma = \frac{1}{W_m C k} \qquad \text{(C6)}$$

Eq. C3 is rewritten as:

$$\frac{a_w}{M} = \alpha a_w{}^2 + \beta a_w + \gamma \qquad \text{(C7)}$$

Eq. C7 was plotted as a_w vs a_w/M (X vs Y) and from the quadratic regression the constants α, β and γ were obtained. The value of these constants is used to calculate the GAB constants: C, W_m, and k. The calculations are presented below.

Substituting Eq C4 into Eq C5 gives

$$k = -\frac{\alpha\ (C-2)}{\beta\ (C-1)} \tag{C8}$$

Substituting Eq C8 into Eq C5 gives

$$\frac{1}{W_m} = -\frac{\alpha\gamma\ \ (C-2)C}{\beta\ (C-1)} \tag{C9}$$

Substituting Eq C9 into Eq C5 gives

$$\frac{\beta^2}{(-\alpha)\gamma} = \frac{(C^2-4C+4)}{(C-1)} \tag{C10}$$

Assigning: $$X = \frac{\beta^2}{(-\alpha)\gamma}$$

Eq C10 can be rewritten as

$$C^2 - (4+X)\ C + (4+X) = 0 \tag{C11}$$

Assigning: $$\theta = 4 + X = 4 + \frac{\beta^2}{(-\alpha)\gamma}$$

Eq. C11 can be solved as:

$$C = \frac{\theta \pm \sqrt{\theta - 4\theta}}{2}$$

This quadratic solution presented gives two mathematical solutions for C, but the solution of C that gives positive values for all GAB constants is correct. Parameter W_m and k can be obtained by subsitution of C into Eq C5 and C6.

APPENDIX D

COMPUTER PROGRAM VALIDATION

1. Model Development

The model used to create the computer program was developed by Pocas (1995). The researcher worked with the Henderson, Chen, Oswin, Halsey and GAB moisture sorption isotherms for modeling the moisture of two component food products. The researcher also prepared a DOS computer program where immediate calculations were done. The model prepared by Pocas (1995) was discussed in Chapter 2 and is explained in detail in Appendix A.

A windows-based program was prepared to calculate the shelf life of two-component food products using the model developed by Pocas (1995) for linear and non-linear isotherms. In addition, the computer program prepared in this research has the option to work with a single product.

2. Model Validation

The data used to verify the operational characteristics of the computer program were taken from Pocas' (1995) work. The results obtained with the new computer program were compared with the ones reported by Pocas (1995) and a difference of ± 1.25% was found. Therefore, it was concluded that the computer program was accurate in its calculations.

The Halsey and GAB equations for cracker and raisin at 20°C, respectively, included in the literature by Pocas (1995), were used to generate the data that were entered in the computer program. The data entered to build the moisture sorption isotherm are presented in the next page.

Cracker		Raisin	
aw	M	aw	M
0.10	0.0510	0.10	0.0260
0.18	0.0600	0.18	0.0466
0.28	0.0700	0.28	0.0712
0.37	0.0800	0.37	0.0964
0.45	0.0900	0.45	0.1222
0.52	0.1000	0.52	0.1489
0.58	0.1100	0.58	0.1765
0.63	0.1200	0.63	0.2050
0.68	0.1300	0.68	0.2344
0.71	0.1400	0.71	0.2645
0.74	0.1500	0.74	0.2953
0.77	0.1600	0.77	0.3265
0.79	0.1700	0.79	0.3582
0.81	0.1800	0.81	0.3901
0.83	0.1900	0.83	0.4222
0.84	0.2000	0.84	0.4543
0.89	0.2500	0.89	0.6123
0.92	0.3000	0.92	0.7597

Table D.1 – aw and M (g/g) values used to obtain the cereal and raisin isotherms at 20°C

The program was run with the same four sets of data presented by Pocas (1995). The runs were designed to understand how the program can facilitate the analysis of the components' weight ratio, storage water activity, packaging barrier properties and total weight to the packaging area ratio in the storage stability curves prediction. The conditions used for the computer simulation are presented in Table D.2.

Run	cracker wt, g	raisin wt, g	total wt, g	a_w	l, mil	P, g.mil/in^2.day.mmHg	Area, in^2
Set A: To evaluate the influence of components weight ratio							
1	10	20	30	0.80	0.985	3.81E-05	69.75
2	15	15	30	0.80	0.985	3.81E-05	69.75
3	20	10	30	0.80	0.985	3.81E-05	69.75
Set B: To evaluate the influence of storage water actvity							
1	15	15	30	0.80	0.985	3.81E-05	69.75
2	15	15	30	0.75	0.985	3.81E-05	69.75
3	15	15	30	0.70	0.985	3.81E-05	69.75
Set C: To evaluate the influence of packaging barrier properties							
1	15	15	30	0.80	0.985	6.35E-05	69.75
2	15	15	30	0.80	0.985	3.81E-05	69.75
3	15	15	30	0.80	1.182	3.81E-05	69.75
Set D: To evaluate the influence of total weight to packaging area ratio							
1	15	15	30	0.80	0.985	3.81E-05	69.75
2	20	20	40	0.80	0.985	3.81E-05	69.75
3	25	25	50	0.80	0.985	3.81E-05	77.50

Table D.2 – Conditions used in the computer simulation

The initial moisture content of the cracker and raisin are 0.077 g/g and 0.090 g/g respectively and the temperature selected was 20°C. The isotherms were obtained at the same temperature.

Figures D.1 – D.3 show the moisture content profile generated by the computer model for the conditions presented in Table D.2. Values in Table D.2 and Figures D.1 – D.3 are equivalent to the ones presented by Pocas (1995).

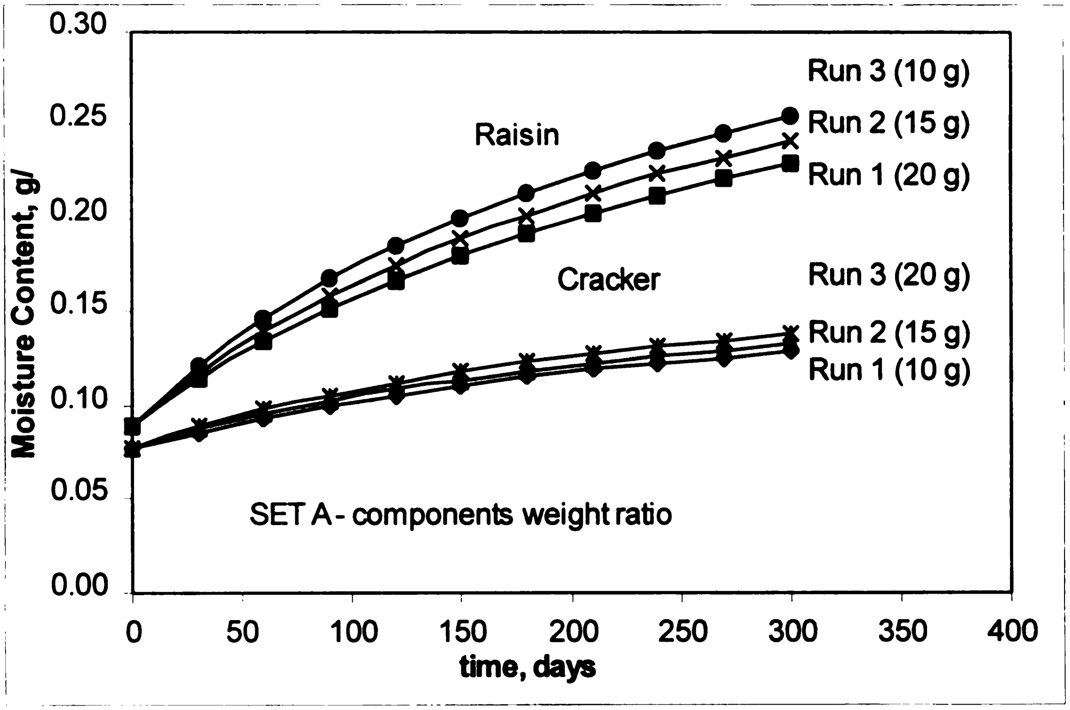

Figure D.1 - Moisture content profile for different components weight ratio.

Note: Predicted values using set data A from Table D.2.

From Figure D.1, it is observed that increasing the ratio of the lower moisture component (Run 3) causes a higher moisture uptake of the mixture. This information would be useful to study the influence of mixture formulation in shelf life.

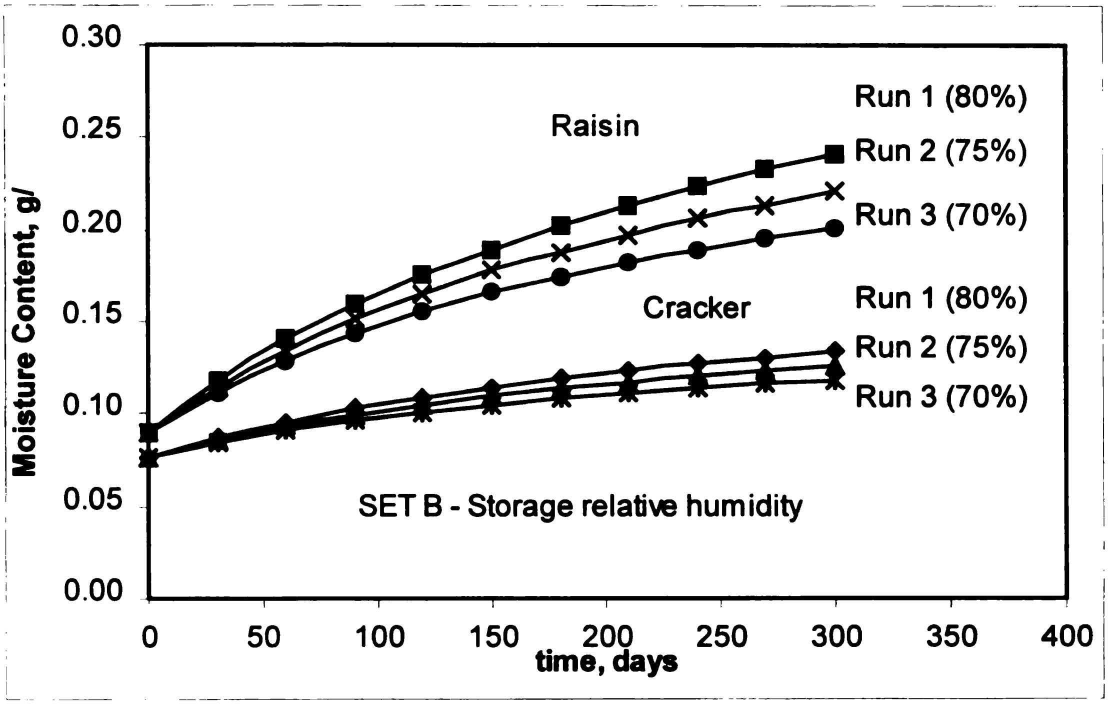

Figure D.2 - Moisture content profile for different storage water activities.

Note: Predicted values using set data B from Table D.2.

From Figure D.2, it is observed that higher relative humidity storage conditions (Run 1) increase the moisture uptake. Knowing the highest and lowest expected storage relative humidity, the upper and lower limits of moisture uptake could be predicted and then the selection of the necessary package barrier can be made.

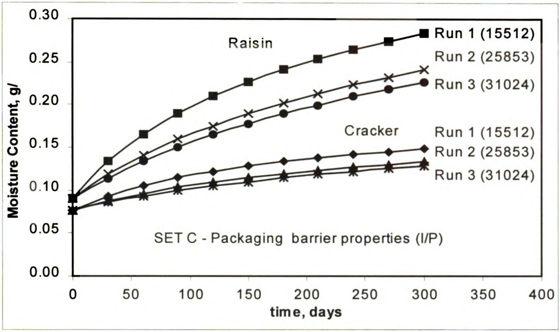

Figure D.3 - Moisture content profile for different packaging barrier properties(l/P).

Note: Predicted values using set data C from Table D.2.

From Figure D.3, it is observed that the lower the packaging resistance to moisture transfer (Run 1); defined as the ration thickness/Permeability (l/P), the higher the moisture uptake. This information could be used to define the lower and the upper limits of packaging barrier properties when selecting film material or film thickness.

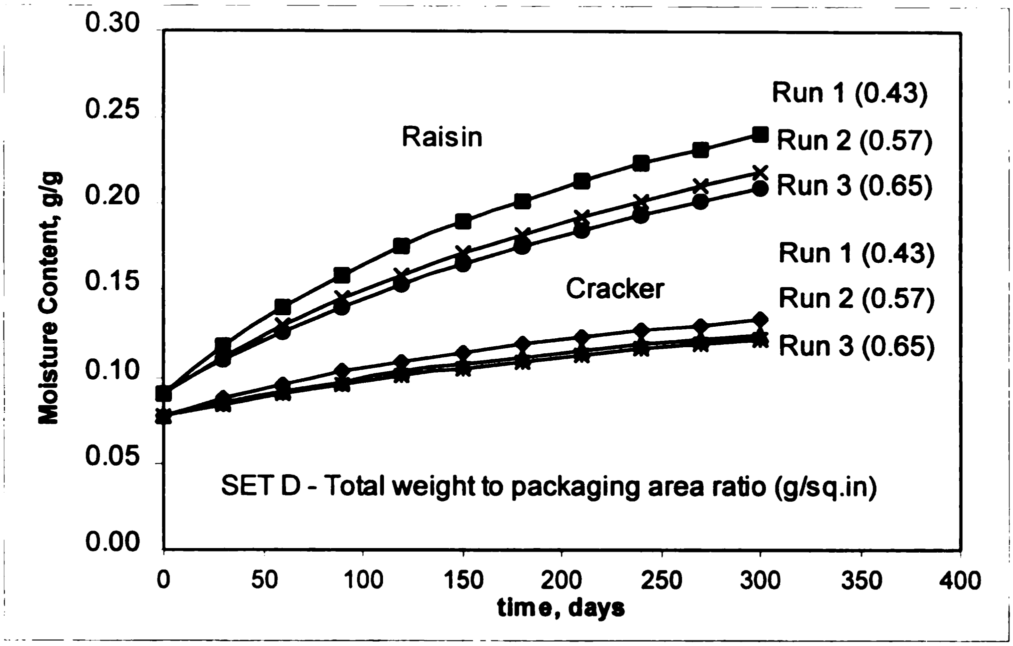

Figure D.4 - Moisture content profile for different total weight to packaging area ratio.

Note: Predicted values using set data D from Table D.2.

From Figure D.4, it is noticed that increasing the ratio total weight to the packaging area (Run 3) would reduce moisture pickup of each component for a selected time.

It is important to mention that the model assumes that the mixed products are in equilibrium at all times and it also assumes that moisture is independently bonded to each product because there are no interactions among the products. The validity of the model assumptions would make the predictions accurate and the computer program a useful tool for packaging design and optimization.

The computer program validation was performed with the data presented in tables D.1 and D.2.

APPENDIX E

MOISTURE SORPTION ISOTHERM DATA FOR THE CEREALS

Point	Water Activity	Corn	Oats	Wheat
1	0.053	0.0153	0.0268	0.0293
2	0.112	0.0268	0.0488	0.0388
3	0.251	0.0401	0.0720	0.0548
4	0.330	0.0516	0.0851	0.0673
5	0.478	0.0801	0.1042	0.0954
6	0.615	0.1135	0.1228	0.1171
7	0.760	0.1645	0.1357	0.1420
8	0.808	0.2046	0.1503	0.1654
9	0.878	0.2819	0.1810	0.2166

Table E.1: Equilibrium Moisture Content (Me, g/g) of Corn, Oats and Wheat at Nine Different Water Activities.

APPENDIX F

MOISTURE PROFILE FOR THE EXPERIMENTAL AND PREDICTED CERAL MIXTURES

Table F1 - Experimental and Predicted Moisture Content (%) of 33/67 corn-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
0	2.25	4.38	2.25	4.38	0	0
1	2.33	4.43	2.35	4.48	1	1
2	2.17	4.38	2.40	4.53	10	3
3	2.26	4.56	2.45	4.58	8	1
4	2.49	4.68	2.50	4.63	0	1
5	2.57	4.85	2.55	4.68	1	3
6	2.58	4.79	2.60	4.78	1	0
7	2.60	4.85	2.65	4.83	2	0
14	2.79	5.11	3.05	5.18	9	1
21	2.99	5.54	3.45	5.53	15	0
28	3.33	5.65	3.80	5.83	14	3
35	3.38	5.77	4.10	6.13	21	6
42	3.53	6.05	4.40	6.38	25	5
49	3.74	6.45	4.70	6.58	26	2
56	4.24	6.75	4.95	6.83	17	1
63	4.58	7.38	5.20	6.98	14	5

	Corn	Wheat
Correlation Coefficient	0.9821	0.9810
Significance	<0.0001	<0.0001

Table F2 - Experimental and Predicted Moisture Content (%) of 50/50 corn-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
0	2.67	4.71	2.67	4.71	0	0
1	2.80	4.75	2.77	4.81	1	1
2	2.87	4.98	2.82	4.86	2	2
3	2.91	4.95	2.87	4.91	1	1
4	2.98	5.18	2.92	4.96	2	4
5	3.10	5.35	2.97	5.01	4	6
6	3.37	5.40	3.07	5.06	9	6
7	3.34	5.40	3.12	5.16	7	4
14	3.68	5.74	3.52	5.51	4	4
21	3.74	5.95	3.87	5.81	3	2
28	4.20	6.27	4.22	6.11	0	3
35	4.34	6.41	4.52	6.41	4	0
42	4.56	6.57	4.82	6.61	6	1
49	4.68	6.89	5.07	6.86	8	0
56	4.89	6.97	5.27	7.01	8	1
63	5.20	7.22	5.52	7.21	6	0

	Corn	Wheat
Correlation Coefficient	0.9913	0.9895
Significance	<0.0001	<0.0001

Table F3 - Experimental and Predicted Moisture Content (%) of 67/33 corn-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
0	2.77	4.49	2.77	4.49	0	0
1	2.93	4.63	2.87	4.59	2	1
2	2.91	4.74	2.92	4.64	0	2
3	3.10	4.68	2.97	4.69	4	0
4	3.20	4.76	3.02	4.79	6	1
5	3.32	4.81	3.12	4.84	6	1
6	3.34	4.95	3.17	4.89	5	1
7	3.40	5.08	3.22	4.94	5	3
14	3.58	5.30	3.62	5.34	1	1
21	3.87	5.60	3.97	5.69	2	2
28	4.18	5.74	4.32	5.99	3	4
35	4.39	6.02	4.62	6.29	5	5
42	4.48	6.11	4.87	6.54	9	7
49	4.68	6.41	5.12	6.74	9	5
56	4.93	6.35	5.37	6.94	9	9
63	5.37	6.56	5.57	7.14	4	9

	Corn	Wheat
Correlation Coefficient	0.9912	0.9942
Significance	<0.0001	<0.0001

Table F4 - Experimental and Predicted Moisture Content (%) of 33/67 corn-oats samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Oats	Corn	Oats	Corn	Oats
0	2.67	10.50				
1	3.11	8.61				
2	3.59	8.23	3.59	8.23	0	0
3	3.92	8.33	3.64	8.28	7	1
4	4.13	8.68	3.69	8.33	11	4
5	4.19	8.69	3.74	8.33	11	4
6	4.27	8.88	3.79	8.38	11	6
7	4.36	9.04	3.84	8.43	12	7
14	4.52	9.16	4.14	8.58	8	6
21	4.67	9.33	4.44	8.78	5	6
28	4.90	9.58	4.69	8.93	4	7
35	5.18	9.77	4.94	9.08	5	7
42	5.46	9.92	5.14	9.18	6	7
49	5.77	10.04	5.39	9.33	7	7
56	5.95	10.31	5.59	9.43	6	9
63	6.44	10.45	5.79	9.53	10	9

	Corn	Oats
Correlation Coefficient	0.9827	0.9812
Significance	<0.0001	<0.0001

Table F5 - Experimental and Predicted Moisture Content (%) of 50/50 corn-oats samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Oats	Corn	Oats	Corn	Oats
0	2.77	10.50				
1	3.31	8.08				
2	3.28	8.09				
3	3.43	8.32				
4	3.56	8.04				
5	3.65	7.98				
6	3.65	8.20				
7	3.76	7.92	3.76	7.92	0	0
14	3.80	8.20	4.11	8.17	8	0
21	3.98	8.35	4.41	8.42	11	1
28	4.77	8.51	4.66	8.62	2	1
35	4.71	8.59	4.91	8.77	4	2
42	5.21	8.85	5.16	8.92	1	1
49	5.40	8.88	5.36	9.07	1	2
56	5.63	9.06	5.56	9.17	1	1
63	5.85	9.25	5.66	9.27	3	0

	Corn	Oats
Correlation Coefficient	0.9759	0.9884
Significance	<0.0001	<0.0001

Table F6 - Experimental and Predicted Moisture Content (%) of 67/33 corn-oats samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Oats	Corn	Oats	Corn	Oats
0	2.77	10.50				
1	3.28	6.70				
2	3.32	5.71	3.32	5.71	0	0
3	3.36	6.15	3.42	5.81	2	6
4	3.41	6.48	3.47	5.86	2	10
5	3.45	6.69	3.47	5.96	1	11
6	3.49	6.68	3.52	6.01	1	10
7	3.60	7.02	3.57	6.11	1	13
14	3.96	7.04	3.92	6.51	1	7
21	3.99	7.20	4.22	6.91	6	4
28	4.06	7.58	4.52	7.26	11	4
35	4.43	7.42	4.77	7.61	8	3
42	4.66	7.77	5.02	7.86	8	1
49	5.32	8.22	5.22	8.11	2	1
56	5.22	7.75	5.47	8.36	5	8
63	5.66	7.92	5.62	8.51	1	7

	Corn	Oats
Correlation Coefficient	0.9774	0.9169
Significance	<0.0001	<0.0001

Table F7 - Experimental and Predicted Moisture Content (%) of 33/67 oats-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Oats	Wheat	Oats	Wheat	Oats	Wheat
0	10.62	4.49				
1	7.35	5.46				
2	6.39	5.52	6.39	5.52	0	0
3	6.90	5.58	6.49	5.57	6	0
4	6.88	5.77	6.54	5.62	5	3
5	6.86	5.82	6.59	5.67	4	2
6	7.03	5.75	6.64	5.72	6	1
7	7.02	5.80	6.69	5.77	5	1
14	7.35	6.11	7.09	6.07	3	1
21	7.50	6.51	7.44	6.32	1	3
28	7.62	6.84	7.74	6.57	2	4
35	7.80	7.10	7.99	6.77	2	5
42	7.83	7.36	8.24	6.97	5	5
49	7.98	7.71	8.44	7.17	6	7
56	8.15	7.85	8.64	7.32	6	7
63	8.34	8.10	8.84	7.47	6	8

	Oats	Wheat
Correlation Coefficient	0.9756	0.9975
Significance	<0.0001	<0.0001

Table F8 - Experimental and Predicted Moisture Content (%) of 50/50 oats-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Oats	Wheat	Oats	Wheat	Oats	Wheat
0	10.62	4.60				
1	8.38	6.52				
2	8.11	6.46				
3	7.85	6.54	7.85	6.54	0	0
4	8.19	6.52	7.90	6.59	4	1
5	8.04	6.56	7.95	6.64	1	1
6	7.95	6.60	8.00	6.64	1	1
7	7.99	6.56	8.05	6.69	1	2
14	8.37	6.74	8.30	6.89	1	2
21	8.74	6.88	8.50	7.09	3	3
28	8.83	6.95	8.70	7.29	1	5
35	9.05	7.28	8.85	7.44	2	2
42	9.17	7.67	9.05	7.59	1	1
49	9.25	7.79	9.15	7.74	1	1
56	9.35	7.91	9.30	7.84	1	1
63	9.59	8.26	9.40	7.99	2	3

	Oats	Wheat
Correlation Coefficient	0.9857	0.9751
Significance	<0.0001	<0.0001

Table F9 - Experimental and Predicted Moisture Content (%) of 67/33 oats-wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Oats	Wheat	Oats	Wheat	Oats	Wheat
0	10.62	4.49				
1	9.13	6.32				
2	8.53	6.41	8.53	6.41	0	0
3	8.85	6.57	8.58	6.46	3	2
4	8.81	6.65	8.63	6.51	2	2
5	9.13	6.55	8.63	6.51	5	1
6	9.07	6.58	8.68	6.56	4	0
7	9.39	6.88	8.68	6.61	8	4
14	9.80	7.06	8.88	6.81	9	4
21	9.55	7.11	9.03	7.01	5	1
28	9.66	7.14	9.13	7.21	5	1
35	9.82	7.24	9.28	7.36	6	2
42	10.07	7.59	9.38	7.51	7	1
49	10.26	7.83	9.48	7.66	8	2
56	10.21	7.80	9.58	7.76	6	1
63	10.66	8.04	9.68	7.91	9	2

	Oats	Wheat
Correlation Coefficient	0.9472	0.9793
Significance	<0.0001	<0.0001

Table F10 - Experimental and Predicted Moisture Content (%) of Corn, Oats and Wheat samples for validation with HDPE (Each table value is the average of two determinations)

Day	Corn			Oats			Wheat		
	Experimental	Predicted	% Difference	Experimental	Predicted	% Difference	Experimental	Predicted	% Difference
0	2.40	2.40	0	10.31	10.31	0	3.63	3.63	0
1	2.54	2.50	1	10.40	10.36	0	3.75	3.68	2
2	2.68	2.55	5	10.41	10.36	0	3.85	3.73	3
3	2.77	2.60	6	10.52	10.36	1	4.08	3.78	7
4	2.92	2.65	9	10.52	10.36	2	4.14	3.83	8
5	2.91	2.70	7	10.53	10.36	2	4.13	3.88	6
6	2.89	2.75	5	10.52	10.36	2	4.18	3.93	6
7	3.00	2.80	7	10.46	10.36	1	4.39	3.98	9
14	3.17	3.10	2	10.55	10.36	2	4.81	4.28	11
21	3.52	3.45	2	10.66	10.36	3	5.12	4.58	11
28	3.55	3.75	6	10.72	10.36	3	5.20	4.88	6
35	3.68	4.00	9	10.79	10.36	4	5.23	5.13	2
42	3.67	4.25	16	10.84	10.41	4	5.43	5.38	1
49	3.69	4.50	22	10.87	10.41	4	5.55	5.63	1
56	3.94	4.70	19	10.85	10.41	4	5.96	5.83	2
63	4.39	4.95	13	10.85	10.41	4	6.22	6.08	2

	Corn	Oats	Wheat
Correlation Coefficient	0.9660	0.8364	0.9774
Significance	<0.0001	<0.0001	<0.0001

Table F11 - Experimental and Predicted Moisture Content (%) of 50/50 corn-wheat samples for validation with LDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Wheat	Corn	Wheat	Corn	Wheat
0	3.43	5.70	3.43	5.70	0	0
1	3.49	5.79	3.63	5.85	4	1
2	3.63	5.88	3.78	6.00	4	2
3	3.80	6.06	3.93	6.10	3	1
4	3.89	6.26	4.08	6.20	5	1
5	3.98	6.40	4.18	6.35	5	1
6	4.07	6.54	4.33	6.45	6	1
7	4.17	6.66	4.48	6.55	8	2
14	5.19	7.51	5.23	7.15	1	5
21	5.57	7.66	5.83	7.55	5	1
28	6.21	8.24	6.28	7.90	1	4
35	6.36	8.24	6.63	8.15	4	1
42	6.79	8.38	6.88	8.35	1	0
49	7.10	8.58	7.13	8.55	0	0
56	7.32	9.05	7.28	8.65	0	4
63	7.68	9.12	7.43	8.75	3	4

	Corn	Wheat
Correlation Coefficient	0.9966	0.9945
Significance	<0.0001	<0.0001

Table F12 - Experimental and Predicted Moisture Content (%) of 50/50 corn-oats samples for validation with LDPE (Each table value is the average of two determinations)

Day	Experimental		Predicted		% Difference	
	Corn	Oats	Corn	Oats	Corn	Oats
0	3.31	10.86				
1	4.50	9.59				
2	4.82	9.49				
3	4.97	9.42				
4	5.03	9.36				
5	5.08	9.29				
6	5.13	9.19				
7	5.16	9.06	5.16	9.06	0	0
14	6.09	9.76	5.76	9.41	5	4
21	6.28	9.84	6.21	9.66	1	2
28	6.77	10.03	6.61	9.86	2	2
35	7.21	10.20	6.86	10.01	5	2
42	7.45	10.41	7.11	10.11	5	3
49	7.74	10.55	7.26	10.21	6	3
56	7.95	10.52	7.41	10.26	7	3
63	8.15	10.58	7.56	10.31	7	3

	Corn	Oats
Correlation Coefficient	0.9934	0.9845
Significance	<0.0001	<0.0001

Table F13 - Experimental and Predicted Moisture Content (%) of 50/50 oats-wheat samples for validation with LDPE (Each table value is the average of two determinations)

Day	Experimental		**Predicted**		% Difference	
	Oats	Wheat	Oats	Wheat	Corn	Oats
0	10.74	5.04				
1	9.27	7.21	9.27	7.21	0	0
2	9.53	7.34	9.32	7.31	2	0
3	9.61	7.42	9.37	7.36	3	1
4	9.52	7.39	9.42	7.46	1	1
5	9.64	7.67	9.47	7.51	2	2
6	9.70	7.71	9.52	7.56	2	2
7	9.58	7.44	9.57	7.61	0	2
14	9.95	8.26	9.77	7.96	2	4
21	10.13	8.53	9.97	8.26	2	3
28	10.39	8.98	10.07	8.46	3	6
35	10.50	9.11	10.17	8.61	3	5
42	10.56	9.35	10.27	8.76	3	6
49	10.42	9.31	10.32	8.81	1	5
56	10.62	9.50	10.37	8.91	2	6
63	10.66	9.68	10.42	8.96	2	7

	Oats	Wheat
Correlation Coefficient	0.9838	0.9940
Significance	<0.0001	<0.0001

Table F14 - Experimental and Predicted Moisture Content (%) of Corn, Oats and Wheat samples for validation with LDPE (Each table value is the average of two determinations)

Day	Corn			Oats			Wheat		
	Experimental	Predicted	% Difference	Experimental	Predicted	% Difference	Experimental	Predicted	% Difference
0	3.20	3.20	0	10.28	10.28	0	4.93	4.93	0
1	3.24	3.40	5	10.21	10.28	1	5.38	5.13	5
2	3.52	3.55	1	10.24	10.28	0	5.62	5.28	6
3	3.47	3.70	6	10.32	10.28	0	5.59	5.43	3
4	3.81	3.85	1	10.39	10.28	1	5.95	5.58	6
5	3.80	4.00	5	10.47	10.28	2	5.90	5.73	3
6	4.11	4.15	1	10.52	10.28	2	6.18	5.83	6
7	4.21	4.30	2	10.53	10.28	2	6.33	5.98	5
14	5.28	5.05	4	10.70	10.28	4	7.51	6.73	10
21	5.64	5.65	0	10.75	10.28	4	8.08	7.28	10
28	5.93	6.15	4	10.80	10.28	5	8.38	7.73	8
35	6.30	6.50	3	10.86	10.28	5	8.85	8.03	9
42	6.68	6.75	1	10.87	10.28	5	9.22	8.28	10
49	7.02	7.00	0	10.87	10.28	5	9.45	8.48	10
56	7.30	7.20	1	10.91	10.28	6	9.91	8.63	13
63	7.59	7.30	4	10.94	10.28	6	9.92	8.73	12

	Corn	Oats	Wheat
Correlation Coefficient	0.9960		0.9976
Significance	<0.0001		<0.0001

APPENDIX G

DETAILED DATA OF VALIDATION EXPERIMENTS

Table G1 - Initial weight (g) of components and pouches weight (g) over time for 33/67 corn-wheat (Validation 1)

Pouch	Corn	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	5.1075	10.5528	20.3582	20.3655							
2	5.0057	10.1450	19.7878	19.7954							
3	5.1353	10.4352	20.4047	20.4123	20.4196						
4	5.0600	10.5672	20.4660	20.4731	20.4801						
5	5.0225	10.1791	20.0617	20.0689	20.0761	20.0828					
6	5.0269	10.5451	20.4165	20.4240	20.4312	20.4383					
7	5.0255	10.3179	20.1583	20.1659	20.1728	20.1796	20.1870				
8	5.1135	10.2701	20.1814	20.1893	20.1963	20.2030	20.2101				
9	5.0539	10.2962	20.1329	20.1400	20.1474	20.1549	20.1626	20.1696			
10	5.1432	10.2544	20.2316	20.2391	20.2459	20.2524	20.2598	20.2661			
11	5.1009	10.0485	19.9568	19.9645	19.9720	19.9790	19.9876	19.9947	20.0018		
12	5.2793	10.1130	20.2401	20.2470	20.2516	20.2605	20.2681	20.2743	20.2814		
13	5.0860	10.2365	20.0376	20.0452	20.0547	20.0621	20.0695	20.0772	20.0842	20.0925	
14	5.1257	10.4106	20.2212	20.2290	20.2371	20.2443	20.2516	20.2589	20.2654	20.2739	
15	5.0330	10.5330	20.2975	20.3053	20.3132	20.3197	20.3266	20.3336	20.3397	20.3481	20.3917
16	5.0434	10.3185	20.1058	20.1133	20.1230	20.1286	20.1363	20.1436	20.1505	20.1590	20.2057
17	5.0657	9.9779	19.8040	19.8110	19.8195	19.8254	19.8328	19.8393	19.8459	19.8534	19.8963
18	5.0244	10.1290	19.8848	19.8919	19.8993	19.9066	19.9142	19.9210	19.9279	19.9359	19.9803
19	5.0735	10.4321	20.2000	20.2083	20.2189	20.2250	20.2328	20.2404	20.2473	20.2565	20.3072
20	5.0766	10.0960	19.9362	19.9435	19.9527	19.9584	19.9657	19.9722	19.9789	19.9870	20.0305
21	5.3952	10.2638	20.5269	20.5351	20.5445	20.5504	20.5579	20.5648	20.5722	20.5804	20.6265
22	5.0870	10.0854	19.8929	19.9004	19.9090	19.9156	19.9229	19.9296	19.9367	19.9456	19.9905
23	5.1250	10.3238	20.1786	20.1864	20.1954	20.2016	20.2090	20.2159	20.2230	20.2312	20.2762
24	5.0013	10.1997	19.9792	19.9873	19.9957	20.0038	20.0120	20.0195	20.0269	20.0357	20.0863
25	5.0287	10.2955	20.0662	20.0741	20.0828	20.0902	20.0982	20.1058	20.1131	20.1222	20.1702
26	5.0542	10.2540	20.2234	20.2315	20.2391	20.2460	20.2536	20.2613	20.2680	20.2768	20.3218
27	5.0795	10.1668	20.0245	20.0320	20.0395	20.0465	20.0535	20.0602	20.0673	20.0752	20.1185
28	5.0809	10.2076	20.1586	20.1663	20.1735	20.1807	20.1877	20.1949	20.2015	20.2096	20.2526
29	5.0271	10.3756	20.2441	20.2518	20.2580	20.2658	20.2726	20.2798	20.2864	20.2942	20.3357
30	5.0721	10.0548	19.7865	19.7942	19.8019	19.8098	19.8173	19.8246	19.8319	19.8401	19.8851
31	5.0310	10.0535	19.7992	19.8074	19.8145	19.8219	19.8295	19.8366	19.8434	19.8511	19.8949
32	5.0487	10.0942	19.8432	19.8509	19.8576	19.8643	19.8715	19.8785	19.8852	19.8929	19.9352

Table G1 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
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10							
11							
12							
13							
14							
15							
16							
17	19.9350						
18	20.0204						
19	20.3521	20.3930					
20	20.0695	20.1057					
21	20.6677	20.7064	20.7425				
22	20.0316	20.0693	20.1046				
23	20.3166	20.3538	20.3902	20.4230			
24	20.1304	20.1709	20.2089	20.2448			
25	20.2136	20.2529	20.2899	20.3249	20.3553		
26	20.3627	20.4000	20.4356	20.4691	20.4986		
27	20.1574	20.1937	20.2283	20.2611	20.2896	20.3216	
28	20.2915	20.3276	20.3614	20.3941	20.4225	20.4539	
29	20.3742	20.4096	20.4432	20.4753	20.5029	20.5341	20.5652
30	19.9251	19.9622	19.9980	20.0313	20.0603	20.0930	20.1211
31	19.9335	19.9694	20.0038	20.0366	20.0650	20.0965	20.1236
32	19.9736	20.0086	20.0423	20.0747	20.1024	20.1339	20.1603

Table G2 - Initial weight (g) of components and pouches weight (g) over time for 33/67 corn-oats (Validation 1)

Pouch	Corn	Oats	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	5.0223	10.0565	19.8182	19.8235							
2	5.0698	10.0303	19.7142	19.7195							
3	5.0135	10.0017	19.8376	19.8428	19.8434						
4	5.0942	10.0236	19.9251	19.9307	19.9316						
5	5.0447	10.0032	19.8163	19.8216	19.8229	19.8261					
6	5.0392	10.0288	19.7508	19.7565	19.7579	19.7608					
7	5.0449	10.0268	19.7335	19.7365	19.7374	19.7395	19.7428				
8	5.0338	10.0254	19.7283	19.7291	19.7306	19.7333	19.7361				
9	5.0162	10.1412	19.9201	19.9236	19.9249	19.9283	19.9308	19.9340			
10	5.0133	10.0110	19.7548	19.7597	19.7610	19.7641	19.7670	19.7704			
11	5.0014	10.1604	19.9696	19.9730	19.9740	19.9770	19.9797	19.9833	19.9871		
12	5.0346	10.0597	19.9025	19.9036	19.9049	19.9074	19.9096	19.9126	19.9158		
13	5.0501	10.1507	19.9095	19.9109	19.9143	19.9172	19.9214	19.9240	19.9281	19.9311	
14	5.0355	10.0014	19.8038	19.8075	19.8109	19.8136	19.8173	19.8202	19.8244	19.8284	
15	5.0159	10.2232	20.0768	20.0803	20.0838	20.0872	20.0908	20.0940	20.0979	20.1003	20.1206
16	5.0854	10.1268	19.9598	19.9634	19.9670	19.9699	19.9737	19.9770	19.9809	19.9839	20.0055
17	5.0014	10.0701	19.7719	19.7776	19.7815	19.7850	19.7891	19.7918	19.7960	19.7997	19.8214
18	5.0637	10.0594	19.7252	19.7286	19.7298	19.7326	19.7366	19.7395	19.7435	19.7464	19.7672
19	5.0660	10.0725	19.8401	19.8450	19.8472	19.8507	19.8542	19.8572	19.8608	19.8638	19.8843
20	5.0648	10.2500	20.1502	20.1534	20.1546	20.1578	20.1610	20.1642	20.1686	20.1713	20.1917
21	5.0663	10.0326	19.8212	19.8258	19.8271	19.8303	19.8339	19.8369	19.8406	19.8432	19.8634
22	5.0065	10.1178	19.8503	19.8518	19.8531	19.8568	19.8604	19.8627	19.8665	19.8691	19.8894
23	5.0848	10.0827	19.9226	19.9251	19.9266	19.9298	19.9332	19.9364	19.9405	19.9434	19.9648
24	5.0547	10.0384	19.7927	19.7951	19.7978	19.8012	19.8050	19.8077	19.8115	19.8147	19.8360
25	5.0784	10.0535	19.8635	19.8666	19.8690	19.8708	19.8742	19.8764	19.8797	19.8825	19.9001
26	5.0682	10.0350	19.9209	19.9257	19.9272	19.9292	19.9323	19.9348	19.9380	19.9402	19.9557
27	5.0633	10.0596	19.9445	19.9473	19.9491	19.9523	19.9550	19.9580	19.9603	19.9635	19.9805
28	5.0455	10.0820	19.9859	19.9880	19.9898	19.9920	19.9948	19.9975	20.0002	20.0021	20.0201
29	5.0770	10.0138	19.7571	19.7597	19.7617	19.7646	19.7677	19.7705	19.7736	19.7765	19.7943
30	5.0040	10.0592	19.7489	19.7511	19.7521	19.7543	19.7572	19.7601	19.7627	19.7656	19.7832
31	5.0214	10.0134	19.6619	19.6662	19.6670	19.6703	19.6731	19.6761	19.6789	19.6819	19.7009
32	5.0202	10.0720	19.7601	19.7620	19.7628	19.7657	19.7681	19.7707	19.7741	19.7771	19.7951

Table G2 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
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10							
11							
12							
13							
14							
15							
16							
17	19.8405						
18	19.7839						
19	19.9016	19.9168					
20	20.2095	20.2248					
21	19.8805	19.8964	19.9125				
22	19.9057	19.9213	19.9368				
23	19.9823	19.9986	20.0149	20.0295			
24	19.8534	19.8698	19.8860	19.9003			
25	19.9141	19.9271	19.9410	19.9526	19.9641		
26	19.9687	19.9806	19.9932	20.0046	20.0156		
27	19.9948	20.0081	20.0216	20.0338	20.0453	20.0575	
28	20.0339	20.0466	20.0599	20.0724	20.0840	20.0963	
29	19.8091	19.8225	19.8357	19.8484	19.8606	19.8728	19.8853
30	19.7977	19.8108	19.8246	19.8370	19.8483	19.8609	19.8727
31	19.7155	19.7288	19.7429	19.7550	19.7669	19.7792	19.7911
32	19.8099	19.8228	19.8368	19.8488	19.8603	19.8722	19.8843

Table G3 - Initial weight (g) of components and pouches weight (g) over time for 33/67 oats-wheat (Validation 1)

Pouch	Oats	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	5.0620	10.1731	20.0784	20.0851							
2	5.0243	9.9529	19.7163	19.7225							
3	5.0790	9.8755	19.5775	19.5840	19.5883						
4	5.0550	10.0314	19.6156	19.6225	19.6271						
5	5.0612	10.1155	19.7494	19.7567	19.7618	19.7672					
6	5.0178	10.3339	19.9717	19.9782	19.9827	19.9876					
7	5.0364	10.0644	19.7512	19.7585	19.7627	19.7675	19.7730				
8	5.0281	9.9176	19.5650	19.5719	19.5760	19.5808	19.5863				
9	5.0559	10.3531	20.0685	20.0754	20.0793	20.0843	20.0897	20.0937			
10	5.0494	10.0189	19.8365	19.8437	19.8478	19.8528	19.8580	19.8622			
11	5.0400	10.4256	20.2087	20.2151	20.2190	20.2244	20.2301	20.2342	20.2388		
12	5.0210	10.1080	19.8336	19.8409	19.8448	19.8500	19.8556	19.8596	19.8638		
13	5.0025	10.0949	19.7689	19.7770	19.7828	19.7882	19.7937	19.7987	19.8034	19.8093	
14	5.0446	10.2344	19.8867	19.8937	19.8989	19.9041	19.9096	19.9140	19.9183	19.9234	
15	5.0480	10.1525	19.8672	19.8741	19.8793	19.8839	19.8888	19.8930	19.8973	19.9031	19.9340
16	5.0317	10.2309	19.9847	19.9918	19.9967	20.0017	20.0070	20.0115	20.0156	20.0220	20.0537
17	5.0440	10.0702	19.7113	19.7185	19.7237	19.7283	19.7341	19.7385	19.7426	19.7489	19.7804
18	5.0318	10.2907	19.9636	19.9708	19.9758	19.9805	19.9861	19.9903	19.9950	20.0010	20.0325
19	5.0184	10.1045	19.8256	19.8333	19.8383	19.8432	19.8489	19.8531	19.8575	19.8638	19.8965
20	5.0040	10.2360	19.8642	19.8729	19.8781	19.8830	19.8884	19.8925	19.8969	19.9026	19.9347
21	5.0188	10.1245	19.6929	19.7060	19.7115	19.7162	19.7215	19.7261	19.7301	19.7362	19.7678
22	5.0289	10.2224	19.8817	19.8885	19.8938	19.8981	19.9040	19.9082	19.9129	19.9189	19.9521
23	5.0567	10.2968	20.0092	20.0155	20.0206	20.0250	20.0307	20.0350	20.0395	20.0454	20.0776
24	5.0257	10.0561	19.7257	19.7327	19.7370	19.7416	19.7470	19.7512	19.7555	19.7613	19.7935
25	5.0547	10.2328	19.8741	19.8821	19.8866	19.8912	19.8972	19.9014	19.9063	19.9124	19.9461
26	5.0709	10.0063	19.7247	19.7318	19.7361	19.7405	19.7465	19.7504	19.7551	19.7614	19.7944
27	5.0774	9.8629	19.5718	19.5791	19.5833	19.5877	19.5935	19.5978	19.6021	19.6080	19.6405
28	5.0013	10.0350	19.6301	19.6377	19.6422	19.6472	19.6530	19.6578	19.6621	19.6681	19.7013
29	5.0383	10.3310	20.1196	20.1263	20.1304	20.1354	20.1408	20.1454	20.1498	20.1556	20.1880
30	5.0278	9.8834	19.6228	19.6294	19.6339	19.6385	19.6437	19.6479	19.6524	19.6581	19.6899
31	5.0764	10.4491	20.2846	20.2915	20.2956	20.3007	20.3061	20.3104	20.3147	20.3207	20.3544
32	5.0110	10.1833	20.0248	20.0319	20.0366	20.0416	20.0472	20.0515	20.0564	20.0621	20.0957

Table G3 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
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11							
12							
13							
14							
15							
16							
17	19.8108						
18	20.0627						
19	19.9272	19.9561					
20	19.9654	19.9937					
21	19.7976	19.8254	19.8531				
22	19.9834	20.0124	20.0416				
23	20.1090	20.1371	20.1659	20.1938			
24	19.8230	19.8509	19.8790	19.9064			
25	19.9784	20.0073	20.0370	20.0648	20.0867		
26	19.8256	19.8541	19.8834	19.9109	19.9320		
27	19.6716	19.7001	19.7289	19.7564	19.7789	19.7973	
28	19.7334	19.7624	19.7932	19.8215	19.8442	19.8638	
29	20.2183	20.2470	20.2761	20.3040	20.3271	20.3454	20.3742
30	19.7197	19.7473	19.7756	19.8025	19.8238	19.8416	19.8629
31	20.3856	20.4142	20.4436	20.4719	20.4935	20.5125	20.5350
32	20.1271	20.1566	20.1854	20.2150	20.2391	20.2583	20.2815

Table G4 - Initial weight (g) of components and pouches weight (g) over time for 50/50 corn-wheat (Validation 1)

Pouch	Corn	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.5408	7.8954	20.2103	20.2311							
2	7.5041	7.4185	19.7357	19.7545							
3	7.5069	7.8571	20.1002	20.1216	20.1279						
4	7.4849	7.4385	19.6341	19.6550	19.6609						
5	7.4491	7.8061	20.0179	20.0370	20.0435	20.0511					
6	7.5331	7.4872	19.8349	19.8545	19.8616	19.8693					
7	7.5505	7.6128	19.9035	19.9237	19.9303	19.9379	19.9444				
8	7.4678	7.7217	19.8421	19.8626	19.8693	19.8770	19.8833				
9	7.6061	7.5766	19.8534	19.8714	19.8787	19.8866	19.8954	19.9009			
10	7.5400	7.3915	19.6408	19.6599	19.6660	19.6731	19.6809	19.6860			
11	7.6120	7.8308	20.0473	20.0640	20.0710	20.0784	20.0861	20.0908	20.0981		
12	7.4961	7.6686	19.8615	19.8787	19.8855	19.8923	19.9005	19.9050	19.9118		
13	7.5170	7.8961	20.1019	20.1199	20.1268	20.1342	20.1418	20.1467	20.1538	20.1598	
14	7.6412	7.7263	20.1453	20.1631	20.1696	20.1768	20.1846	20.1893	20.1966	20.2022	
15	7.5744	7.3953	19.7465	19.7618	19.7676	19.7744	19.7812	19.7865	19.7932	19.7986	19.8373
16	7.5493	7.3403	19.5806	19.6043	19.6132	19.6238	19.6346	19.6429	19.6541	19.6638	19.7247
17	7.5895	7.3641	19.6829	19.7018	19.7092	19.7176	19.7255	19.7310	19.7392	19.7459	19.7903
18	7.4485	7.8897	20.0987	20.1173	20.1237	20.1309	20.1385	20.1430	20.1504	20.1569	20.1982
19	7.6538	7.3501	19.8160	19.8359	19.8422	19.8494	19.8567	19.8618	19.8686	19.8749	19.9152
20	7.7505	7.7898	20.3306	20.3487	20.3554	20.3627	20.3705	20.3754	20.3825	20.3888	20.4312
21	7.4536	7.5401	19.6766	19.6944	19.7003	19.7078	19.7152	19.7199	19.7267	19.7329	19.7738
22	7.5673	7.3317	19.6451	19.6621	19.6681	19.6748	19.6822	19.6866	19.6932	19.6993	19.7397
23	7.5835	7.6060	19.9204	19.9372	19.9436	19.9506	19.9579	19.9624	19.9691	19.9750	20.0144
24	7.7839	7.5946	20.1407	20.1568	20.1636	20.1706	20.1781	20.1827	20.1890	20.1954	20.2363
25	7.5598	7.3520	19.6332	19.6494	19.6556	19.6628	19.6707	19.6753	19.6820	19.6888	19.7329
26	7.5472	7.7665	20.0706	20.0889	20.0949	20.1020	20.1090	20.1140	20.1199	20.1261	20.1657
27	7.5697	7.8148	20.1378	20.1558	20.1616	20.1688	20.1759	20.1807	20.1868	20.1931	20.2336
28	7.5378	7.8221	20.0330	20.0496	20.0563	20.0640	20.0717	20.0764	20.0832	20.0896	20.1328
29	7.5540	7.4640	19.7713	19.7888	19.7951	19.8019	19.8092	19.8138	19.8196	19.8258	19.8660
30	7.4727	7.3648	19.4196	19.4368	19.4429	19.4492	19.4565	19.4614	19.4677	19.4736	19.5132
31	7.6142	7.5793	19.8007	19.8172	19.8237	19.8310	19.8387	19.8434	19.8499	19.8560	19.8975
32	7.4815	7.3546	19.5557	19.5713	19.5778	19.5846	19.5925	19.5971	19.6036	19.6097	19.6510

Table G4 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	19.8354						
18	20.2402						
19	19.9576	19.9935					
20	20.4748	20.5121					
21	19.8163	19.8520	19.8849				
22	19.7813	19.8164	19.8495				
23	20.0561	20.0917	20.1259	20.1495			
24	20.2778	20.3144	20.3490	20.3734			
25	19.7777	19.8153	19.8508	19.8764	19.9136		
26	20.2071	20.2420	20.2750	20.2991	20.3339		
27	20.2748	20.3109	20.3440	20.3678	20.4033	20.4369	
28	20.1764	20.2141	20.2493	20.2742	20.3110	20.3457	
29	19.9067	19.9420	19.9741	19.9977	20.0322	20.0646	20.0896
30	19.5524	19.5876	19.6194	19.6419	19.6766	19.7087	19.7338
31	19.9396	19.9760	20.0095	20.0334	20.0691	20.1024	20.1285
32	19.6922	19.7281	19.7606	19.7842	19.8192	19.8518	19.8773

Table G5 - Initial weight (g) of components and pouches weight (g) over time for 50/50 corn-oats (Validation 1)

Pouch	Corn	Oats	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.5362	7.5295	19.8248	19.8302							
2	7.5117	7.5083	19.7326	19.7376							
3	7.5264	7.5120	19.7602	19.7654	19.7695						
4	7.4928	7.5045	19.6488	19.6575	19.6625						
5	7.4926	7.5185	19.6862	19.6915	19.6958	19.7003					
6	7.4990	7.5083	19.7414	19.7460	19.7504	19.7548					
7	7.5076	7.5264	19.7986	19.8044	19.8090	19.8136	19.8171				
8	7.4963	7.5016	19.6220	19.6266	19.6310	19.6356	19.6387				
9	7.5188	7.5133	19.6865	19.6914	19.6961	19.6997	19.7042	19.7082			
10	7.4770	7.5153	19.6914	19.6964	19.7006	19.7045	19.7083	19.7117			
11	7.5003	7.5030	19.6663	19.6709	19.6748	19.6792	19.6826	19.6861	19.6897		
12	7.4611	7.5142	19.7511	19.7563	19.7607	19.7653	19.7687	19.7734	19.7770		
13	7.5163	7.5067	19.5792	19.5848	19.5893	19.5937	19.5972	19.6010	19.6055	19.6090	
14	7.5094	7.4998	19.6184	19.6227	19.6261	19.6311	19.6350	19.6385	19.6427	19.6463	
15	7.4928	7.5153	19.5757	19.5802	19.5840	19.5879	19.5914	19.5950	19.5990	19.6018	19.6291
16	7.5067	7.5060	19.6436	19.6477	19.6517	19.6567	19.6600	19.6638	19.6680	19.6719	19.6995
17	7.5325	7.4997	19.7037	19.7089	19.7128	19.7170	19.7207	19.7241	19.7283	19.7322	19.7595
18	7.5323	7.5022	19.6707	19.6757	19.6802	19.6841	19.6883	19.6917	19.6963	19.6999	19.7283
19	7.5334	7.5151	19.6941	19.6981	19.7020	19.7056	19.7094	19.7132	19.7172	19.7211	19.7472
20	7.5426	7.5052	19.7157	19.7202	19.7238	19.7280	19.7315	19.7358	19.7395	19.7435	19.7703
21	7.4974	7.5289	19.7231	19.7277	19.7317	19.7357	19.7395	19.7433	19.7475	19.7517	19.7782
22	7.4953	7.5055	19.7822	19.7871	19.7912	19.7954	19.7989	19.8030	19.8070	19.8112	19.8387
23	7.5095	7.5478	19.6849	19.6899	19.6936	19.6982	19.7023	19.7066	19.7107	19.7149	19.7428
24	7.5060	7.5220	19.6020	19.6071	19.6111	19.6157	19.6196	19.6241	19.6285	19.6319	19.6606
25	7.5452	7.5133	19.7420	19.7466	19.7508	19.7550	19.7589	19.7633	19.7671	19.7714	19.7975
26	7.4947	7.5226	19.7033	19.7075	19.7120	19.7169	19.7198	19.7242	19.7278	19.7321	19.7575
27	7.5283	7.5166	19.7159	19.7198	19.7240	19.7283	19.7320	19.7356	19.7401	19.7440	19.7696
28	7.5394	7.5064	19.8516	19.8565	19.8610	19.8656	19.8694	19.8740	19.8789	19.8830	19.9106
29	7.4990	7.5071	19.7380	19.7424	19.7466	19.7511	19.7542	19.7581	19.7628	19.7670	19.7928
30	7.5081	7.5162	19.7455	19.7506	19.7553	19.7597	19.7634	19.7672	19.7721	19.7761	19.8027
31	7.5030	7.5045	19.8009	19.8072	19.8119	19.8166	19.8194	19.8246	19.8297	19.8335	19.8623
32	7.4937	7.5093	19.7853	19.7906	19.7950	19.7996	19.8027	19.8071	19.8116	19.8156	19.8423

Table G5 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	19.7852						
18	19.7548						
19	19.7722	19.7941					
20	19.7950	19.8174					
21	19.8042	19.8268	19.8509				
22	19.8643	19.8872	19.9110				
23	19.7691	19.7923	19.8167	19.8399			
24	19.6874	19.7106	19.7354	19.7586			
25	19.8225	19.8448	19.8687	19.8903	19.9092		
26	19.7820	19.8036	19.8273	19.8481	19.8663		
27	19.7952	19.8173	19.8416	19.8620	19.8809	19.8951	
28	19.9374	19.9621	19.9880	20.0105	20.0305	20.0450	
29	19.8173	19.8403	19.8645	19.8854	19.9044	19.9183	19.9395
30	19.8283	19.8516	19.8775	19.8988	19.9183	19.9329	19.9543
31	19.8895	19.9140	19.9404	19.9628	19.9827	19.9978	20.0205
32	19.8674	19.8909	19.9161	19.9375	19.9570	19.9716	19.9930

Table G6 - Initial weight (g) of components and pouches weight (g) over time for 50/50 oats-wheat (Validation 1)

Pouch	Oats	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.5117	7.4910	19.7218	19.7266							
2	7.5069	7.4940	19.8017	19.8069							
3	7.5065	7.5176	19.7060	19.7110	19.7149						
4	7.5017	7.5260	19.7734	19.7784	19.7826						
5	7.5070	7.4247	19.6722	19.6768	19.6810	19.6855					
6	7.5095	7.4394	19.7464	19.7512	19.7551	19.7590					
7	7.5109	7.5282	19.7687	19.7734	19.7771	19.7809	19.7857				
8	7.5078	7.5104	19.7489	19.7536	19.7575	19.7613	19.7667				
9	7.5160	7.5860	19.9251	19.9297	19.9331	19.9368	19.9411	19.9447			
10	7.5086	7.5820	19.8894	19.8949	19.8988	19.9028	19.9075	19.9113			
11	7.5108	7.5933	20.0453	20.0502	20.0537	20.0576	20.0623	20.0665	20.0704		
12	7.5126	7.5416	19.9359	19.9412	19.9448	19.9491	19.9540	19.9586	19.9629		
13	7.5137	7.4315	19.6386	19.6434	19.6471	19.6511	19.6553	19.6598	19.6647	19.6670	
14	7.5044	7.4730	19.7596	19.7658	19.7700	19.7746	19.7796	19.7846	19.7904	19.7933	
15	7.5092	7.4707	19.8304	19.8355	19.8393	19.8432	19.8481	19.8527	19.8573	19.8606	19.8844
16	7.5042	7.5821	19.8993	19.9032	19.9078	19.1116	19.9166	19.9209	19.9250	19.9281	19.9519
17	7.5064	7.4817	19.6704	19.6754	19.6802	19.6844	19.6896	19.6940	19.6983	19.7024	19.7276
18	7.5096	7.4712	19.7775	19.7827	19.7863	19.7905	19.7952	19.7998	19.8044	19.8075	19.8319
19	7.5045	7.5391	19.8044	19.8091	19.8129	19.8171	19.8210	19.8263	19.8303	19.8335	19.8569
20	7.5184	7.5817	19.8625	19.8676	19.8719	19.8763	19.8813	19.8864	19.8905	19.8943	19.9194
21	7.5022	7.4550	19.6455	19.6505	19.6551	19.6591	19.6640	19.6688	19.6732	19.6766	19.7011
22	7.5112	7.5474	19.7953	19.8005	19.8047	19.8088	19.8140	19.8185	19.8236	19.8269	19.8517
23	7.5160	7.5555	19.7891	19.7940	19.7978	19.8016	19.8065	19.8109	19.8155	19.8188	19.8426
24	7.5069	7.5562	19.6596	19.6649	19.6689	19.6731	19.6781	19.6826	19.6875	19.6813	19.7150
25	7.5129	7.5394	19.7794	19.7854	19.7895	19.7938	19.7991	19.8041	19.8072	19.8121	19.8383
26	7.5153	7.5143	19.5308	19.5357	19.5398	19.5442	19.5489	19.5545	19.5584	19.5627	19.5876
27	7.5048	7.5501	19.7406	19.7450	19.7492	19.7533	19.7581	19.7630	19.7670	19.7711	19.7951
28	7.5148	7.4370	19.6051	19.6104	19.6142	19.6175	19.6219	19.6273	19.6315	19.6347	19.6579
29	7.5082	7.4989	19.9132	19.9182	19.9215	19.9256	19.9292	19.9335	19.9376	19.9411	19.9620
30	7.5047	7.5324	19.7890	19.7948	19.7989	19.8031	19.8083	19.8136	19.8187	19.8223	19.8489
31	7.5036	7.5072	19.7598	19.7646	19.7688	19.7719	19.7774	19.7825	19.7862	19.7901	19.8133
32	7.5116	7.5254	19.7220	19.7273	19.7308	19.7349	19.7395	19.7447	19.7495	19.7527	19.7769

Table G6 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	19.7519						
18	19.8560						
19	19.8798	19.9007					
20	19.9442	19.9670					
21	19.7254	19.7485	19.7673				
22	19.8764	19.8997	19.9195				
23	19.8658	19.8881	19.9064	19.9267			
24	19.7391	19.7623	19.7808	19.8006			
25	19.8642	19.8885	19.9082	19.9290	19.9479		
26	19.6136	19.6372	19.6567	19.6776	19.6963		
27	19.6813	19.8411	19.8627	19.8848	19.9048	19.9209	
28	19.8191	19.7026	19.7214	19.7407	19.7584	19.7729	
29	19.9834	20.0038	20.0214	20.0397	20.0560	20.0707	20.0841
30	19.8742	19.8986	19.9190	19.9405	19.9595	19.9756	19.9904
31	19.8373	19.8586	19.8778	19.8979	19.9156	19.9306	19.9451
32	19.8015	19.8233	19.8432	19.8638	19.8818	19.8968	19.9114

Table G7 - Initial weight (g) of components and pouches weight (g) over time for 67/33 corn-wheat (Validation 1)

Pouch	Corn	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	10.0334	5.0740	19.7860	19.7972							
2	10.0266	5.1051	20.0008	20.0116							
3	10.0462	4.9173	19.7591	19.7688	19.7736						
4	10.0783	4.9830	19.8573	19.8684	19.8737						
5	10.0778	4.9428	19.7767	19.7870	19.7921	19.7989					
6	10.0589	5.0772	19.7783	19.7889	19.7947	19.8018					
7	10.0861	5.0567	19.8788	19.8897	19.8952	19.9024	19.9080				
8	10.0438	4.9809	19.7242	19.7395	19.7449	19.7522	19.7579				
9	10.0218	4.9453	19.7547	19.7706	19.7770	19.7850	19.7932	19.7994			
10	10.0486	5.0778	19.9424	19.9571	19.9633	19.9706	19.9776	19.9831			
11	10.0957	4.9478	19.7739	19.7885	19.7949	19.8025	19.8094	19.8144	19.8210		
12	10.0171	5.0674	19.7218	19.7346	19.7409	19.7480	19.7558	19.7607	19.7675		
13	10.0307	4.9178	19.8226	19.8358	19.8419	19.8489	19.8562	19.8609	19.8680	19.8741	
14	10.0390	4.9832	19.8209	19.8316	19.8377	19.8445	19.8513	19.8554	19.8627	19.8688	
15	10.0400	4.9399	19.9151	19.9285	19.9344	19.9413	19.9475	19.9521	19.9589	19.9638	20.0008
16	10.0948	5.0562	20.1557	20.1673	20.1735	20.1805	20.1872	20.1921	20.1992	20.2047	20.2444
17	10.0766	5.1133	19.9350	19.9458	19.9525	19.9599	19.9671	19.9723	19.9795	19.9858	20.0279
18	9.9998	4.9647	19.6353	19.6470	19.6531	19.6604	19.6678	19.6726	19.6798	19.6859	19.7278
19	10.0720	5.0457	19.7839	19.7965	19.8027	19.8101	19.8170	19.8216	19.8288	19.8349	19.8754
20	10.0507	4.9690	19.6928	19.7062	19.7126	19.7202	19.7279	19.7325	19.7398	19.7461	19.7866
21	10.0189	4.9272	19.7600	19.7724	19.7788	19.7855	19.7927	19.7971	19.8044	19.8107	19.8505
22	10.0368	4.9933	19.8087	19.8203	19.8274	19.8343	19.8417	19.8463	19.8533	19.8593	19.8987
23	10.0960	4.9790	19.7846	19.7955	19.8021	19.8092	19.8166	19.8216	19.8285	19.8347	19.8757
24	10.0402	5.0560	19.7096	19.7240	19.7306	19.7379	19.7458	19.7507	19.7585	19.7653	19.8077
25	10.0422	5.0806	19.8285	19.8400	19.8472	19.8549	19.8624	19.8673	19.8754	19.8818	19.9237
26	10.0723	4.9521	19.7394	19.7510	19.7571	19.7634	19.7706	19.7747	19.7816	19.7872	19.8233
27	10.0524	5.0149	19.8001	19.8123	19.8183	19.8260	19.8329	19.8371	19.8447	19.8507	19.8901
28	9.9961	4.9032	19.5825	19.5969	19.6036	19.6107	19.6185	19.6229	19.6303	19.6367	19.6773
29	10.0118	5.0325	19.7519	19.7640	19.7708	19.7778	19.7853	19.7900	19.7972	19.8030	19.8429
30	9.9982	5.0360	19.8707	19.8852	19.8909	19.8977	19.9056	19.9092	19.9166	19.9224	19.9611
31	10.0733	5.0605	19.8836	19.8957	19.9017	19.9081	19.9158	19.9203	19.9274	19.9331	19.9710
32	10.0713	5.0782	19.9298	19.9429	19.9492	19.9551	19.9628	19.9669	19.9740	19.9790	20.0155

Table G7 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	20.0688						
18	19.7682						
19	19.9170	19.9524					
20	19.8295	19.8651					
21	19.8916	19.9261	19.9587				
22	19.9403	19.9754	20.0078				
23	19.9170	19.9530	19.9848	20.0087			
24	19.8510	19.8880	19.9224	19.9474			
25	19.9667	20.0034	20.0375	20.0623	20.0986		
26	19.8614	19.8935	19.9237	19.9461	19.9796		
27	19.9310	19.9655	19.9973	20.0207	20.0560	20.0887	
28	19.7195	19.7552	19.7883	19.8122	19.8469	19.8791	
29	19.8844	19.9193	19.9507	19.9748	20.0099	20.0431	20.0685
30	20.0014	20.0358	20.0675	20.0911	20.1254	20.1579	20.1829
31	20.0110	20.0458	20.0783	20.1022	20.1374	20.1714	20.1976
32	20.0542	20.0863	20.1162	20.1384	20.1720	20.2035	20.2282

Table G8 - Initial weight (g) of components and pouches weight (g) over time for 67/33 corn-oats (Validation 1)

Pouch	Corn	Oats	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	10.0417	5.0170	19.8175	19.8224							
2	10.0367	5.0066	19.7134	19.7180							
3	10.0406	5.0295	19.8436	19.8477	19.8518						
4	10.0427	5.0246	19.8095	19.8140	19.8182						
5	10.0823	5.0256	19.8439	19.8487	19.8523	19.8560					
6	10.0954	5.0395	19.9241	19.9292	19.9330	19.9373					
7	10.0050	5.0252	19.7175	19.7221	19.7264	19.7303	19.7353				
8	10.0460	5.0388	19.8579	19.8618	19.8657	19.8697	19.8743				
9	10.0646	5.0400	19.8456	19.8498	19.8544	19.8582	19.8648	19.8692			
10	10.0778	5.0290	19.8192	19.8238	19.8279	19.8318	19.8379	19.8420			
11	10.0772	5.0336	19.8038	19.8086	19.8126	19.8165	19.8224	19.8270	19.8324		
12	10.1002	5.0130	19.8077	19.8118	19.8160	19.8203	19.8259	19.8302	19.8353		
13	10.0890	5.0130	19.8853	19.8894	19.8940	19.8986	19.9043	19.9088	19.9148	19.9184	
14	10.0662	5.0149	19.8383	19.8428	19.8472	19.8515	19.8576	19.8618	19.8675	19.8714	
15	10.0254	5.0015	19.8188	19.8235	19.8276	19.8315	19.8375	19.8419	19.8479	19.8519	19.8805
16	10.0910	5.0097	19.8911	19.8958	19.8995	19.9038	19.9092	19.9137	19.9191	19.9238	19.9514
17	10.0905	5.0234	19.9321	19.9373	19.9418	19.9464	19.9522	19.9573	19.9633	19.9678	19.9976
18	10.0489	5.0140	19.7633	19.7684	19.7723	19.7768	19.7831	19.7875	19.7941	19.7983	19.8295
19	10.0860	5.0088	19.8493	19.8546	19.8582	19.8629	19.8693	19.8740	19.8799	19.8840	19.9140
20	10.0733	5.0090	19.8654	19.8706	19.8749	19.8794	19.8861	19.8907	19.8965	19.9019	19.9335
21	10.0392	5.0080	19.7051	19.7095	19.7139	19.7186	19.7238	19.7286	19.7342	19.7386	19.7680
22	10.0384	5.0108	19.7484	19.7533	19.7575	19.7621	19.7677	19.7724	19.7781	19.7823	19.8119
23	10.0664	5.0097	19.8284	19.8330	19.8371	19.8416	19.8473	19.8520	19.8574	19.8621	19.8906
24	10.0385	5.0117	19.8228	19.8282	19.8321	19.8364	19.8423	19.8470	19.8527	19.8571	19.8861
25	10.0138	5.0122	19.8108	19.8159	19.8204	19.8254	19.8308	19.8355	19.8414	19.8455	19.8752
26	10.0230	5.0019	19.6946	19.6991	19.7036	19.7080	19.7138	19.7182	19.7236	19.7279	19.7564
27	10.0475	5.0230	19.7655	19.7704	19.7750	19.7794	19.7849	19.7898	19.7959	19.7999	19.8296
28	10.0609	5.0276	19.8087	19.8133	19.8181	19.8227	19.8289	19.8334	19.8396	19.8435	19.8735
29	10.0596	5.0022	19.7266	19.7319	19.7375	19.7430	19.7496	19.7553	19.7620	19.7669	19.8014
30	10.0251	5.0260	19.7261	19.7305	19.7354	19.7399	19.7453	19.7500	19.7558	19.7598	19.7892
31	10.0540	5.0258	19.7483	19.7535	19.7579	19.7623	19.7681	19.7728	19.7785	19.7828	19.8123
32	10.0019	5.0157	19.6930	19.6975	19.7017	19.7063	19.7115	19.7169	19.7225	19.7269	19.7559

Table G8 - Continuation

Table G8 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	20.0278						
18	19.8595						
19	19.9432	19.9716					
20	19.9631	19.9922					
21	19.7965	19.8250	19.8493				
22	19.8407	19.8690	19.8934				
23	19.9193	19.9485	19.9733	19.9992			
24	19.9157	19.9435	19.9683	19.9945			
25	19.9046	19.9331	19.9585	19.9848	20.0079		
26	19.7857	19.8135	19.8384	19.8636	19.8869		
27	19.8596	19.8881	19.9135	19.9394	19.9625	19.9829	
28	19.9032	19.9318	19.9570	19.9832	20.0070	20.0276	
29	19.8346	19.8672	19.8950	19.9242	19.9499	19.9724	19.9956
30	19.8183	19.8470	19.8719	19.8975	19.9207	19.9416	19.9604
31	19.8418	19.8703	19.8952	19.9214	19.9452	19.9658	19.9851
32	19.7865	19.8156	19.8416	19.8686	19.8921	19.9137	19.9332

Table G9 - Initial weight (g) of components and pouches weight (g) over time for 67/33 oats-wheat (Validation 1)

Pouch	Oats	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	10.0163	5.0683	19.7103	19.7166							
2	10.0254	5.0457	19.6918	19.6969							
3	10.0121	5.0780	19.7032	19.7084	19.7113						
4	10.0611	5.2052	19.9985	20.0030	20.0058						
5	10.0054	5.0230	19.7575	19.7624	19.7646	19.7682					
6	10.0282	5.1076	19.8929	19.8977	19.9002	19.9033					
7	10.0211	5.2404	19.9137	19.9184	19.9208	19.9240	19.9282				
8	10.0134	5.1177	19.8178	19.8220	19.8252	19.8282	19.8322				
9	10.0084	5.0410	19.7392	19.7439	19.7465	19.7497	19.7534	19.7567			
10	10.0222	5.1219	19.7209	19.7253	19.7284	19.7316	19.7358	19.7393			
11	10.0001	4.9479	19.6034	19.6078	19.6108	19.6136	19.6178	19.6214	19.6252		
12	10.0052	4.9952	19.5982	19.6019	19.6046	19.6072	19.6115	19.6152	19.6188		
13	10.0183	5.0404	19.7040	19.7069	19.7092	19.7120	19.7161	19.7201	19.7231	19.7268	
14	10.0111	5.3270	20.1166	20.1216	20.1235	20.1265	20.1302	20.1339	20.1376	20.1393	
15	10.0252	5.2015	19.9749	19.9798	19.9817	19.9847	19.9882	19.9923	19.9964	19.9991	20.0181
16	10.0168	5.0374	19.8047	19.8095	19.8111	19.8135	19.8173	19.8206	19.8240	19.8261	19.8429
17	10.0065	5.2242	19.9161	19.9201	19.9222	19.9251	19.9286	19.9316	19.9355	19.9379	19.9549
18	10.0128	5.1697	19.8372	19.8424	19.8438	19.8466	19.8504	19.8537	19.8576	19.8595	19.8766
19	10.0136	5.1615	19.8084	19.8131	19.8151	19.8178	19.8221	19.8261	19.8295	19.8318	19.8513
20	10.0000	5.1254	19.7957	19.8003	19.8022	19.8058	19.8103	19.8130	19.8170	19.8201	19.8383
21	10.0123	4.9868	19.6277	19.6315	19.6338	19.6363	19.6399	19.6426	19.6461	19.6483	19.6664
22	10.0141	5.1849	19.9724	19.9772	19.9782	19.9810	19.9850	19.9881	19.9919	19.9940	20.0123
23	10.0025	5.2238	19.9600	19.9647	19.9663	19.9691	19.9729	19.9768	19.9796	19.9819	19.9991
24	10.0244	5.1170	19.8885	19.8938	19.8957	19.8987	19.9023	19.9060	19.9096	19.9119	19.9301
25	10.0027	5.2057	19.7834	19.7883	19.7899	19.7927	19.7962	19.8005	19.8041	19.8065	19.8250
26	10.0160	5.1957	19.9202	19.9250	19.9277	19.9301	19.9339	19.9378	19.9403	19.9427	19.9600
27	10.0237	5.1732	19.8363	19.8411	19.8431	19.8462	19.8502	19.8539	19.8574	19.8599	19.8792
28	10.0153	5.3351	20.1286	20.1329	20.1351	19.1380	20.1416	20.1452	20.1482	20.1509	20.1688
29	10.0304	5.0205	19.9131	19.9172	19.9195	19.9220	19.9256	19.9289	19.9318	19.9340	19.9510
30	10.0092	5.1749	19.8520	19.8570	19.8598	19.8627	19.8669	19.8695	19.8740	19.8766	19.8958
31	10.0056	5.0281	19.8436	19.8483	19.8502	19.8533	19.8572	19.8609	19.8641	19.8666	19.8846
32	10.0273	5.0853	19.7930	19.7970	19.7994	19.8029	19.8061	19.8104	19.8140	19.8167	19.8353

Table G9 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	19.9713						
18	19.8927						
19	19.8694	19.8863					
20	19.8554	19.8716					
21	19.6828	19.6980	19.7112				
22	20.0282	20.0436	20.0571				
23	20.0155	20.0311	20.0449	20.0587			
24	19.9473	19.9633	19.9775	19.9919			
25	19.8429	19.8593	19.8743	19.8888	19.9020		
26	19.9758	19.9916	20.0056	20.0196	20.0317		
27	19.8969	19.9137	19.9294	19.9448	19.9581	19.9695	
28	20.1857	20.2015	20.2166	20.2314	20.2446	20.2551	
29	19.9668	19.9821	19.9960	20.0098	20.0225	20.0325	20.0420
30	19.9142	19.9320	19.9475	19.9629	19.9772	19.9878	19.9986
31	19.9016	19.9176	19.9327	19.9469	19.9605	19.9707	19.9804
32	19.8515	19.8691	19.8837	19.8992	19.9122	19.9225	19.9330

Table G10 - Initial and pouches weight (g) over time for individually packaged corn (Validation 1)

Pouch	Prod	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.1650	19.8664	19.8721							
2	15.1593	19.9363	19.9411							
3	15.3085	20.1045	20.1089	20.1143						
4	15.0751	19.8405	19.8449	19.8499						
5	14.8748	19.6302	19.6346	19.6397	19.6452					
6	14.9980	19.7662	19.7706	19.7757	19.7803					
7	15.0410	19.7978	19.8028	19.8087	19.8126	19.8187				
8	15.0339	19.7569	19.7618	19.7683	19.7730	19.7788				
9	15.2314	19.9674	19.9722	19.9775	19.9816	19.9870	19.9898			
10	14.8031	19.5295	19.5340	19.5400	19.5447	19.5500	19.5541			
11	15.2272	19.9190	19.9252	19.9298	19.9346	19.9399	19.9433	19.9468		
12	15.4573	20.2578	20.2629	20.2686	20.2730	20.2788	20.2824	20.2857		
13	14.6629	19.3393	19.3434	19.3491	19.3530	19.3591	19.3617	19.3655	19.3706	
14	15.8510	20.4770	20.4814	20.4873	20.4913	20.4972	20.4995	20.5035	20.5080	
15	14.8205	19.5890	19.5919	19.5981	19.6022	19.6087	19.6112	19.6153	19.6211	19.6517
16	14.6453	19.2655	19.2698	19.2767	19.2807	19.2869	19.2891	19.2940	19.2989	19.3305
17	15.2340	19.9995	20.0019	20.0075	20.0111	20.0164	20.0181	20.0223	20.0254	20.0534
18	15.2428	19.9410	19.9452	19.9499	19.9537	19.9592	19.9612	19.9660	19.9705	19.9999
19	16.0074	20.5925	20.5967	20.6023	20.6064	20.6118	20.6139	20.6180	20.6227	20.6525
20	14.7187	19.4293	19.4355	19.4433	19.4484	19.4560	19.4593	19.4650	19.4710	19.5092
21	15.4436	19.9988	20.0053	20.0133	20.0186	20.0258	20.0296	20.0360	20.0429	20.0815
22	15.2124	19.8980	19.9045	19.9121	19.9167	19.9242	19.9266	19.9327	19.9390	19.9771
23	15.0570	19.8135	19.8205	19.8267	19.8312	19.8382	19.8421	19.8470	19.8531	19.8886
24	15.1637	19.9684	19.9740	19.9815	19.9863	19.9938	19.9980	20.0039	20.0101	20.0490
25	15.1945	19.9392	19.9446	19.9534	19.9589	19.9667	19.9707	19.9769	19.9832	20.0230
26	15.3205	20.0246	20.0310	20.0391	20.0451	20.0520	20.0567	20.0624	20.0694	20.1095
27	15.3072	19.9730	19.9778	19.9858	19.9914	19.9989	20.0021	20.0072	20.0138	20.0501
28	15.1096	19.8525	19.8594	19.8662	19.8715	19.8776	19.8814	19.8871	19.8930	19.9290
29	15.1738	19.8553	19.8610	19.8689	19.8745	19.8813	19.8853	19.8907	19.8968	19.9347
30	15.1520	19.8346	19.8401	19.8467	19.8522	19.8588	19.8631	19.8682	19.8746	19.9108
31	15.2983	19.9773	19.9829	19.9896	19.9954	20.0019	20.0058	20.0104	20.0164	20.0526
32	15.0753	19.8701	19.8760	19.8845	19.8896	19.8978	19.9019	19.9072	19.9136	19.9527

Table G10 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	20.0783						
18	20.0274						
19	20.6805	20.7051					
20	19.5442	19.5749					
21	20.1179	20.1494	20.1794				
22	20.0112	20.0418	20.0710				
23	19.9213	19.9501	19.9779	20.0036			
24	20.0840	20.1146	20.1445	20.1723			
25	20.0600	20.0915	20.1221	20.1517	20.1795		
26	20.1463	20.1786	20.2091	20.2386	20.2660		
27	20.0843	20.1139	20.1419	20.1699	20.1956	20.2199	
28	19.9624	19.9908	20.0183	20.0456	20.0708	20.0947	
29	19.9702	20.0007	20.0297	20.0579	20.0844	20.1091	20.1367
30	19.9454	19.9750	20.0026	20.0306	20.0561	20.0800	20.1073
31	20.0864	20.1152	20.1424	20.1699	20.1953	20.2195	20.2462
32	19.9936	20.0286	20.0603	20.0923	20.1223	20.1490	20.1790

Table G11 - Initial and pouches weight (g) over time for individually packaged oats (Validation 1)

Pouch	Prod	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.0166	19.7936	19.7972							
2	15.7745	20.4825	20.4852							
3	15.0354	19.6621	19.6654	19.6666						
4	15.0619	19.8272	19.8283	19.8299						
5	15.3166	20.1245	20.1257	20.1272	20.1273					
6	15.0549	19.8409	19.8430	19.8448	19.8442					
7	15.0577	19.8235	19.8266	19.8286	19.8280	19.8284				
8	15.2421	19.9907	19.9928	19.9936	19.9935	19.9933				
9	15.3405	20.1012	20.1038	20.1045	20.1048	20.1047	20.1045			
10	15.0403	19.7855	19.7883	19.7897	19.7891	19.7894	19.7890			
11	15.0745	19.7100	19.7137	19.7154	19.7150	19.7150	19.7149	19.7151		
12	15.1864	19.8661	19.8677	19.8693	19.8691	19.8694	19.8692	19.8697		
13	15.0820	19.8807	19.8836	19.8846	19.8845	19.8842	19.8840	19.8846	19.8862	
14	15.0525	19.7806	19.7822	19.7824	19.7834	19.7836	19.7830	19.7834	19.7853	
15	15.0052	19.7434	19.7456	19.7465	19.7473	19.7474	19.7474	19.7479	19.7492	19.7493
16	15.0520	19.7254	19.7285	19.7288	19.7295	19.7308	19.7308	19.7309	19.7322	19.7321
17	15.6214	20.2250	20.2275	20.2283	20.2288	20.2287	20.2285	20.2294	20.2307	20.2311
18	15.3554	20.0525	20.0553	20.0558	20.0561	20.0565	20.0568	20.0577	20.0587	20.0591
19	15.0740	19.7679	19.7703	19.7708	19.7712	19.7718	19.7720	19.7729	19.7738	19.7740
20	15.0574	19.8684	19.8717	19.8720	19.8730	19.8738	19.8742	19.8744	19.8753	19.8758
21	15.3670	19.9621	19.9641	19.9648	19.9657	19.9660	19.9663	19.9665	19.9680	19.9676
22	15.0916	19.6762	19.6773	19.6777	19.6785	19.6787	19.6785	19.6790	19.6801	19.6800
23	15.0956	19.6857	19.6889	19.6893	19.6900	19.6906	19.6905	19.6910	19.6922	19.6929
24	15.2592	19.8549	19.8559	19.8558	19.8565	19.8570	19.8570	19.8571	19.8586	19.8586
25	15.1387	19.7643	19.7651	19.7670	19.7669	19.7667	19.7662	19.7667	19.7675	19.7671
26	15.0120	19.7329	19.7332	19.7340	19.7348	19.7360	19.7358	19.7363	19.7376	19.7367
27	15.1978	19.9342	19.9353	19.9363	19.9348	19.9374	19.9370	19.9377	19.9388	19.9383
28	15.0982	19.7625	19.7649	19.7663	19.7659	19.7664	19.7663	19.7669	19.7684	19.7678
29	15.1261	19.9870	19.9890	19.9897	19.9901	19.9911	19.9901	19.9907	19.9923	19.9915
30	14.9780	19.7530	19.7535	19.7545	19.7547	19.7559	19.7552	19.7561	19.7574	19.7567
31	15.1215	19.8023	19.8029	19.8032	19.8038	19.8047	19.8038	19.8049	19.8050	19.8053
32	15.1085	19.7914	19.7918	19.7922	19.7926	19.7935	19.7930	19.7937	19.7950	19.7944

Table G11 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	20.2328						
18	20.0602						
19	19.7753	19.7763					
20	19.8773	19.8779					
21	19.9692	19.9695	19.9690				
22	19.6816	19.6823	19.6816				
23	19.6950	19.6955	19.6959	19.6967			
24	19.8600	19.8611	19.8611	19.8625			
25	19.7685	19.7691	19.7685	19.7696	19.7695		
26	19.7383	19.7389	19.7389	19.7393	19.7392		
27	19.9403	19.9404	19.9401	19.9409	19.9410	19.9419	
28	19.7700	19.7705	19.7698	19.7708	19.7705	19.7716	
29	19.9938	19.9944	19.9937	19.9946	19.9945	19.9958	19.9986
30	19.7587	19.7598	19.7590	19.7602	19.7600	19.7608	19.7638
31	19.8077	19.8086	19.8079	19.8091	19.8092	19.8102	19.8127
32	19.7971	19.7975	19.7972	19.7982	19.7981	19.7996	19.8022

Table G12 - Initial and pouches weight (g) over time for individually packaged wheat (Validation 1)

Pouch	Prod	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.0535	19.8027	19.8096							
2	15.5948	20.3122	20.3199							
3	15.1708	19.9090	19.9171	19.9247						
4	15.1626	19.8572	19.8658	19.8720						
5	15.5436	20.2485	20.2562	20.2625	20.2681					
6	15.2576	19.9509	19.9581	19.9653	19.9720					
7	15.2012	19.9712	19.9787	19.9860	19.9920	19.9987				
8	15.6075	20.4418	20.4493	20.4552	20.4624	20.4689				
9	15.2492	19.9696	19.9768	19.9831	19.9894	19.9958	20.0006			
10	15.8516	20.6107	20.6177	20.6244	20.6301	20.6356	20.6413			
11	15.5885	20.2405	20.2478	20.2534	20.2594	20.2638	20.2696	20.2734		
12	15.0359	19.8498	19.8560	19.8637	19.8692	19.8742	19.8815	19.8855		
13	15.7086	20.3499	20.3566	20.3649	20.3713	20.3792	20.3932	20.4063	20.4202	
14	15.2462	19.8805	19.8874	19.8935	19.8993	19.9063	19.9117	19.9166	19.9212	
15	15.2558	19.8587	19.8651	19.8739	19.8797	19.8864	19.8937	19.8995	19.9046	19.9495
16	15.6744	20.4310	20.4378	20.4450	20.4514	20.4576	20.4642	20.4700	20.4748	20.5170
17	14.8858	19.6264	19.6334	19.6399	19.6454	19.6513	19.6575	19.6623	19.6670	19.7055
18	15.6235	20.3880	20.3946	20.3996	20.4055	20.4116	20.4169	20.4227	20.4268	20.4645
19	15.0109	19.7016	19.7092	19.7155	19.7216	19.7264	19.7322	19.7379	19.7424	19.7797
20	14.9992	19.6725	19.6799	19.6866	19.6929	19.6989	19.7034	19.7085	19.7132	19.7503
21	15.4204	20.1805	20.1866	20.1928	20.1976	20.2021	20.2075	20.2122	20.2169	20.2505
22	15.1245	19.8881	19.8940	19.9007	19.9061	19.9103	19.9169	19.9223	19.9263	19.9635
23	15.4460	20.1786	20.1855	20.1905	20.1967	20.2025	20.2077	20.2126	20.2171	20.2527
24	15.7004	20.4991	20.5060	20.5115	20.5178	20.5243	20.5302	20.5353	20.5402	20.5797
25	15.4658	20.3550	20.3614	20.3671	20.3724	20.3791	20.3840	20.3888	20.3939	20.4314
26	15.6956	20.3308	20.3378	20.3451	20.3510	20.3573	20.3629	20.3678	20.3741	20.4144
27	15.5988	20.1820	20.1887	20.1947	20.2006	20.2064	20.2112	20.2159	20.2214	20.2576
28	14.9920	19.5580	19.5653	19.5709	19.5767	19.5815	19.5871	19.5910	19.5970	19.6334
29	15.5753	20.2703	20.2764	20.2825	20.2878	20.2933	20.2988	20.3050	20.3124	20.3601
30	15.3545	20.0013	20.0084	20.0141	20.0199	20.0251	20.0311	20.0355	20.0412	20.0792
31	15.0840	19.8100	19.8162	19.8243	19.8307	19.8368	19.8425	19.8475	19.8536	19.8939
32	14.8450	19.5483	19.5551	19.5610	19.5665	19.5713	19.5769	19.5817	19.5874	19.6228

Table G12 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	19.7399						
18	20.4986						
19	19.8142	19.8450					
20	19.7841	19.8137					
21	20.2814	20.0388	20.3367				
22	19.9976	20.0281	20.0578				
23	20.2871	20.3167	20.3468	20.3741			
24	20.6161	20.6477	20.6791	20.7086			
25	20.4654	20.4959	20.5259	20.5543	20.5817		
26	20.4520	20.4852	20.5170	20.5475	20.5771		
27	20.2914	20.3217	20.3507	20.3786	20.4053	20.4307	
28	19.6671	19.6973	19.7262	19.7541	19.7805	19.8057	
29	20.4037	20.4418	20.4779	20.5118	20.5438	20.5735	20.6058
30	20.1144	20.1456	20.1756	20.2042	20.2318	20.2580	20.2858
31	19.9319	19.9653	19.9972	20.0270	20.0559	20.0834	20.1115
32	19.6565	19.6858	19.7140	19.7413	19.7676	19.7927	19.8185

Table G13 - Initial weight (g) of components and pouches weight (g) over time for 50/50 corn-wheat (Validation 2)

Pouch	Corn	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.5224	7.4768	17.1714	17.2228							
2	7.5236	7.4746	17.1521	17.2035							
3	7.5015	7.6243	17.5517	17.5940	17.6097						
4	7.5445	7.4746	17.2107	17.2552	17.2738						
5	7.5260	7.3393	17.3193	17.3573	17.3723	17.3908					
6	7.5473	7.2754	17.2423	17.2840	17.3018	17.3192					
7	7.5218	7.3268	17.2430	17.2859	17.3027	17.3249	17.3397				
8	7.5180	7.7824	17.7171	17.7603	17.7787	17.8008	17.8183				
9	7.5503	7.3750	17.3230	17.3626	17.3799	17.4012	17.4184	17.4367			
10	7.5253	7.6820	17.6152	17.6613	17.6808	17.7028	17.7224	17.7440			
11	7.5163	7.6680	17.5468	17.5913	17.6096	17.6328	17.6501	17.6706	17.6889		
12	7.5467	7.4971	17.3866	17.4421	17.4638	17.4862	17.5071	17.5308	17.5514		
13	7.5306	7.4079	17.4942	17.5354	17.5520	17.5728	17.5888	17.6079	17.6243	17.6384	
14	7.4747	7.5506	17.5605	17.6019	17.6186	17.6395	17.6553	17.6739	17.6915	17.7052	
15	7.4786	7.6853	17.7403	17.7842	17.8006	17.8212	17.8378	17.8461	17.8742	17.8892	17.9913
16	7.5033	7.3464	17.4393	17.4824	17.4975	17.5185	17.5354	17.5539	17.5714	17.5865	17.6822
17	7.5545	7.4074	17.5329	17.5742	17.5901	17.6107	17.6269	17.6453	17.6627	17.6769	17.7822
18	7.5830	7.6305	17.7509	17.7929	17.8106	17.8316	17.8477	17.8664	17.8835	17.8990	18.0056
19	7.4838	7.2874	17.3181	17.3616	17.3793	17.4012	17.4179	17.4367	17.4542	17.4690	17.5726
20	7.5924	7.3844	17.6185	17.6615	17.6781	17.6995	17.7149	17.7326	17.7491	17.7633	17.8684
21	7.5811	7.7645	17.7609	17.8014	17.8166	17.8367	17.8537	17.8724	17.8886	17.9030	18.0018
22	7.5385	7.6326	17.7791	17.8163	17.8305	17.8508	17.8641	17.8813	17.8967	17.9092	17.9985
23	7.5075	7.6720	17.4621	17.5047	17.5214	17.5434	17.5595	17.5791	17.5969	17.6116	17.7181
24	7.4927	7.4259	17.3486	17.3927	17.4105	17.4332	17.4506	17.4703	17.4888	17.5040	17.6118
25	7.5065	7.2974	17.5144	17.5609	17.5780	17.6032	17.6200	17.6418	17.6610	17.6765	17.7891
26	7.5039	7.3785	17.3660	17.4076	17.4239	17.4462	17.4629	17.4824	17.5008	17.5152	17.6200
27	7.5460	7.3042	17.3622	17.4052	17.4237	17.4463	17.4634	17.4835	17.5025	17.5185	17.6255
28	7.5566	7.2908	17.5800	17.6259	17.6439	17.6677	17.6854	17.7061	17.7252	17.7419	17.8534
29	7.5473	7.4164	17.5719	17.6152	17.6331	17.6565	17.6739	17.6943	17.7127	17.7285	17.8417
30	7.5508	7.4965	17.4514	17.4900	17.5059	17.5274	17.5429	17.5617	17.5782	17.5913	17.6939
31	7.4925	7.3537	17.8053	17.8497	17.8676	17.8913	17.9087	17.9297	17.9480	17.9631	18.0769
32	7.5135	7.6216	17.7605	17.8013	17.8179	17.8404	17.8577	17.8764	17.8937	17.9092	18.0213

Table G13 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	17.8690						
18	18.0915						
19	17.6592	17.7308					
20	17.9543	18.0251					
21	18.0870	18.1593	18.2200				
22	18.0762	18.1420	18.1953				
23	17.8056	17.8772	17.9375	17.9913			
24	17.6965	17.7730	17.8315	17.8870			
25	17.8786	17.9557	18.0175	18.0726	18.0977		
26	17.7035	17.7780	18.8363	17.8914	17.9149		
27	17.7153	17.7909	17.8497	17.9040	17.9288	17.9637	
28	17.9470	18.0220	18.0852	18.1415	18.1668	18.2074	
29	17.9319	18.0076	18.0700	18.1256	18.1511	18.1907	18.2003
30	17.7769	17.8475	17.9078	17.9649	17.9924	18.0342	18.0463
31	18.1668	18.2450	18.3052	18.3638	18.3898	18.4298	18.4412
32	18.1119	18.1893	18.2502	18.3065	18.3343	18.3761	18.3879

Table G14 - Initial weight (g) of components and pouches weight (g) over time for 50/50 corn-oats (Validation 2)

Pouch	Corn	Oats	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.4942	7.5233	17.2974	17.3238							
2	7.5060	7.5112	17.2311	17.2557							
3	7.4795	7.5045	17.4419	17.4688	17.4776						
4	7.4848	7.5285	17.4271	17.4533	17.4627						
5	7.5305	7.5040	17.4934	17.5215	17.5312	17.5429					
6	7.5158	7.5043	17.4430	17.4711	17.4819	17.4923					
7	7.4948	7.5185	17.4738	17.5016	17.5123	17.5223	17.5370				
8	7.5055	7.5268	17.4692	17.4951	17.5059	17.5165	17.5301				
9	7.5283	7.5125	17.2519	17.2809	17.2918	17.3027	17.3163	17.3287			
10	7.5208	7.5235	17.3384	17.3671	17.3777	17.3878	17.4016	17.4133			
11	7.5199	7.5160	17.3327	17.3625	17.3741	17.3870	17.4022	17.4152	17.4254		
12	7.5098	7.5192	17.3279	17.3566	17.3671	17.3773	17.3906	17.4023	17.4116		
13	7.5155	7.5217	17.6473	17.6721	17.6811	17.6905	17.7023	17.7133	17.7216	17.7315	
14	7.4834	7.5216	17.5169	17.5433	17.5536	17.5644	17.5780	17.5895	17.5995	17.6101	
15	7.5166	7.5075	17.5526	17.5781	17.5875	17.5978	17.6108	17.6212	17.6306	17.6411	17.7037
16	7.4808	7.5055	17.5056	17.5320	17.5420	17.5520	17.5649	17.5749	17.5849	17.5957	17.6564
17	7.5377	7.5136	17.6560	17.6834	17.6938	17.7048	17.7173	17.7292	17.7390	17.7501	17.8155
18	7.5215	7.5159	17.6343	17.6608	17.6711	17.6808	17.6941	17.7048	17.7145	17.7249	17.7886
19	7.5046	7.5064	17.5694	17.5937	17.6026	17.6120	17.6245	17.6348	17.6441	17.6542	17.7136
20	7.5154	7.5024	17.6285	17.6547	17.6643	17.6747	17.6875	17.6990	17.7081	17.7189	17.7841
21	7.5231	7.5131	17.6105	17.6356	17.6451	17.6551	17.6675	17.6781	17.6872	17.6978	17.7622
22	7.5190	7.5074	17.6481	17.6745	17.6845	17.6947	17.7070	17.7182	17.7270	17.7374	17.8028
23	7.5151	7.5284	17.5797	17.6048	17.6148	17.6246	17.6372	17.6483	17.6575	17.6673	17.7295
24	7.5158	7.5016	17.6035	17.6289	17.6392	17.6495	17.6625	17.6740	17.6836	17.6944	17.7584
25	7.5202	7.5128	17.6631	17.6897	17.6995	17.7090	17.7222	17.7344	17.7430	17.7532	17.8163
26	7.5268	7.5142	17.6747	17.7010	17.7111	17.7215	17.7355	17.7472	17.7564	17.7674	17.8310
27	7.4991	7.5313	17.7118	17.7367	17.7466	17.7569	17.7688	17.7791	17.7882	17.7991	17.8613
28	7.4808	7.5024	17.5745	17.5990	17.6085	17.6186	17.6310	17.6419	17.6507	17.6611	17.7219
29	7.5099	7.5075	17.5603	17.5858	17.5965	17.6069	17.6193	17.6306	17.6394	17.6500	17.7117
30	7.4925	7.5036	17.6392	17.6630	17.6722	17.6820	17.6936	17.7052	17.7139	17.7247	17.7858
31	7.4971	7.5276	17.5962	17.6203	17.6293	17.6388	17.6517	17.6622	17.6720	17.6823	17.7454
32	7.4954	7.5119	17.6169	17.6419	17.6514	17.6611	17.6730	17.6838	17.6930	17.7031	17.7650

Table G14 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	17.8732						
18	17.8455						
19	17.7666	17.8101					
20	17.8402	17.8849					
21	17.8178	17.8624	17.9031				
22	17.8602	17.9041	17.9436				
23	17.7854	17.8273	17.8649	17.8928			
24	17.8166	17.8603	17.8992	17.9278			
25	17.8705	17.9140	17.9522	17.9802	17.9992		
26	17.8867	17.9317	17.9719	18.0009	18.0203		
27	17.9153	17.9573	17.9942	18.0223	18.0421	18.0607	
28	17.7732	17.8164	17.8535	17.8818	17.9009	17.9181	
29	17.7670	17.8092	17.8469	17.8745	17.8938	17.9111	17.9158
30	17.8408	17.8837	17.9212	17.9476	17.9660	17.9834	17.9891
31	17.8032	17.8455	17.8848	17.9136	17.9328	17.9504	17.9553
32	17.8199	17.8636	17.9022	17.9316	17.9517	17.9704	17.9759

Table G15 - Initial weight (g) of components and pouches weight (g) over time for 50/50 oats-wheat (Validation 2)

Pouch	Oats	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	7.5204	7.4334	17.3698	17.3980							
2	7.5134	7.8200	17.7714	17.7998							
3	7.5098	7.8041	17.7237	17.7522	17.7625						
4	7.5190	7.4081	17.3673	17.3947	17.4045						
5	7.5242	7.2557	17.1823	17.2091	17.2214	17.2329					
6	7.5028	7.7310	17.5645	17.5937	17.6057	17.6167					
7	7.5234	7.8025	18.0520	18.0504	18.0604	18.0722	18.0820				
8	7.5064	7.3919	17.5425	17.5674	17.5776	17.5890	17.5984				
9	7.5187	7.3082	17.4419	17.4693	17.4801	17.4923	17.5033	17.5147			
10	7.5048	7.3240	17.4512	17.4745	17.4829	17.4927	17.5012	17.5113			
11	7.5069	7.6770	17.7639	17.7899	17.8006	17.8128	17.8232	17.8341	17.8463		
12	7.5288	7.6720	17.4853	17.5129	17.5242	17.5365	17.5466	17.5579	17.5686		
13	7.5133	7.3854	17.5533	17.5807	17.5900	17.6013	17.6111	17.6217	17.6323	17.6397	
14	7.5348	7.3664	17.4370	17.4626	17.4727	17.4836	17.4954	17.5073	17.5202	17.5290	
15	7.5296	7.3702	17.5119	17.5367	17.5468	17.5589	17.5692	17.5802	17.5920	17.5996	17.6601
16	7.5199	7.6400	17.6701	17.6995	17.7111	17.7232	17.4344	17.7463	17.7590	17.7669	17.8326
17	7.5174	7.3967	17.4795	17.5066	17.5182	17.5303	17.5410	17.5524	17.5638	17.5716	17.6360
18	7.5123	7.6442	17.7752	17.8042	17.8155	17.8280	17.8394	17.8509	17.8635	17.8711	17.9351
19	7.5088	7.3115	17.3820	17.4115	17.4235	17.4353	17.4466	17.4579	17.4701	17.4779	17.5404
20	7.5085	7.7863	17.7815	17.8074	17.8179	17.8298	17.8422	17.8543	17.8671	17.8764	17.9417
21	7.5124	7.7707	17.8166	17.8455	17.8571	17.8698	17.8815	17.8931	17.9060	17.9142	17.9785
22	7.5069	7.4619	17.3820	17.4124	17.4250	17.4396	17.4530	17.4663	17.4797	17.4889	17.5638
23	7.5245	7.4840	17.4296	17.4605	17.4732	17.4874	17.5009	17.5143	17.5293	17.5385	17.6123
24	7.5143	7.3149	17.2468	17.2780	17.2896	17.3028	17.3142	17.3259	17.3390	17.3479	17.4146
25	7.5173	7.3017	17.3071	17.3355	17.3472	17.3597	17.3712	17.3829	17.3960	17.4040	17.4714
26	7.5315	7.5678	17.6422	17.6700	17.6803	17.6917	17.7015	17.7114	17.7223	17.7302	17.7876
27	7.5316	7.3877	17.2957	17.3312	17.3450	17.3593	17.3740	17.3875	17.4017	17.4115	17.4831
28	7.5253	7.4641	17.3945	17.4261	17.4372	17.4501	17.4619	17.4740	17.4869	17.4955	17.5589
29	7.5079	7.8546	17.7545	17.7840	17.7956	17.8082	17.8196	17.8313	17.8433	17.8520	17.9186
30	7.5083	7.6079	17.4834	17.5133	17.5240	17.5359	17.5474	17.5579	17.5695	17.5776	17.6415
31	7.5164	7.7071	17.6058	17.6376	17.6498	17.6636	17.6767	17.6894	17.7037	17.7128	17.7838
32	7.5240	7.6526	17.7266	17.7585	17.7701	17.7832	17.7951	17.8062	17.8196	17.8289	17.8967

Table G15 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	17.6811						
18	17.9801						
19	17.5845	17.6178					
20	17.9890	18.0321					
21	18.0254	18.0624	18.0879				
22	17.6162	17.6561	17.6847				
23	17.6638	17.7026	17.7302	17.7514			
24	17.4613	17.5018	17.5319	17.5564			
25	17.5198	17.5587	17.5868	17.6101	17.6168		
26	17.8297	17.8666	17.8963	17.9230	17.9333		
27	17.5316	17.5692	17.5951	17.6152	17.6184	17.6249	
28	17.6046	17.6463	17.6745	17.6994	17.7077	17.7196	
29	17.9691	18.0141	18.0446	18.0726	18.0813	18.0944	18.0963
30	17.6866	17.7282	17.7576	17.7834	17.7911	17.8043	17.8066
31	17.8343	17.8745	17.9029	17.9257	17.9311	17.9416	17.9424
32	17.9451	17.9856	18.0143	18.0384	18.0458	18.0574	18.0593

Table G16 - Initial and pouches weight (g) over time for individually packaged corn (Validation 2)

Pouch	Corn	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.0709	17.4848	17.5081							
2	15.1108	17.5022	17.5266							
3	15.1302	17.5093	17.5337	17.5523						
4	15.0884	17.4899	17.5136	17.5310						
5	15.0495	17.6714	17.6944	17.7119	17.7307					
6	15.0578	17.6367	17.6606	17.6788	17.6969					
7	15.1577	17.7114	17.7385	17.7592	17.7802		17.8237			
8	15.0627	17.6307	17.6519	17.6668	17.6835		17.7195			
9	15.0192	17.6899	17.7120	17.7268	17.7434		17.7786			
10	15.1063	17.7877	17.8100	17.8259	17.8441		17.8791			
11	15.0067	17.3990	17.4245	17.4432	17.4642		17.5047	17.5228		
12	15.0964	17.4985	17.5212	17.5425	17.5642		17.6039	17.6232		
13	15.0864	17.5538	17.5764	17.5947	17.6112		17.6489	17.6658	17.6820	
14	15.1224	17.6718	17.6938	17.7095	17.7253		17.7588	17.7737	17.7893	
15	15.0814	17.6774	17.7039	17.7242	17.7456		17.7887	17.8072	17.8275	17.9431
16	15.0065	17.6000	17.6242	17.6414	17.6597		17.6973	17.7136	17.7311	17.8322
17	15.1461	17.7053	17.7287	17.7455	17.7617		17.7968	17.8111	17.8274	17.9226
18	15.1263	17.6907	17.7127	17.7283	17.7438		17.7779	17.7927	17.8088	17.9010
19	15.0837	17.6090	17.6319	17.6483	17.6654		17.7013	17.7162	17.7338	17.8308
20	15.0598	17.5151	17.5379	17.5543	17.5704		17.6053	17.6205	17.6363	17.7297
21	15.1438	17.5319	17.5544	17.5718	17.5884		17.6210	17.6352	17.6529	17.7465
22	15.0812	17.5072	17.5302	17.5484	17.5664		17.6026	17.6186	17.6362	17.7343
23	15.0966	17.6586	17.6803	17.6965	17.7124		17.7483	17.7627	17.7792	17.8727
24	15.1047	17.6710	17.6931	17.7103	17.7260		17.7617	17.7772	17.7920	17.8895
25	15.0541	17.6854	17.7065	17.7226	17.7392		17.7740	17.7886	17.8048	17.8998
26	15.1196	17.6969	17.7608	17.7775	17.7939		17.7922	17.8082	17.8263	17.9336
27	15.0919	17.7379	17.7197	17.7372	17.7542		17.8294	17.8435	17.8598	17.9539
28	15.0400	17.6287	17.6505	17.6674	17.6841		17.7206	17.7354	17.7518	17.8467
29	15.0142	17.5345	17.5570	17.5746	17.5902		17.6255	17.6412	17.6581	17.7536
30	15.0201	17.6148	17.6379	17.6537	17.6688		17.7033	17.7181	17.7343	17.8243
31	15.0338	17.4518	17.4753	17.4929	17.5101		17.5477	17.5636	17.5810	17.6793
32	15.0996	17.5443	17.5692	17.5869	17.6036		17.6405	17.6569	17.6739	17.7682

Table G16 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
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14							
15							
16							
17	17.9969						
18	17.9755						
19	17.9079	17.9680					
20	17.8044	17.8652					
21	17.8203	17.8810	17.9371				
22	17.8121	17.8740	17.9335				
23	17.9500	18.0107	18.0664	18.1198			
24	17.9660	18.0271	18.0822	18.1403			
25	17.9773	18.0361	18.0898	18.1410	18.1881		
26	18.0173	18.0768	18.1380	18.1939	18.2399		
27	18.0298	18.0889	18.1443	18.1987	18.2438	18.2868	
28	17.9244	17.9822	18.0381	18.0918	18.1362	18.1787	
29	17.8321	17.8931	17.9485	18.0023	18.0473	18.0907	18.1248
30	17.8976	17.9534	18.0090	18.0625	18.1061	18.1492	18.1841
31	17.7558	17.8122	17.8696	17.9253	17.9730	18.0182	18.0538
32	17.8461	17.9056	17.9646	18.0205	18.0666	18.1129	18.1457

Table G17 - Initial and pouches weight (g) over time for individually packaged oats (Validation 2)

Pouch	Oats	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.0550	17.4439	17.4472							
2	15.0058	17.3330	17.3352							
3	15.0217	17.6347	17.6374	17.6366						
4	15.0384	17.6687	17.6721	17.6715						
5	15.0383	17.6442	17.6476	17.6475	17.6467					
6	15.1028	17.6727	17.6762	17.6759	17.6755					
7	15.0384	17.6406	17.6437	17.6431	17.6421		17.6433			
8	15.0452	17.5366	17.5394	17.5389	17.5377		17.5390			
9	15.0196	17.5293	17.5328	17.5319	17.5305		17.5320			
10	15.0577	17.5796	17.5830	17.5820	17.5807		17.5813			
11	15.0203	17.5660	17.5694	17.5687	17.5679		17.5701	17.5700		
12	15.0028	17.5079	17.5118	17.5105	17.5095		17.5109	17.5103		
13	15.0178	17.4572	17.4611	17.4602	17.4596		17.4612	17.4614	17.4601	
14	15.0802	17.5183	17.5227	17.5215	17.5206		17.5222	17.5218	17.5209	
15	17.0449	17.5557	17.5606	17.5600	17.5591		17.5611	17.5615	17.5602	17.5588
16	15.0107	17.4639	17.4679	17.4670	17.4659		17.4669	17.4669	17.4649	17.4611
17	15.0284	17.4097	17.4130	17.4110	17.4094		17.4095	17.4093	17.4072	17.4031
18	15.0607	17.4714	17.4753	17.4738	17.4722		17.4730	17.4732	17.4709	17.4675
19	15.0752	17.4539	17.4580	17.4567	17.4553		17.4561	17.4560	17.4535	17.4507
20	15.0558	17.4529	17.4570	17.4551	17.4533		17.4533	17.4536	17.4511	17.4484
21	15.0164	17.4435	17.4477	17.4462	17.4449		17.4457	17.4458	17.4435	17.4403
22	15.0822	17.4776	17.4813	17.4798	17.4781		17.4775	17.4781	17.4760	17.4725
23	15.1745	17.6476	17.6520	17.6500	17.6481		17.6480	17.6482	17.6460	17.6425
24	15.0066	17.4273	17.4320	17.4311	17.4291		17.4298	17.4298	17.4280	17.4254
25	15.1205	17.5177	17.5212	17.5203	17.5180		17.5183	17.5184	17.5161	17.5133
26	15.1336	17.5303	17.5341	17.5329	17.5308		17.5317	17.5317	17.5295	17.5267
27	15.0137	17.4627	17.4668	17.4659	17.4638		17.4641	17.4643	17.4618	17.4592
28	15.1325	17.5720	17.5759	17.5745	17.5728		17.5731	17.5732	17.5710	17.5690
29	15.0889	17.4892	17.4928	17.4914	17.4895		17.4899	17.4899	17.4879	17.4854
30	15.0034	17.4207	17.4248	17.4237	17.4218		17.4222	17.4223	17.4203	17.4187
31	15.0394	17.4993	17.5031	17.5016	17.4998		17.4999	17.5002	17.4982	17.4970
32	15.0206	17.4936	17.4983	17.4974	17.4955		17.4970	17.4967	17.4953	17.4951

Table G17 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
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13							
14							
15							
16							
17	17.4019						
18	17.4663						
19	17.4493	17.4499					
20	17.4468	17.4469					
21	17.4394	17.4388	17.4428				
22	17.4707	17.4698	17.4727				
23	17.6410	17.6403	17.4265	17.6467			
24	17.4242	17.4241	17.6429	17.4296			
25	17.5113	17.5106	17.5142	17.5180	17.5215		
26	17.5239	17.5237	17.5273	17.5320	17.5346		
27	17.4571	17.4571	17.4604	17.4648	17.4678	17.4728	
28	17.5669	17.5670	17.5698	17.5733	17.5763	17.5812	
29	17.4834	17.4828	17.4851	17.4887	17.4916	17.4957	17.4966
30	17.4158	17.4166	17.4202	17.4254	17.4276	17.4331	17.4331
31	17.4948	17.4948	17.4976	17.5018	17.5045	17.5090	17.5093
32	17.4928	17.4935	17.4964	17.5005	17.5030	17.5074	17.5083

Table G18 - Initial and pouches weight (g) over time for individually packaged wheat (Validation 2)

Pouch	Wheat	Prod + Pouch	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14
1	15.3790	17.9260	17.9519							
2	15.6283	18.2268	18.2527							
3	15.5623	18.1720	18.2003	18.2264						
4	15.2582	17.8596	17.8861	17.9104						
5	15.2352	17.7926	17.8186	17.8416	17.8652					
6	15.3939	17.9595	17.9865	18.0107	18.0343					
7	15.1549	17.7345	17.7598	17.7835	17.8068		17.8539			
8	15.0945	17.7275	17.7513	17.7743	17.7977		17.8442			
9	15.3655	17.9474	17.9725	17.9965	18.0197		18.0634			
10	15.4886	18.0487	18.0735	18.0965	18.1194		18.1652			
11	15.0642	17.6554	17.6803	17.7030	17.7249		17.7682	17.7875		
12	15.1069	17.6615	17.6884	17.7145	17.7397		17.7897	17.8115		
13	15.6049	18.0659	18.0904	18.1143	18.1373		18.1826	18.2054	18.2273	
14	15.0957	17.5899	17.6166	17.6433	17.6670		17.7164	17.7392	17.7597	
15	15.5784	18.0248	18.0501	18.0755	18.0993		18.1472	18.1721	18.1981	18.3383
16	15.1394	17.6405	17.6638	17.6862	17.7073		17.7507	17.7702	17.7894	17.9025
17	15.1894	17.6989	17.7245	17.7496	17.7726		17.8196	17.8398	17.8601	17.9912
18	15.3440	17.8486	17.8729	17.8969	17.9210		17.9685	17.9895	18.0107	18.1308
19	15.1504	17.5633	17.5874	17.6111	17.6338		17.6802	17.6999	17.7203	17.8393
20	15.3789	17.8742	17.8986	17.9203	17.9427		17.9897	18.0094	18.0306	18.1531
21	14.6958	17.4393	17.4637	17.4885	17.5112		17.5595	17.5811	17.6030	17.7276
22	15.1084	17.6028	17.6263	17.6508	17.6738		17.7185	17.7420	17.7642	17.8935
23	15.0714	17.5342	17.5580	17.5824	17.6044		17.6510	17.6724	17.6929	17.8162
24	15.4717	17.9428	17.9696	17.9983	18.0236		18.0763	18.1006	18.1255	18.2651
25	15.1461	17.6387	17.6613	17.6825	17.7022		17.7440	17.7674	17.7908	17.9291
26	15.6520	18.0933	18.1191	18.1423	18.1649		18.2124	18.2329	18.2537	18.3854
27	15.3973	17.8350	17.8607	17.8868	17.9099		17.9611	17.9836	18.0054	18.1279
28	15.4627	17.9287	17.9526	17.9751	17.9964		18.0415	18.0623	18.0835	18.2076
29	15.0167	17.5025	17.5310	17.5589	17.5854		17.6369	17.6604	17.6828	17.8123
30	15.2429	17.7494	17.7760	17.8006	17.8249		17.8759	17.8981	17.9205	18.0501
31	15.0896	17.5800	17.6048	17.6272	17.6495		17.6981	17.7187	17.7394	17.8650
32	15.0935	17.7058	17.7399	17.7719	17.8036		17.8583	17.8843	17.9101	18.0466

Table G18 - Continuation

Pouch	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 63
1							
2							
3							
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10							
11							
12							
13							
14							
15							
16							
17	18.0842						
18	18.2177						
19	17.9271	17.9970					
20	18.2422	18.3075					
21	17.8120	17.8727	17.9212				
22	17.9820	18.0445	18.0939				
23	17.9024	17.9672	18.0184	18.0654			
24	18.3585	18.4235	18.4756	18.5208			
25	18.0208	18.0866	18.1392	18.1858	18.2206		
26	18.4786	18.5455	18.6001	18.6484	18.6857		
27	18.2169	18.2808	18.3323	18.3788	18.4134	18.4446	
28	18.3002	18.3651	18.4182	18.4669	18.5025	18.5349	
29	17.9030	17.9646	18.0143	18.0575	18.0888	18.1181	18.1365
30	18.1403	18.2024	18.2511	18.2975	18.3311	18.3617	18.3813
31	17.9509	18.0148	18.0660	18.1142	18.1497	18.1817	18.2035
32	18.1380	18.2018	18.2522	18.2937	18.3230	18.3501	18.3662