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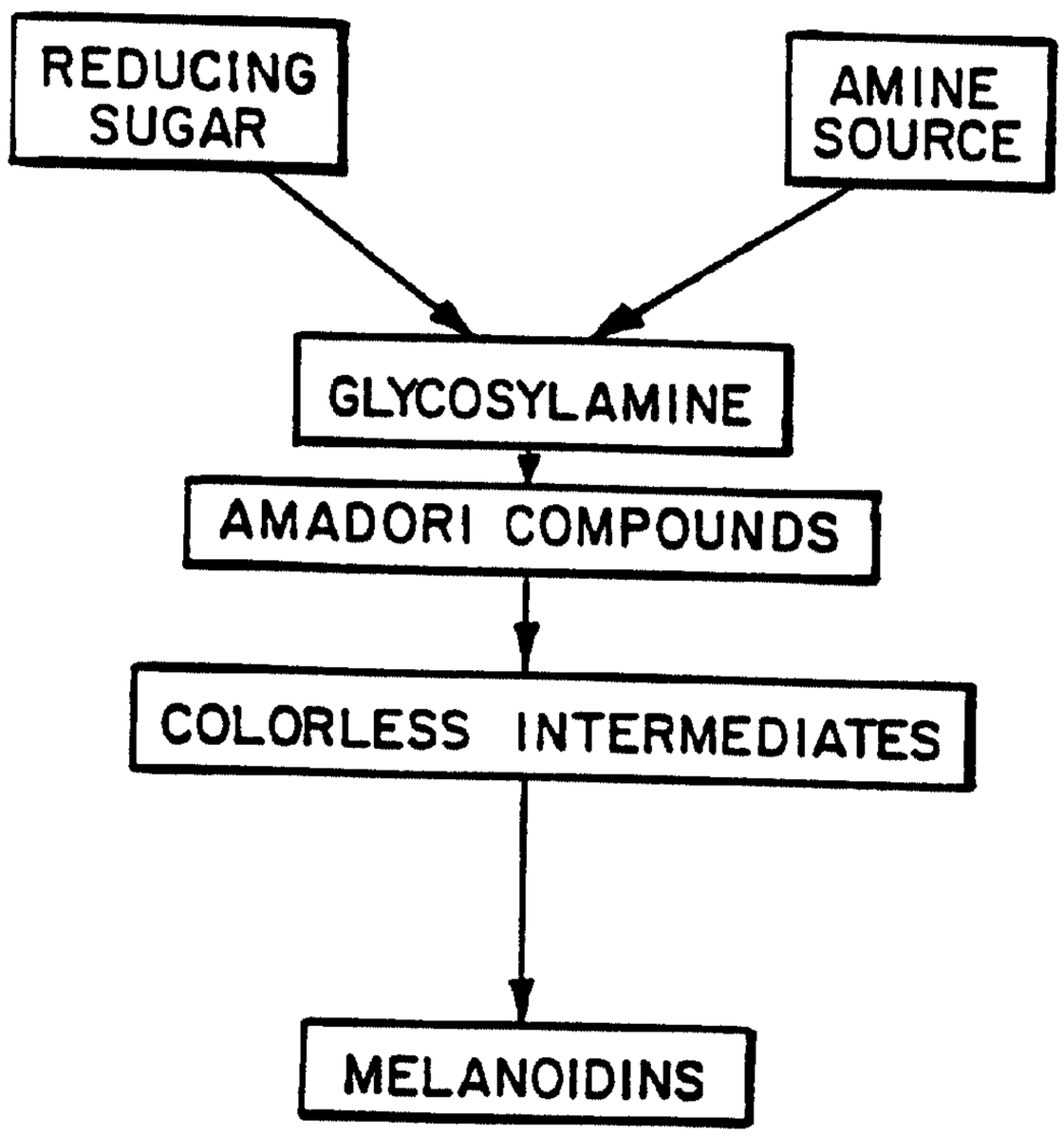
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(57) Abrégé/Abstract:
A food product having a browning surface area or region for developing a desired browning effect during preparation of the food product for consumption by microwave irradiation. The food product includes a starch-based component and a browning system applied to the component to provide the browning surface area or region. The browning system includes Maillard browning reactants for developing the desired browning effect during microwave irradiation, and a carrier system which contains the Maillard browning reactants. The carrier system maintains the Maillard browning reactants in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at temperatures of up to about 40°F for up to several days.

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(57) Abstract

A food product having a browning surface area or region for developing a desired browning effect during preparation of the food product for consumption by microwave irradiation. The food product includes a starch-based component and a browning system applied to the component to provide the browning surface area or region. The browning system includes Maillard browning reactants for developing the desired browning effect during microwave irradiation, and a carrier system which contains the Maillard browning reactants. The carrier system maintains the Maillard browning reactants in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at temperatures of up to about 40° F for up to several days.

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PROCESS FOR MICROWAVE BROWNING AND PRODUCT PRODUCED THEREBY

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The present invention relates to a process for microwave-induced food browning, and to a food product. Using principles of food science and, more specifically, the principles of food browning chemistry, a browning system has been achieved that may be used to brown select regions of foods upon exposure to microwave radiation. Further, the invention includes a process for making a food product using computer, food, and color science.

A major part of the appetizing appearance of conventionally heated foods is imparted by brown colors developed on their surfaces during preparation. Consumers have come to expect this appearance and consider it desirable in a variety of food products including meat, cheese, and cereal grain based products. It is not usually difficult to obtain a browned appearance using conventional cooking because the reactions leading to brown colors will proceed for the components comprising the surface of most foods under conventional baking conditions. However, it has been very difficult to obtain brown colors on the surfaces of foods prepared in microwave ovens without using browning devices.

Reasons why surfaces of microwave prepared products do not brown have been suggested (see for example, D.C.T. Pei, Baker's Digest, February 1982). This reference states that the heat in a conventional oven is transmitted from the oven environment to the food surface via convection and transmitted from the surface to the interior of the product via conduction. This process of heat transfer enables the food surface to dehydrate and rise above the boiling point of water by the end of the conventional bake time. Microwaves, however, penetrate the surface of the product and directly heat the interior of the product. This induces moisture transfer to the surface. Evaporation of the moisture from the surface to the microwave oven environment usually restricts the surface temperature to a maximum of about the boiling point of water during the microwave bake time. The resultant surface temperature is too low to enable the browning reactions to proceed at the necessary rate with the browning reactants inherent to the product surface. In addition to the depressed rate of microwave browning versus conventional browning due to the temperature conditions, microwave preparation times are generally much shorter than conventional preparation times. Therefore, according to the aforementioned reference, the surface conditions and preparation times, resulting from the basic differences in heat transfer mechanisms between microwave and conventional heating, create a very difficult problem for those desiring to effect browning in a microwave oven.

Generally, the solutions to microwave browning can be divided into the following categories: packaging aided, cosmetic, and reactive coating approaches. The

first approach involves the use of microwave susceptors which heat to temperatures exceeding the boiling point of water and brown surfaces in close proximity or direct contact (see for example, U.S. Pat. No. 4,266,108). Limitations of commercially available susceptors include the requirement of close proximity or direct contact, their generally uncontrolled temperature profile, and their generally high cost. The second approach is cosmetic and includes various surface applied formulations that are brown prior to application (U.S. Pat. No. 4,640,837). The third approach involves coating the surface with a formula that will react to yield a brown color at the surface conditions described above. Two such variations of this approach are described in U.S. Pat. Nos. 4,735,812 and 4,448,791.

A discussion of microwave heating can be found in U.S. patent application Ser. No. 085,125 to Pesheck, et al.

The success of a product approach to browning requires control over the rate of the browning reaction. During the shelf life of a product, the rate of browning should be controlled or the product may brown prior to preparation by the consumer. This is usually unacceptable to the consumer. Then, on exposure to a microwave field, the rate should be sufficiently high to brown the product during the short preparation times generally encountered with microwave products.

The invention described herein is primarily based on the chemistry of Maillard browning. Non-enzymatic browning of this type is well characterized, the literature on the subject is extensive and it is the most common form of browning in heated food systems.

There are many reviews of Maillard browning and associated reactions (e.g., Carbohydrates, In: Food Chemistry, H.D. Belitz and W. Grosch, Chapter 4, second edition, 1987.

lthough the myriad of individual reactions leading to the development of the brown melanoidin polymers has been extensively studied, reactions after the initial few steps are not well characterized. This complex series of reactions may be divided into three major categories: the initial condensation of the amine and the carbonyl, the formation of colorless intermediates, and the formation of colored compounds (e.g., the melanoidin polymers). Figure 4 illustrates this highly simplified reaction scheme.

Promotion of browning in a microwave oven is a difficult problem. Initially, attempts were made to develop a microwave Maillard browning system capable of browning refrigerated doughs (e.g., Pillsbury refrigerated buttermilk biscuits). However, as mentioned earlier, there exist several inherent problems with respect to accomplishing this task (e.g., short cook time, etc.). One browning system examined employed pectin gels as the browning agent carrier. Although the gel system did brown microwave-prepared biscuit dough samples to a limited extent, the prepared biscuit dough samples in this study were found to have less than optimal crumb structure and surface texture.

Other food approved carrier systems were used in an attempt to improve the surface textural properties of the microwave prepared biscuit samples. Shortening was found to be preferred due to its ease of manipulation and broad product system applicability. Biscuit dough samples were coated with a mixture of reducing sugar, soy protein, and shortening; placed in a microwave oven; and cooked for a time sufficient to brown the surface. Unfortunately, it was observed that during the microwave cooking cycle, the biscuit samples became very dehydrated and overdone. In a further attempt to improve the textural properties of the biscuit samples, the samples were placed into a sealed plastic pouch prior to microwave treatment. Surprisingly, the pouched biscuit samples not only remained moist and soft, but also browned to a much greater extent in a much shorter time, when compared to biscuit samples prepared without a pouch.

U.S. Patent Serial No. 4,842,876 to K Anderson, et al. discloses the use of a pouch.

These observations led to the conclusion that steam-containing packaging, and possibly other means of enhancing browning, in conjunction with microwave browning ingredient formulation, could be used as a means to control the browning reaction in such a manner as to allow product browning to coincide with product textural development.

The literature (e.g., Color Science Concepts and Methods, Quantitative Data and Formulae, G. Wyszecki and W. S. Stiles, John Wiley and Sons, Inc. 1982, this reference is incorporated by reference herein),

indicates that the measurement of color is a very complicated subject.

A Pacific Scientific Gardner XL-20 Colorimeter and Milton Roy Visible Spectrophotometer were used throughout the research for this invention. The following discussion of the primary responses is based upon the instruction manual for the Gardner instrument (Gardner Laboratory Inc., 5521 Landy Lane, Bethesda, MD).

Three responses were recorded for a routine color measurement. L corresponds to a scale defining a range from black (L=0) to white (L=100). Another value, a_L, defines the range from green (a_L=-40) to red (a_L=+40). Finally, b_L defines a range from blue (b_L=-40) to yellow (b_L=+40). Subsequently, zero values for a_L and b_L correspond to white, grey, or black depending on the L value. Hue (type of color: orange, blue, etc.) and chroma (color intensity: vivid or dull) are defined by a_L and b_L. Figure 1, which is from the Gardner manual, illustrates the three dimensional space describing this system.

The L a_L b_L system is only one system of describing colors. Others include the L a* b* system and the Y x' y' system. Equations are available to convert from one system to another.

The L* a* b* system (Figure 2) is very similar to the L a_L b_L system in that the same relative scales apply (L* is white to black, a* is green to red, and b* is blue to yellow). The Y x' y' system (Figure 3), however, adopts a somewhat different form. The x' and y' coordinates define a point on an irregular portion of an x' y' plane that is composed of various colors. The perimeter of this area is graduated in nanometers

corresponding to the wavelength of the corresponding hue. Both hue and chroma are defined by x' and y'. Y, a scale running perpendicular to x' and y', is a measure of lightness, somewhat analogous to L or L*.

SUMMARY OF THE INVENTION

The present invention involves a process for preparing a system for a microwave food product which browns during exposure to microwave radiation in a time sufficient to prepare a food for consumption. The process includes the steps of: selecting an appropriate carrier which is effective to inhibit browning during the manufacture, distribution, and shelf life of the product (if required), determining the microwave cook time for desirable texture or temperature, selecting particular browning agent(s) and controller(s) to yield the desired browned appearance in an appropriate microwave exposure time, preparing the browning system using these preselected components, and delivering the system to the desired or preselected region(s) of the food product.

The present invention further involves a process for browning a food product during exposure to microwave radiation for a time sufficient to prepare said food product for consumption. The invention encompasses alterations in color appearance. Consequently, application of the invention involves attaining acceptable textural characteristics of the target food product during microwave cooking. When the appropriate formulation and microwave recipe have been obtained, the invention described herein can be applied to attain a desirable browned appearance.

In accordance with one aspect of this invention, there is provided a food product having a

browning region for developing a desired browning effect during preparation of the food product for consumption, the food product comprising:

(a) a starch based component;

(b) a browning system applied to the starch based component to provide the browning region; and

(c) the browning system comprising Maillard browning reactants for developing the desired browning effect during microwave irradiation, and a carrier system containing the Maillard browning reactants, the carrier system maintaining the Maillard browning reactants in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at a temperature of about 40°F (about 4°C) for at least about two days.

The invention further extends to a process for making a food product which has a browning region for developing a desired browning effect during preparation of the food product for consumption by microwave irradiation, the process comprising:

(a) selecting a starch based component;

(b) applying a browning system to a browning surface area of the starch based component; and

(c) the browning system comprising Maillard browning reactants for developing a desired browning effect during microwave irradiation, and a carrier system

containing the Maillard browning reactants, the carrier system maintaining the Maillard browning reactants in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at a temperature of about 40°F (about 4°C) for at least about two days (about 48 hours).

The browning region is usually and preferably an external surface region or area of the food product. However, where the browning region is within or extends to within the food product, it may be in selected areas or regions within the food product or may extend substantially throughout the food product.

In an alternative embodiment of the invention, only one of a pair of Maillard reactants may be contained in the carrier system in a substantially reactively immobilized state. Thus, in accordance with this embodiment of the invention, there is provided a food product having a browning surface region for developing a desired browning effect during preparation of the food product for consumption by microwave irradiation, the food product comprising:

(a) a starch based component;

(b) a first Maillard browning reactant applied to the browning surface area of the starch based component;

(c) a second Maillard browning reactant applied to the browning surface area, the second Maillard browning reactant being complementary to the first Maillard browning reactant for reacting

therewith to develop the desired browning effect during microwave irradiation; and

(d) the second Maillard browning reactant being contained in a carrier system for maintaining that Maillard browning reactant in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at a temperature of about 40°F (about 4°C) for at least about two days.

In accordance with this invention, the carrier system maintains at least one of the Maillard browning reactants in a substantially reactively immobilized state so that the reactants will not produce any significant browning effect during manufacture of the food product, during handling and storage of the food product under appropriate conditions, and preferably during the freeze/thaw cycles or cooling/heating cycles which are not unusual in frozen or refrigerated food products after manufacture of the food products and before they are heated for consumption by the consumer.

The carrier system is preferably such that the Maillard browning reactants will remain substantially reactively immobilized at temperatures of up to about 40°F (about 4°C) for periods of up to at least about two days, and preferably up to at least about four to six days.

Preferably, the carrier system is such that the Maillard browning reactants may be maintained in a substantially reactively immobilized state even at

temperatures up to about 70°F. for at least about 2 days, and preferably for up to about four to six days.

In accordance with a further aspect of the invention, there is provided a process for making a food product which has a surface area developing a desired brown coloration during preparation of the food product for consumption by microwave irradiation for a predetermined period of time, the process comprising:

(a) preparing a suspension comprising substantially homogeneous coparticles of reducing sugar and proteinaceous substance in lipid to produce a browning suspension; and

(b) applying an amount of the browning suspension to an area of the surface of the food product, the amount being sufficient to develop the desired surface coloration during microwave irradiation of the food product for the predetermined period of time.

In accordance with yet a further aspect of the invention, there is provided a process for preparing a food product having a browning surface area for developing a desired browning effect during preparation of the food product for consumption, the process comprising:

(a) forming a solution comprising water, reducing sugar and proteinaceous substance, the reducing sugar and proteinaceous substance being in a ratio effective to produce Maillard browning to a desired degree;

(b) dehydrating said solution to produce a stable coparticulate browning composition which will brown when a food product to which it is applied is prepared for consumption by microwave irradiation for the predetermined period;

(c) suspending a quantity of the coparticulate browning composition in a lipid;

(d) applying the lipid to a browning surface area of a food product; and

(e) storing the food product at a temperature below about 40°F (about 4°C).

The Maillard browning reactants may be reactants of any appropriate type. The browning reactants may therefore include aldehyde or ketone-containing carbohydrates (for example, reducing sugars) capable of participating in Maillard browning, and amine-containing ingredients (for example, proteins, peptides, or amino acids) capable of participating in Maillard browning.

Embodiments of the invention may involve prereacting the Maillard browning reactants to yield substantially or generally colorless Maillard browning intermediates, or intermediates which generally match the color of the food product to which they are to be applied and which are therefore generally colorless in the context of their application to a manufactured food product. The reactants or intermediates may therefore be generally colorless, or may be "in situ colorless" where they generally match the color of the food

product. These are the intended meanings of "colorless" and "in situ colorless" in the context of this application. The invention may further involve the formation of homogeneous coparticulates of the original reactants and any intermediates; may involve the formation of heterogeneous particles by the absorption of the browning reactants onto particles (for example, silicates); and may involve the incorporation of browning controllers.

In some cases, the addition of browning controllers to affect the rate of subsequent Maillard browning in situ may be used. Browning controllers may include Ph-adjusting ingredients (e.g., sodium bicarbonate, sodium hydroxide), phosphate salts (e. g., sodium or potassium phosphate salts), enzymes (e.g., mutarotase or a protease), metal ions (e.g., iron and copper salts), steam-retaining packaging, packaging susceptors, and ionizable salts capable of affecting the dielectric properties of the browning system in such a way that the temperature of the browning system is greater, upon exposure to microwave energy, than when salt is absent.

While this invention relates particularly to a food product having a browning external surface area to develop a desired brown coloration during preparation of the food product for consumption by microwave irradiation for a predetermined period of time, other regions of food products may likewise be treated with the browning system of this invention.

One aspect of the invention may involve preparing a suspension comprising substantially homogeneous coparticles of the Maillard browning reactants. The substantially homogeneous coparticles of

aldehyde or ketone-containing carbohydrate and amine-containing substances capable of participating in Maillard browning reactions, may be formed, for example, by dehydrating an aqueous solution comprising a reducing sugar and a proteinaceous substance. Such dehydration can allow some prereaction and can lead to the formation of particles with the Maillard browning reactants and any subsequent substantially colorless intermediates, in what can be described as intimate integrated physical contact. Such coparticle formation can facilitate the later Maillard browning reaction by the proximity and/or prereaction of reactants in situ on the surface of a food product being prepared for consumption in a microwave oven.

The browning systems including the Maillard browning reactants, intermediates thereof and/or coparticles thereof, are preferably substantially colorless or the color of the food surface of the food product prior to preparation for consumption by microwave irradiation so that the browning surface area of the food product will develop a desired final browning coloration during microwave preparation and not before. Browning before microwave preparation can often lead to a lack of consumer acceptance. For this reason, the carrier system is designed to reactively immobilize or substantially reactively immobilize at least one of the components of the browning system (for example, the amino-containing substance, the aldehyde or ketone-containing carbohydrates, or water) from the remainder.

By "substantially reactively immobilized" is meant that the browning system, when stored for a period of up to two days, at a temperature of 40°F (4°C), will not produce any unacceptable or significant browning

effect, and will generally provide substantially the same browning potential upon exposure to microwave radiation before storage as it will after storage.

In preferred embodiments of the invention, the Maillard browning reactants are substantially reactively immobilized so that they will not produce any unacceptable or significant browning effect when stored for periods of up to about four days, of up to about six days, or for longer periods under appropriate conditions, at temperatures of about 40°F, or at temperatures above 40°F and up to about 70°F.

The aldehyde or ketone-containing carbohydrate capable of participating in Maillard browning used in preparing the browning agent of the present invention is preferably a reducing sugar, more preferably an aldose or ketose of 3-6 carbons, and most preferably glucose, fructose, or xylose. The amine-containing substance capable of participating in Maillard browning is preferably a proteinaceous substance and is more preferably a peptide or protein in native or denatured form. Most preferred proteins include soy protein, egg albumin, whey protein, and casein. When the protein is denatured to make more chemically accessible its amino groups, it is preferably denatured by heat, acid, physical manipulation, or proteolytic digestion. The aldehyde or ketone-containing carbohydrate and amine-containing substance capable of participating in Maillard browning may be present in a weight:weight ratio generally between about 1:10 and about 10:1 (more preferably between about 3:1 and 1:3) commensurate with a desired degree of Maillard browning.

The carrier system of this invention preferably includes a lipid. Where the food product can

provide sufficient moisture for the Maillard reaction during microwave irradiation, the carrier system may be free of moisture to facilitate reactive immobilization of the Maillard browning reactants. Where the food product cannot provide sufficient moisture for the Maillard browning reaction during microwave irradiation of the food product, the carrier system may include water. In this aspect of the invention, the carrier system includes adsorptive materials (for example, silicate particles) to adsorb the water and/or the Maillard reactants to maintain them in a reactively immobilized state. In an alternative arrangement, the Maillard browning reactants may be maintained in a substantially reactively immobilized state within a hydrophobic carrier system, such as lipid, with the lipid separating the reactants from the moisture required during microwave irradiation to provide the browning effect. A preferred lipid is shortening of the type commonly used in food products, most preferably a shortening derived from a vegetable oil such as that from sunflower, corn, safflower, rape seed, soybean, or other plants.

The prereaction of an aldehyde or ketone-containing carbohydrate and amine-containing substance capable of participating in Maillard browning under conditions facilitating reactions leading to Maillard browning generally involves an aqueous environment, a neutral to alkaline Ph, and sufficient heat (e.g., 50°C-100°C) to facilitate a Maillard reaction. The reaction should be halted before a noticeable difference in visible color is observed when the above said agents are applied to the product system. This halting of the reaction may be accomplished by lowering the temperature

(e.g., to between 0°C and 10°C), but could also be done by other means such as removal of water.

Substantially colorless browning systems are preferred since they can be associated with any product. However, it is to be understood that "colorless" in situ is more important since the browning system should not change the appearance of the substrate when the system is in place prior to microwave cooking. As an example, a cookie dough or wheat bread dough system can have a prebrowned system applied that is "colorless" on the product.

Preferred carriers include lipids (shortenings, oils, and waxes), water, water-lipid emulsions or polyols such as glycerol, and emulsions of silicate particles to adsorb and thus isolate the reactants. The preferred carriers substantially reactively isolate the browning agents and thus prevent or retard development of a browned appearance prior to exposure to microwave radiation. Isolating the browning agents can also be attained by freezing a product coated with an aqueous slurry of browning agents and possibly controllers to yield an ice matrix as a carrier when used in a reliably controlled frozen distribution system. Another aspect of the carrier is that it may be selected to provide browning on a high or low moisture product.

This invention further extends to a method of producing a food product with a preselected color in a preselected region of the food product, said method comprising:

(a) selecting at least one parameter from a group comprising: color producing agent, heating time value, agent concentration

value, final food color value, substrate color;

(b) inputting said selected parameter into computer means programmed with a functional relationship between said selected parameter and at least one of the other said parameters and operable to provide output information about at least one of the other said parameters;

(c) making a food product in accordance with said output information;

(d) heating said food product;

(e) and wherein said color producing agent assists in approximately producing said final food color value in a preselected region of said food product.

The output information may include a final food product color that includes hue and chroma and said selected parameter may be at least one of a color producing agent, heating time value and agent concentration value.

The selected parameter may include a final food product color value that includes hue value and chroma value and said output may include at least one of a parameter selected from a group comprising color producing agent, heating time value and agent concentration value.

In the method, the computer means may include color graphics output means, and the method may comprise adjusting the final food product color value on the color graphics output means until a desired color is achieved, and outputting information from said computer means relating to at least one of said parameters.

The method may comprise comparing a preselected colored sample to color on the color graphics display means and adjusting the color on said colored graphic display means to approximately match the color of said sample.

Further in accordance with the invention, a method for producing a food product having a desired color, comprises the steps of:

(a) using computer means to display color for a food product as a function of at least one of the following parameters: a browning agent selected from the group comprising proteins and reducing sugars or prereacted browning intermediates thereof, controllers selected from the group comprising metal ions, salts, enzymes, pH adjusting agents, steam retaining packaging, carriers, and microwave exposure time of the food product;

(b) selecting a desired color for the food product and adjusting one or more of said parameters, if necessary, to provide adjusted parameters which produce a computer color display of the desired color using said computer means; and

(c) preparing a food product in accordance with said adjusted parameters.

The invention further extends to a method of producing a food product with a desired color in a preselected region of the food product, said method comprising:

(a) selecting at least one parameter from a group comprising color producing agent, agent concentration value, hue value and chroma value;

(b) inputting the selected said parameter into an input means operatively associated with a programmed processor means having a program in memory means operatively associated therewith for computing an output parameter comprising at least one of the nonselected said parameters based upon a functional relationship between the selected parameter and the output parameter;

(c) outputting said output parameter from output means operatively associated with said programmed processor means; and

(d) making a food product in accordance with said selected parameter and said output parameter.

The invention further extends to a programmed computer means adapted to output food color information, said computer means including:

(a) a processor means operable for manipulating at least a portion of first color information and outputting second color information;

(b) input means operably connected to said processor means and operable for inputting information to said processor means;

(c) display means operably connected to said processor means and operable for

displaying said second color information; and

(d) memory means operably connected to said processor means for storage of information used by the processor means, said memory means storing third information relating food preparation to food product color.

In an embodiment of the invention, the third information may include a portion of time a color agent is associated with a food product.

The color agent may include a browning agent, and the browning agent preferably includes Maillard browning reactants or intermediates.

The invention also extends to a programmed computer means for determining how to prepare a food product to produce a predetermined desired color, comprising:

(a) input means for receiving input signals which are indicative of parameters that determine the color of a food product when it is heated;

(b) programmed memory means which is programmed to functionally relate a desired color of a food product to parameters that determine the color of the food product when it is heated;

(c) processor means operatively associated with the input means, the processor means being operative to receive input signals which are indicative of parameters that determine the color of a food product when it is heated, the

processor means being operatively connected to the programmed memory means, the processor means being operative to produce output signals indicative of the color of a food product when it is heated where the food product is made in accordance with such parameters; and

(d) output means operatively associated with the processor means, the output means being responsive to output signals from the processor means, the output means being operative to display information indicative of the color of the food product when it is heated.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically shows the three-dimensional space of the L a_L b_L system for color evaluation.

Figure 2 schematically shows the three-dimensional space of the L* a* b* system for color evaluation.

Figure 3 schematically shows the three-dimensional space of the Y x' Y' system for color evaluation.

Figure 4 schematically illustrates a simplified overall Maillard browning scheme.

Figure 5 depicts the changes in transmittance (from 400 to 700 nm) for moist biscuit samples after treatment with low (M0), medium (M15), and high (M30) moisture browning systems.

Figure 6 depicts the changes in transmittance (from 400 to 660 nm) for dry biscuit samples after

treatment with low (D0), medium (D15), and high (D30) moisture browning systems.

Figure 7 illustrates a lag phase for color development in the Maillard reaction.

Figure 8 shows that the lag phase in the Maillard reaction is temperature dependent.

Figure 9 shows that prereaction of Maillard reactants substantially reduces the lag phase in color development.

Figure 10 illustrates the linear relationship between concentration of protein sample and ninhydrin color development.

Figure 11 shows a linear relationship of protein lysine content and ninhydrin color development.

Figure 12 shows relationships between Gardner L and a_L values from biscuit samples and 1) protein lysine content; and 2) slope of the linear relationship between ninhydrin chromphore absorbance and protein concentration.

Figure 13 shows the relationship of Gardner L values and biscuit coating thickness.

Figure 14 shows the relationship of Gardner a_L and b_L values and biscuit coating thickness.

Figure 15 shows surface or internal temperature profiles for biscuits heated by microwaves in an open or closed system.

Figure 16 shows shelf life performance in terms of resultant Gardner L values of the browning coating on refrigerated biscuits.

Figure 17 shows shelf life performance in terms of resultant Gardner a_L and b_L values of the browning coating on refrigerated biscuits.

Figure 18 shows a 1931 chromaticity diagram of bovine serum albumin (BSA) and various amino acids at different stages of Maillard browning with glucose.

Figure 19 shows changes in biscuit surface color between storage day 1 and 6 at 0°F, 40°F and 70°F prior to microwave preparation.

Figure 20 depicts pre-to-post microwave change in biscuit surface color after 6 days storage.

Figure 21 shows an example of the triplet patch browser computer display.

Figure 22 shows an example of the gauge browser computer display.

Figure 23 shows an example of the N by N color patch browser computer display.

Figure 24 shows a 1931 chromaticity diagram of various reducing sugars at various stages of Maillard browning in reaction with lysine.

Figures 25, 26, and 27 compare certain shelf life studies performed with a food product treated in accordance with this invention (identified as "P"), and a food product prepared in accordance with an embodiment selected from U.S. Patent 4,448,791 (identified as "C"), when stored at 0°F (-18°C)--Fig. 25, when stored at 40°F (4°C)--Fig. 26, and when stored at 70°F (21°C)--Fig. 27. The graphs of Figs. 25-27 plot DE vs. days. DE is a parameter which is identified as the "color change" and describes the magnitude of the difference between the color of the brown surface area of the food product at day 0 and any given day.

DETAILED DESCRIPTION

Unless otherwise specified, all percents reported herein are by weight.

In one preferred embodiment of the present invention, a preferred preliminary step involves prereacting an aldehyde-containing or ketone-containing carbohydrate and an amine-containing substance capable of participating in Maillard browning under conditions initiating a Maillard reaction scheme. This prereaction involves the substantial completion of preliminary chemical reactions affecting the rate of Maillard browning, but most preferably does not result in the development of visually noticeable colors, or results in a substantially colorless product as defined. Amine loss can be measured by HPLC to indicate degree of reaction.

A preparation comprising reducing sugar and an amine-containing substance capable of participating in Maillard browning may also contain mutarotase to catalyze the formation of sugar forms more reactive in the Maillard reaction. A preparation comprising an aldehyde or ketone-containing carbohydrate and a protein may also contain a protease to increase the number of reactive amino groups thereby facilitating the Maillard reaction. The inclusion of phosphate or carbonate, for example as a potassium or sodium salt, may also be used to accelerate the Maillard reaction.

The invention thus involves a process for browning a food product during exposure to microwave radiation for a time sufficient to prepare said food product for consumption. This includes subjecting a food product, prepared as described above, to microwave heating for a time sufficient to prepare said food product for consumption. The process of the present invention may additionally involve storing the browning system or treated food product at temperatures low

enough to inhibit a browning reaction in the applied browning system.

The aldehyde-containing or ketone-containing ingredient is generally an aldose or ketose having 3-6 carbons per molecule, most preferably is glucose, fructose, or xylose. The process of the present invention may, for example, involve a reducing sugar selected from the group consisting of glyceraldehyde, xylose, glucose, mannose, galactose, ribose, dihydroxyacetone, arabinose, and fructose. Although one or more amino acids may be used to react with the reducing sugar to facilitate Maillard browning, a protein or protein mixture is preferred. A protein, for example, may be egg albumin, cereal protein, whey, casein, soy protein, and/or mixtures thereof. Hydrolyzed proteins or peptides may also be used.

The carrier of the present invention may be any substance capable of delivering browning agents to the product system while preferably retaining them reactively immobilized, and preferably includes a lipid. Preferred lipids include shortening such as an animal, vegetable, synthetic fatty substance or wax used in foods but more preferably consists essentially of shortening and oils derived from a vegetable oil such as soy oil, cottonseed oil, safflower oil, corn oil, rapeseed oil, sunflower oil, or a combination thereof. The carrier system may also comprise a water-lipid emulsion, or a polyol such as glycerol.

Food products particularly usable with the present invention include imitation cheese, dairy products such as cheese, and starch-based products such as biscuits, sweet rolls, cake, bread, french toast,

pizza crust, potatoes and products made from comminuted foods such as wheat flour and corn meal.

Most preferably, the food product is a dough-based product or dough-like product (hereinafter referred to as dough-based product) such as biscuits, cookies, breads, pastries, pie crusts and their precursors; or batter based products such as cakes, cookies, cupcakes, muffins, pancakes, and waffles. The present invention is usable with food products with any browning system-treated surface dimension, which surface increases by 20% or more sometime over the history of the product (e.g., during manufacturing, storage, cooking and heating).

Applicants have also found that food products in the form of biscuit dough samples, when treated with a browning system in accordance with this invention, also brown satisfactorily when cooked in a conventional oven.

Due to the broad application of the browning systems described herein, a model system was developed that could be used to rapidly screen variables with respect to color development. This model system allowed the effects of variables upon browning rates to be readily evaluated.

Filter papers with an applied browning formulation were used as a rapid screening tool and were found to correlate well to food product systems. Even better model system/product correlations could be obtained if color measurement backplates corresponding to a particular product's optical properties were identified and used, but are not required.

Using the model system and two food systems (biscuit dough and cake batter), statistical models were

developed to aid in the selection of some preferred browning agents and enhancers.

For the model system, a browning system coating was spread over five water-wetted filter papers which were then microwaved for desired times. Their color was recorded with a Gardner colorimeter using a white background plate.

1.7 grams of browning coating was spread onto the top surface of each of nine biscuits (top surface area = 23 cm^2/biscuit) which were then microwaved inside a steam-retaining pouch for 2 minutes. After completion of the microwave cycle, the biscuits were kept inside the pouch for 2 minutes. Gardner color measurements were made on all but the center biscuit.

For cakes, 7 grams of browning drys 1:1 (protein:reducing sugar) were dusted onto a pregreased (7 grams of Crisco shortening) microwave cake pan (surface area 531.4 cm^2). Pillsbury Microwave Yellow Cake batter was deposited in the pan and microwaved for 6.5 minutes. Four color measurements per cake were then taken using a Gardner colorimeter.

A Box-Behnken type design was chosen to study the effect of varying microwave time, albumin, soy, xylose, glucose, and sodium bicarbonate on the developed brown color of microwaved filter papers (measured by Gardner L a_L b_L values).

The variables and their limits are given below:

TABLE 1

VARIABLE NAME	MW TIME (SECS)	SUGAR: SOY: PROTEIN (RATIO)	ALBUMIN (RATIO)	GLUCOSE: XYLOSE (RATIO)	SODA %
CODE	A	B	C	D	E
- 1	40	0.2	0.0	0.0	00
0	80	1.0	1.0	1.0	25
+ 1	120	5.0	infinity	infinity	50

1) Litton Generation II microwave oven.
2) Sugar(s) + Protein(s) = 50% of total formulation.
3) % Oil = 50% - % Soda.

The accuracy of the generated predictive model equations, as measured by the r-square value is:

$L = 0.91 \quad a_L = 0.86 \quad b_L = 0.78 \quad (n = 56 \text{ runs})$

The generated predictive equations for L, a_L, and b_L for the model system are:

$$L = 73.7292 - 8.3927(A) - 4.4667(B) - 1.5982(C) + 2.1045(D) - 5.5469(E) - 5.4750(B)(E) + 4.3002(A)(D) + 2.7434(B)^2 - 2.3659(A)(E) + 3.1124(A)(C) - 2.5482(C)(D) + 1.2451(D)^2 + 1.6531(E)^2 - 1.4267(D)(E) + 1.8850(B)(C) - 1.8200(A)(B)$$

$$a_L = 6.8605 + 4.1416(A) + 2.5350(B) - 0.2513(C) - 0.9071(D) + 2.8294(E) + 3.6075(B)(E) - 2.9141(A)(D) - 1.6313(B)^2 - 1.9742(A)(C) + 1.6255(C)(D) - 1.1568(E)^2 + 1.1257(D)(E) - 0.8210(D)^2 - 0.8087(C)(E)$$

$$b_L = 26.3620 + 2.3819(A) + 0.7850(B) - 1.4763(C) - 2.2132(D) - 0.2482(E) + 4.2300(A)(B) - 2.8568(B)^2 + 2.1625(B)(E) - 2.4279(A)(E) + 2.4259(C)(D) - 2.0503(A)(C) - 2.6300(B)(D) - 1.8540(D)^2 - 1.8490(A)^2 + 1.3448$$

Where

A = microwave time (seconds)

B = sugar/protein ratio

C = soy protein/albumin ratio

D = glucose/xylose ratio

E = sodium bicarbonate (%)

Two statistical methods were used to incorporate model system information into product color predictive equations:

Method I: The slope and intercept of actual product color versus actual filter paper color is obtained for their corresponding browning formulations using the "error in both variables" method. This is a statistical method similar to the commonly used "least squares" method for fitting linear relationships. It includes, however, a treatment to incorporate variation in the x variable in addition to the y variable. This intercept and slope serve as the constants for an equation of the type y = mx+b where x is the color value predicted from the model system design equation and y is the predicted product color.

Method II: The actual product color is incorporated into the model system design as a new independent variable. This new variable was designated F and takes the coefficient of -1 when it refers to the model system and +1 when it applies to the product.

Fifteen browning formulations were run on biscuit dough samples to study the browning reaction of variables B, C, D, and E previously studied in the model system. Variable A, time, was excluded due to the fact that the product system has a fixed microwave cook time.

Thirteen browning formulations were run on cake batter samples to study the browning reaction of variables B, C, and D previously studied in the model system. Variable A, time, was excluded for the reasons mentioned previously. Variable E, soda, was excluded because it creates brown specks in microwave cakes.

Both statistical methods (I and II) were used to incorporate the model system information as an aid in the development of product color predictive equations. The accuracy of the color predictions using the statistical methods (I and II) can be expressed as the overall standard deviation of the difference between the predicted product color and the actual product color. Table 2 below summarizes this information:

TABLE 2

COOKED BISCUITS

	Gardner Values Standard Deviations			Number of Runs
	L	a_L	b_L	
Method I	4.2	2.4	2.8	15
Method II	3.1	1.2	2.4	15

Method II also reports an r-square value for the complete design equation (n=73, 58 filter papers and 15 biscuits) as follows: L = 0.96; a_L = 0.90; b_L = 0.72.

The generated predictive equations for L, a_L, and b_L for the biscuit system are:

$$L = 65.1715 - 8.4162(A) - 7.5052(B) - 0.2301(C) + 4.8245(D) - 6.1878(E) - 8.4143(F) - 5.4750(B)(E) + 4.1348(A)(D) + 2.2306(D)(F) - 3.0385(B)(F) - 2.3307(A)(E) + 2.2960(B)^2 + 1.5160(D)^2 + 3.0317(A)(C) - 2.0016(C)(D) + 1.6427(C)(E) + 1.5150(E)^2 + 1.8850(B)(C) - 1.8200(A)(B) - 0.8322(D)(E)$$

$$a_L = 9.3443 + 4.1364(A) + 3.7612(B) - 0.4329(C) - 2.3756(D) + 2.8541(E) + 2.4114(F) + 3.6075(B)(E) - 2.7354(A)(D) - 1.3632(D)(F) + 1.0836(D)(E) - 1.9408(A)(C) - 1.2176(C)(E) - 1.2869(E)^2 - 1.3640(B)^2 - 0.9825(D)^2 + 1.0739(C)(D) + 1.2262(B)(F)$$

$$b_L = 26.5557 + 2.3494(A) + 0.4139(B) - 1.0559(C) - 1.6218(D) - 0.7297(E) + 0.3779(F) + 4.2300(A)(B) + 1.9762(D)(E) - 2.8372(B)^2 - 2.3792(A)(E) - 2.0822(A)^2 - 1.7320(D)^2 + 1.8841(B)(E) - 2.6300(B)(D) + 1.8205(C)(D) - 2.647(A)(C)$$

Where

A = microwave time (seconds)

B = sugar/protein ratio

C = soy protein/albumin ratio

D = glucose/xylose ratio

E = sodium bicarbonate (%)

F = +1 (for biscuits; an input of -1 will yield a prediction of model system values)

TABLE 3

COOKED CAKES

Gardner Values

Standard Deviations	L	a_L	b_L	Number of Runs
Method I	2.6	2.0	1.2	13
Method II	2.4	1.7	1.5	13

Method II also reports an r-square value for the complete design equation (n=71, 58 filter papers and 13 cakes) as follows: $L = 0.91$; $a_L = 0.84$; $b_L = 0.83$.

The predictive equations for L, a_L, and b_L for the cake system are:

$$L = 67.9230 - 8.3560(A) - 4.3888(B) - 1.5775(C) + 2.1958(D) - 5.6057(E) - 6.3698(F) - 5.5917(B)(E) + 4.1804(A)(D) + 2.5173(B)^2 - 2.4211(A)(E) + 2.8752(A)(C) - 1.3210(C)(D) + 1.5362(B)(C) + 0.9396(D)^2 - 1.8200(A)(B) + 1.2811(E)^2 - 1.1212(D)(E)$$

$$a_L = 8.5680 + 4.0798(A) + 2.4954(B) - 0.3304(C) - 1.1262(D) + 2.8549(E) + 1.8608(F) + 3.6670(B)(E) - 2.7477(A)(D) - 1.7792(B) - 1.9441(A)(C) + 0.9318(C)(D) + 1.0565(D)(E) - 1.0105(C)(E) - 1.0610(E)^2 - 0.8462(B)(C) - 0.5450(D)^2$$

$$b_L = 30.1557 + 2.3504(A) + 1.9159(B) - 0.7553(C) - 0.6540(D) - 0.1255(E) + 3.9003(F) + 4.2300(A)(B) - 2.6023(B)^2 + 1.5747(D)(F) - 2.3806(A)(E) - 1.8550(A)_2 - 1.5176(D)_2 + 2.1625(B)(E) + 1.1309(B)(F) - 1.9772(A)(C) + 1.3757(C)(D) + 1.2645(D)(E) - 1.1994(B)(D) + 0.5272(C)(F)$$

Where

A = microwave time (seconds)

B = sugar/protein ratio

C = soy protein/albumin ratio

D = glucose/xylose ratio

E = sodium bicarbonate (%)

F = +1 (for cakes, an input of -1 will yield a prediction of model system values)

For both product systems studied, Method II was chosen over Method I because it generated predictive equations with better accuracy. Other product systems might yield better predictive equations with Method I.

The statistical approach described above is very flexible with respect to incorporating other browning agents and browning controllers. It is also very adaptable to other product systems. This can be accomplished using either Method I or Method II described above.

The equations developed using the statistical procedure described herein are not limited to the examples given above and can be used with other food products and browning system components. In addition, these equations can be used in conjunction with a computer program and the appropriate computer hardware, to display the predicted brown color of a selected browning system on a computer screen. This enables the actual visual perception of the predicted color. This is more useful to those unskilled in color science who design microwave food products than the values associated with color measurement (e.g., L a_L b_L).

For example, the equations above developed for the model system, biscuits, and cakes were incorporated into a computer program that enables the color of the

resultant browning formula to be displayed on a computer monitor.

The computer used was an Apple MacIntosh™-II with 5 megabytes of main memory, a Spectrum™ display (1024x768x8) board and 19" Spectrum™ monitor.

The computer software was ParcPlac™ Smalltalk-80 V12.2/VM1.1 with Knowledge Systems Corporation Pluggable Gauges™ package. Various software fragments supplied by ParcPlace as "Goodies" were incorporated in the "Color" section of the program.

These software packages running on the above hardware provide basic systems functions to which are added the See Lab functions which provide interactive color synthesis capability. The computer program is Smalltalk code.

For best results, the computer monitor should be calibrated and adjusted for ambient lighting to generate light psychophysically equivalent to the actual color. This is accomplished by methods outlined by William Cowan and Colin Ware in their Tutorial: "Color Perception" of SIGGRAPH '84 conference (available through the Association of Computing Machinery).

As described herein, the color system used was the Gardner L a_L b_L system. However, it is to be understood that other tri-stimulus value color measuring systems can also be utilized and can be easily accommodated in the computer system or the method as described herein. These other color systems include Yx'y', CIE L a b, XYZ and RGB. These different color measuring systems can be correlated to one another as set forth in Color Science discussed herein. The systems are interchangeable. Further, the method of making a colored food product and the computer system

can be used for other desired food colors in addition to browning.

A food product can be made with a preselected color in a preselected region of a food product by including the following steps:

(a) using a food preparation parameter which can include either food formula information, for example, the component parts of the food; color producing agent; agent concentration value; carrier type; final food color value, which may include one or more of the three tri-stimulus values e.g. L a_L b_L, hue and chroma; substrate color; color controller information; and can include food processing conditions, for example, heating time, mixing conditions, pretreatment agent/controller, particle sizing and coating parameters;

(b) inputting information about one or more of the above-described parameters into a computer means that is programmed with a functional relationship between the selected parameter(s) and one or more of the other parameters. The computer means is operable to provide output information about at least one of the other said parameters;

(c) displaying output information from the computer means by a color graphic display means e.g. a CRT or print output, for example the L a_L b_L numbers or actual colors;

(d) adjusting the color graphic display means to compensate or to calibrate the screen for the particular computer system and color graphic display means so that uniformity of color from system to system can be accomplished; and

(e) utilizing output information from the computer means in making a food product in accordance with the output information.

While the process of this invention is particularly suitable for use in preparing food products for consumption by subjecting them to microwave irradiation, the process can also be applied to food products which are to be prepared for consumption by cooking or baking in conventional ovens and systems.

Further adjustings in the process can be done in accordance with the one or more of the preceding steps until a final color which is desired or preselected is achieved on the food product. The parameters need not necessarily be adjusted if they were properly preselected initially. The thus made food product is heated or otherwise processed to achieve the desired or preselected color. The color producing agent assists in producing the approximate preselected color in the final food product in a preselected region of the food.

The computer means includes a processor means which is operably connected to an output means, for example a color graphics display means or a printer or the like for providing output color information. An input means is operably connected to the processor

means. An input means can be a keyboard or the like or a color measuring device.

Generally, the processor means and the memory means are a suitable digital computer such as an Apple MacIntosh-II™, and the color graphic means can be a color CRT and controller.

The processor means is operable for manipulating input color information from the memory means. It can by selection of the operator manipulate one or more of the food preparation parameters. The memory means stores information which can include a functional relationship between one or more of the above-described food processing parameters and formula parameters and preferably receives information from the input means. Any of the above-described parameters can be utilized as input in order to provide output color information.

Functional relations can be determined by using the statistical approach as discussed.

The computer system is particularly useful with Maillard browning agents and/or intermediates.

The information stored in the memory means can include color information about a food product prior to heating or formation and after heating.

The processor interprets the input from the memory means or the input means and uses an algorithm and stored data to produce output information.

A feature of the present invention is that in the browning system and other color systems, food coloring builds pigments in situ during formation and/or heating of the food product. A paint system, for example, has a pigment formed prior to introducing into a carrier system. Further, food substrate color, before

and/or after heating, should be included in the evaluation because of the somewhat transparent nature of the formed color. The food substrate can affect the final food product color. Further, another important feature of the present invention is that it can predict color of a food product as it changes with time or time and temperature or perhaps more accurately total heat input. Current color predicting computers (like those used for paint) do not concern themselves with how color changes with time or temperature. Further, the present invention can also accommodate pigments and dyes as color agents. Another complication for food systems is that a color agent can migrate into or from an initial position in the food product substrate.

In order to facilitate the more rapid development of browning, the use of prereacted typical browning ingredients was studied and found to be feasible. It is well documented that the complex Maillard browning reaction proceeds through many steps prior to color development. When a prereacted but substantially colorless mixture of reducing sugar and amino acid and their reaction products, prepared as described below, was applied to a surface and subjected to microwaves, it was determined that browning was achieved sooner than when the same ingredients, but not prereacted, were analogously used.

A study of a model system with glutamine and glucose was conducted. Through reaction of these two compounds in solution, it was observed that a lag phase in color development occurred (Figure 7). In this system, at 100°C, the colorless lag phase was about 6 minutes. It was determined, by running this reaction at various temperatures, that the lag phase was temperature

dependent (Figure 8). More important to the objectives of this invention, the lag phase could be eliminated for in situ browning. A sample of the reactant solution was heated to a point just prior to development of measurable browning. The reaction was then radically slowed by rapid cooling. This prereacted solution was compared to a dissolved reactant solution by spectrophotometrically measuring color development with time at 100°C. The results clearly indicated that the lag phase was eliminated in this manner (Figure 9).

The reduction of lag time in color development with prereacted as compared to non-prereacted systems was noted. A precipitate formed when ethanol was added to a prereacted solution. Comparing the browning development of these precipitates to the browning development of the relative initial reactants under controlled microwave conditions indicated significantly higher browning for the prereacted samples.

To determine whether prereacted solutions could aid in the microwave browning of specific food products, tortillas and pizza crusts were evaluated. Prereacted solutions of glutamine and glucose were applied to surfaces of the products. Solutions of the initial reactants were similarly applied to control products. Objective color evaluations of the two types of samples showed significantly higher browning for the prereacted samples for both pizza crusts and tortillas. See Tables 4 and 5 below.

TABLE 4
TORTILLA SAMPLES

	Prereacted Reactants	Initial Reactants	Untreated Control
L	72.9	78.9	81.6
a_L	-0.5	-1.8	-1.6
b_L	15.6	13.2	12.1

All scores are statistically different with a confidence level of 99.99%.

TABLE 5
PIZZA CRUST SAMPLES

	Prereacted Reactants	Initial Reactants	Untreated Control
L	51.9	57.0	64.3
a_L	5.3	4.1	2.0
b_L	17.3	17.1	19.4

All scores are statistically different with a confidence level of 99.999% (except b_L value prereacted versus initial reactants).

The term "coparticulates" as used herein describes formation of uniform particles containing two or more browning agents. Such coparticulates may be prepared by first dissolving or suspending the Maillard browning reactants in water. After such reactants, for example, albumin and glucose, are dissolved or suspended, the mixture is then substantially dehydrated,

for example, by lyophilization or spray drying. The dry matter left after lyophilization or spray drying is preferably ground to produce a fine powder. This fine powder, which contains the protein and reducing sugar in an intimate physical relationship and/or prereacted state, is then usable to provide Maillard browning in a desired period of time. Such coparticulates may be suspended in a carrier and applied to a food product. The carrier serves to substantially reactively isolate the coparticulate reactants from water so that Maillard browning does not immediately ensue. When the suspension of coparticulates is applied to a food product and microwave energy is applied, the coparticulates are exposed to water from the food product and undergo Maillard reactions leading to browning. Such coparticles contain the reactants in an intimate physical relationship and/or prereacted state so that they may further react upon exposure to heat and moisture. When the reactants are present but are not intimately associated and/or prereacted, the in situ Maillard browning reactions are hampered even though moisture may be present. Many of the components of the present invention (e.g., the various proteinaceous substances and reducing sugars) may be utilized as coparticulates to control browning of microwave-prepared food products. It may be viewed that the protein acts as a "sponge" for reducing sugar in aqueous solution during as well as after lyophilization. Polarized light microscopy of coparticles indicates a homogeneity of structure.

Browning "drys" are individual particles of Maillard reactants which have never been mixed in liquid form. These dry particles may be suspended in a lipid

and applied to a food product. Upon microwaving, the "drys" brown more slowly than corresponding prereacted intermediates or coparticles. This may make such a system useful where long periods of microwave exposure are required to prepare a product. The use of coparticulates is more effective than the application of "drys" for food products requiring more rapid browning.

Another similar embodiment of the present invention involves the formation of particles of browning agents and browning system insoluble adsorptive particles such as heterogeneous silicate particles to which browning agents have been adsorbed. Specifically, said browning particles may be formed by blending an aqueous solution of browning controller (e.g., potassium phosphate), protein (e.g., whey), and reducing sugar (e.g., xylose) with calcium silicate until a smooth paste is produced. The above paste can then be suspended in a carrier system, such as shortening and glycerol, and applied to a food product. By adsorbing the browning agents or reactants onto a particle, the local concentration of browning agents is effectively increased. Adsorbed water promotes browning agent solubilization during microwave heating, thereby increasing the rate of Maillard browning. The silicate particles, by adsorbing the Maillard browning reactant and the water, have the effect of retaining them substantially reactively immobilized in the carrier system so that no significant browning effect will occur prior to microwave irradiation. Browning may be adjusted by varying the amounts of reducing sugar, protein, and water adsorbed to the silicate particle. Several other support particles were found suitable to effect browning, including silicon dioxide (such as

Cabosil™, Zeosyl™, and Zeothix™) and sodium aluminum silicate (such as Zeolex™).

The coparticulate and silicate approaches to browning have proven to be superior to the application of drys. Many of the components of the present invention (e.g., the various proteinaceous substances and reducing sugars) may be utilized in a particle containing system to effect browning of microwave heated food products.

It was observed that browning reaction rates were increased in the presence of phosphates, independent of the pH of the system. This observation was confirmed in a microwave environment using model systems. The results indicated that the addition of phosphates significantly increased the browning color intensity of a xylose:albumin:shortening (1:1:2) system after 90 seconds of microwave time. Table 6 indicates that the phosphate effect was significant despite decreases in pH (KH_2PO_4 was the phosphate source used).

TABLE 6

MODEL SYSTEM PHOSPHATE EVALUATION

Sample	pH	Average L Value*
Control	7.5	67.1
PO_4 /NaOH	6.7	54.6
PO_4	5.8	64.8
PO_4 (2X)	5.5	61.7

* Number of samples equals 5.

There is support in the literature for the observed effect of phosphates (J. Sci. Fd. Agric.,

17:245, 1966). Citrates and carbonates have also been observed to enhance browning.

As described earlier, increasing the amount of open chain form of the sugar enhances the browning reaction rate. This is especially significant because, in most of the systems studied, sugar levels were browning rate limiting. Mutarotase was evaluated with the model system procedure. Mutarotase was obtained from Sigma Chemical Company, St. Louis, MO. Mutarotase (aldose-1-epimerase) catalyzes the interconversion of alpha-D-glucose and beta-D-glucose involving an open-chain form. Results indicate a significant increase in brown color when mutarotase was present in the glucose:albumin:shortening system. The concentration of mutarotase employed was 50 units/0.69 g of a 1:1:2 albumin:glucose:shortening browning formula where one unit increases the spontaneous mutarotation of alpha-D-glucose to beta-D-glucose by 1.0 micromole per minute at pH 7.4 at 25°C. The average L values (n=5) after 120 seconds of microwave exposure was equal to 68.7 for mutarotase-supplemented samples and 73.8 for unsupplemented control samples.

The degree of isolation and protection afforded the browning agent(s) by the carrier system can be modified to fit the distribution needs of the product. The invention described herein provides a method of making a microwave surface browning formula capable of performing in any food distribution system (e.g., frozen, refrigerated, or shelf stable) by selecting an appropriate carrier.

The following experiment was conducted to demonstrate the effect of distribution temperature and carrier composition on browning system stability and

reactivity. The examined temperature ranges reflect the three most common distribution temperatures encountered in the food industry, namely frozen (-18°C), refrigerated (4°C), and shelf stable (21°C). The carriers evaluated were chosen to reflect a wide range of ability to protect and isolate the browning reagents under the three distribution temperatures mentioned above. The three carriers evaluated were shortening, oil, and water. In addition, dry browning reagents were applied directly to the product surface in an attempt to evaluate the effect of no carrier. The browning system used in this study consisted of a 1:1 soy protein:xylose mixture dispersed into an equal amount (by weight) of shortening, oil, or water. In the case of the dry ingredients, an equivalent amount of soy protein and xylose to that used in the carrier based systems was applied.

The experiment consisted of applying the various browning systems described above to the surface of unleavened dough. Treated biscuit dough samples were then placed into plastic pouches, flushed with CO_2, sealed and stored under the three temperature ranges mentioned earlier. The L, a_L, b_L values of the sample surfaces were evaluated after 1, 3, and 6 days storage for each distribution temperature prior to and after microwave preparation.

Figure 19 graphically depicts the change in surface color between storage day one and six prior to microwave preparation. Color change is defined as the square root of $((L1-L6)^2 + (a_L1-a_L6)^2 + (b_L1-b_L6)^2)$; where L1, a_L1, b_L1 and L6, a_L6, b_L6 are equal to the L, a_L, b_L values recorded after storage day one and six respectively. Figure 19 shows at -18°C all four

carriers to provide about the same degree of browning agent protection as evidenced by the relatively small extent of color change over the six-day storage period. However, at 4°C, a discernible trend in browning system color stability was observed. At refrigeration temperatures, the extent of ingredient stability and protection provided by the different systems varies as follows (listed from most to least stable): shortening oil water no carrier system. Lastly, at 21°C in this test, the only carrier capable of preventing the browning reagents from prereacting over the six-day study period was very hydrophobic (e. g., shortening).

Figure 20 graphically depicts the pre-to-post microwaving change in biscuit sample surface color after six days storage. The greater the degree of protection provided the product, either by carrier system selection or distribution temperature, the greater the extent of microwave color development as evidenced by larger pre-to-post microwaving color differences. Hence, shortening, which provides the same extent of protection, displays the same relative amount of microwave color development at all three distribution temperatures. More temperature sensitive browning systems (e.g., dry browning ingredients) display an inverse relationship between storage temperature and microwave heating color development (i.e., the lower the storage temperature, the greater the microwave color development and vice versa).

The findings of this study indicate that it is possible to produce a microwave browning system capable of performing over a wide range of distribution temperatures by selecting an appropriate carrier system.

Another means of browning system control is that of product and browning system moisture contents. In an attempt to evaluate the relationship between product and browning system moisture contents and microwave browning, a series of experiments were conducted in which low and high moisture product systems were treated with low, medium, and high moisture browning systems. The "moist product" system used was Pillsbury biscuit dough samples (total moisture = 42%) while the "dry product" system used was microwave precooked Pillsbury buttermilk biscuit samples (total moisture = 16%). The formulations of the low, medium, and high moisture browning systems evaluated are given below:

Low Moisture	Medium Moisture	High Moisture
25% xylose	25% xylose	25% xylose
25% soy protein	25% soy protein	25% soy protein
50% shortening	35% shortening	20% shortening
	15% water	30% water

The moist and dry samples were coated with the browning systems as prepared in Example 1. Figure 5 graphically depicts the changes in transmittance (from 400 to 700 nm) for the biscuit samples after treatment with low, medium, and high moisture browning systems. As Figure 5 shows, as the moisture content of the browning system is increased, there is a corresponding increase in light transmitted over the visible spectrum. As the moisture content of the browning system was increased, less microwave browning occurred. However, when the dry samples were treated and prepared in a similar fashion, the results were different. Figure 6

graphically depicts the changes in transmittance (from 400 to 700 nm) for dry samples treated with low, medium, and high moisture browning systems. Upon close examination of Figure 6, it would appear that for the dry system, the medium moisture browning system was the better of those tested for microwave browning color development. Although the high and low moisture browning systems browned generally to the same extent on the dry biscuit samples, as evidenced by their similar transmittance spectra; neither browned to the extent that the medium moisture browning system did. Hence, by varying the moisture content of either the product or browning system, it is possible to control microwave browning.

A particularly effective and widely applicable microwave browning system is comprised of three basic ingredients: a reducing sugar, an amino compound (protein), and lipid. A browning system composed of xylose and proteins suspended in a shortening matrix has been used thus far to brown the surfaces of biscuit dough, cake batter, pastry dough, roll dough, coffee cake batter, bread dough, pizza crust dough, and french toast. Advantages of this system include its simplicity, adaptability to existing products and processes, ability to be adjusted to coincide with product textural development, stability through shelf life, and dual applicability to microwave and conventional preparations. Several means of controlling the development of color have been identified. These include adjusting the concentrations of the reactants, as well as the use of pH level, phosphates, intermediates, coparticulates, mutarotase, protease, steam-retaining packaging, and the use of dielectric

affecting salts. Reducing sugars and amino compounds are reactants required for Maillard browning while the lipid serves as a carrier that suppresses Maillard browning for a required shelf life but allows rapid reaction on exposure to microwave radiation. A third component required for Maillard browning, water, can be provided by the food system itself as a result of exposure to microwave energy and/or may be supplied by the carrier in certain applications. The ratios of the three components relative to one another play an important role in overall system performance as does the amount of browning coating applied to the surface. A system composed, by weight, of one part sugar to one part protein to two parts vegetable shortening has performed very effectively in many systems.

Although the mode of incorporation of the browning system to various products can vary, the general operating principle of the browning system does not change. In most product systems, the browning coating was applied to the surface of the product as a thin layer. Such a coating may comprise browning agents in various forms such as drys (previously unmixed and unreacted), coparticulates from reactants previously mixed in a solution and the solvent removed, or intermediates.

An important advantage of a browning system described herein is that during refrigerated storage, the browning agents (sugar and protein or intermediates) are held, reactively immobilized in a lipid environment of extremely low water content. Such a system effectively retards the Maillard reaction rate to the extent that browning does not appreciably occur during storage. Reactive isolation is not needed when there is

a very short shelf life, for example, in a commercial setting. Water can be used as a carrier for a product when it is to be microwave heated immediately after application. This system is particularly useful in batter and dough-based systems.

Maillard browning reactions between various amino compounds (e.g., amino acids and proteins) and a given reducing sugar source have been shown to develop different observable brown hues under identical reaction conditions. Similarly, Maillard Browning reactions between various sugar sources (e.g., glucose, fructose, and xylose) and a given protein source have been shown to develop different observable brown hues under identical reaction conditions.

The reason different proteins produce various brown hues under identical reaction conditions is a function of the reactivities, and accessibility, of their component amino acids. The more reactive and accessible the component amino acids of a given protein source, the greater its browning potential.

The reactivity of the protein used in the browning systems has an important effect on the final hue and color intensity observed in the product systems. The brown color produced by the browning system upon exposure to microwave energy appears to be, in part, a function of the type and reactivity of protein employed.

The effect of protein on color formation was examined for microwave-prepared biscuit dough samples treated with lipid browning systems containing various food proteins. The results were evaluated by Gardner colorimetric analysis. The hue values of the browning systems evaluated varied from 578.90 nm (nanometer) for gluten to 588.25 nm for sodium caseinate with chroma

ranging from 42% for gluten up to 64.7% for albumin. The results of this study indicated that chroma and hue are functions of both individual protein amino acid composition and the overall extent of Maillard browning.

Experiments examining the color development pathway of various amino acid and protein sources have shown that regardless of the amino compound employed in the browning system, all follow the same general color development trajectory when plotted on an x', y' 1931 chromaticity diagram, differing only in overall magnitude after a given reaction time (see Figure 18). The effect of amino acid/protein type on Maillard browning color development appears to be a scalar function with directional coordinates fixed and magnitude a function of the reactivity of the amino acid/protein source used and reaction time.

This provides another means of browning control, for example, a product requiring a relatively long microwave cooking time could use a protein of lower reactivity.

A study was conducted in which the amount of ninhydrin-reactive lysine present in a series of food proteins was experimentally determined. The lysine content was correlated with Gardner colorimetric values obtained from biscuit dough samples treated with the microwave browning system containing these proteins. A linear relationship was found between the absorbance of the ninhydrin chromophore and concentration of protein sample (see Figure 10). The extent of absorbance (slope of the linear relationship) was a linear function of the lysine content of each protein sample (see Figure 11).

Gardner L and a values obtained from biscuit dough samples exposed to microwaves after treatment with

microwave browning formulas incorporating the various proteins showed a linear relationship when plotted against gm Lys/100 gm protein and extent of chromophore absorbance (e.g., the slope of the linear relationship between ninhydrin chromophore absorbance versus mg protein, see Figure 12).

A direct relationship was observed between the amount of lysine per given amount of protein, ninhydrin chromophore absorbance, and extent of Maillard browning (as reflected by lower Gardner L values and higher Gardner a values). The determination of ninhydrin chromophore absorbance values could be a quick and efficient screening method for predicting the performance level of a given protein in a Maillard-based microwave browning system. One could specifically choose a protein source of a given reactivity such that the product could brown to an appropriate extent upon completion of the microwave cooking cycle. In addition, the ninhydrin evaluation could also be an effective test to assure uniform performance of a given protein (e.g., a quality assurance tool in a manufacturing facility).

In addition to protein reactivity, the physical condition of the protein employed in the browning system was found to have an effect on browning color development. Physical shearing (denaturation) of proteins increased the rate of Maillard browning. Gardner colorimetric analysis of biscuit samples treated with browning compounds which had been sheared in an electric mixer prior to product application resulted in lower Gardner L values and higher Gardner a_L values as compared to those values obtained with unsheared control samples.

TABLE 7

BISCUIT SURFACE L, a_L, b_L VALUES

VERSUS BROWNING SYSTEM SHEAR TIME[1]

	MIX TIME		
	0 (min.)	7.5 (min.)	15 (min.)
L	60.0	58.9	56.1
a_L	11.9	13.1	13.8
b_L	28.2	28.2	27.3

1) Used a Hamilton Beach Scovill electric mixer (mixing speed set on 5)

By shearing the protein browning system prior to product application, an increased number of primary and secondary amino groups were likely exposed and created via the disruption of the proteins quaternary, tertiary, secondary, and primary structure. Increasing the total number of possible Maillard reaction sites effectively increased the overall extent of Maillard browning. Denaturing the protein through other means may have a similar effect.

Experiments examining the color development pathway of various reducing sugars have shown that regardless of the sugar employed in the browning system, all follow the same general color development pathway when plotted on an x', y' 1931 chromaticity diagram, differing only in overall magnitude after a given reaction time (see Figure 24). The effect of reducing sugar type on Maillard Browning color development appears to be a scalar function with directional coordinates fixed and magnitude a function of the inherent reactivity of the reducing sugar used and reaction time.

In general, the greater the amount of microwave browning system applied to a given product, the more extensive color develops. The relationship between quantity of browning system applied and color developed in a biscuit model system was examined. The top surface of Pillsbury buttermilk biscuit dough samples were coated with various amounts of a 1:1:2, by weight, soy protein:xylose:shortening browning system ranging from 0 to 2.5 grams. Upon completion of microwave heating, biscuit surface color was evaluated via Gardner colorimetric analysis.

The findings of this study are graphically depicted in Figures 13 and 14. The plot of "average Gardner L values versus grams browning system applied per biscuit" clearly shows that biscuit surface color darkens quite rapidly (reflected by the rapid drop in observed L values from 71.4 to 57.7) as the amount of the browning system applied to the biscuit sample surface increased from 0 to 1.5 grams. Browning system applied in excess of 1.5 grams produced little, if any, further effect on the observed L value of the biscuit sample surface.

Gardner a_L values, which quantify the amount of green to red coloration, were observed to increase (i.e., become more "red") as the amount of applied browning system increased from 0.5 to 1.5 grams. Amounts of applied browning system in excess of 1.5 grams resulted in a slight decrease in observed Gardner a_L values.

Gardner b_L values, which measure the extent of blue to yellow coloration, were not significantly affected by the quantity of applied browning system.

The results of this study also showed that the hue and chroma of microwave prepared biscuit samples coated with about 1.5 +/- 0.2 grams browning system most closely approximate the hue and chroma of a conventionally baked biscuit control (see Figures 13 and 14).

Different reducing sugars are known to have an effect on the rate of Maillard browning. Of the reducing sugars studied, xylose has been found to brown most effectively. However, glucose, particularly in conjunction with inorganic phosphate catalysts, pH-affecting controllers, intermediate formation and/or coparticulate formation, is also useful. Table 8 shows the Gardner L, a_L, b_L values obtained from biscuit dough samples treated with a browning system employing glucose in conjunction with sodium bicarbonate (a pH affecting controller). Note that as % soda and pH increases, Gardner L values decrease while a_L values increase.

TABLE 8

1:1:2 GLUCOSE:SOY PROTEIN: SHORTENING SYSTEM

ave. Gardner values

% Soda	L values	a_L values	b_L values	pH
0.00	71.5	3.7	23.0	6.58
1.96	65.4	6.1	24.2	7.25
3.85	61.0	7.6	23.7	7.48
5.66	59.7	8.7	24.1	7.56
9.10	57.4	9.3	23.5	7.72

Color development is directly proportional to the amount of time the microwave browning system is exposed to microwave energy and, when applicable, the steam environment created thereby. Luxtron temperature

studies of biscuit dough browning systems show that the longer the system is exposed to microwave energy, the greater the observed temperature (surface and ambient) and subsequent color (browning) development.

EXAMPLE 1

BISCUITS

A biscuit dough microwave browning system was designed to utilize browning chemistry and packaging technology.

1.78 grams of a browning system comprising one part soy protein, one part xylose, and two parts solid vegetable shortening was applied with a spatula to the top surface of Pillsbury Buttermilk Biscuit dough samples (top surface area = 23 cm^2). The browning system was pliable enough for smooth application.

Nine coated samples were placed into a pregreased plastic pan. The pan of samples was subsequently sealed in a plastic pouch (9 3/4" x 11 3/8") to retain product moisture and to protect against atmospheric contamination.

Prior to microwave heating, the pouch was punctured four times (two punctures at each end) to allow for steam venting during the microwave cooking cycle. The samples were subjected to 2 minutes of microwave heating in a Litton Generation II microwave oven, oven power set on "high". Upon completion of the microwave cooking cycle, the biscuit sample package was removed from the microwave oven and allowed to rest undisturbed for approximately 2 to 3 minutes. During this 2-to-3 minute post-microwave exposure period, a significant amount of browning occurred. Upon completion of the post-microwave resting period, the

outer plastic package was removed, thereby releasing the entrapped steam and arresting the browning process. The microwave prepared biscuits appeared golden brown similar in appearance to conventionally baked biscuit products.

Results obtained from temperature studies of pouched versus nonpouched package systems showed significantly lower surface and atmosphere temperatures recorded for the nonpouched system when compared to the pouched system (see FIG. 15). This indicates that in the pouched system there was sufficient energy and/or moisture available to facilitate the browning reaction mechanism with this particular selection of browning agents and controllers.

EXAMPLE 2

Biscuit Silicate Application

A silicate based microwave browning system was tested.

Whey protein (32.64 g) and xylose (16.76 g) were dissolved in 100 ml of water. Calcium silicate (29.92 g) was placed in a Oster blender and blended on a high setting for 10-15 seconds to fluff the silicate. The protein/xylose solution was added in two equal aliquots and blended after each addition for 30-35 seconds on high to make a smooth paste. Melted Crisco™ shortening (61.92 g) and glycerol (30.76 g) were added to the water silicate paste and blended for 30-35 seconds on high. The paste was scraped into the center of the bowl and blended for an additional 30-35 seconds. Upon completion of blending, the silicate based browning system was stored at 5°C. until use.

2g of refrigerated silicate based browning system was spread evenly onto the surface of Pillsbury Buttermilk Biscuit dough samples (see Example 1). A total of eight biscuit dough samples were prepared as described above and placed into a hard plastic tray and sealed in a plastic pouch with the corners perforated to permit steam venting. The biscuit dough samples were baked in a Litton Generation II microwave oven on high for 2 minutes. After the 2-minute cooking cycle and a subsequent 2-minute room temperature cooling period, the microwave browned biscuit samples were removed from the pouch. After the microwave cooking cycle and room temperature cooling period, the biscuits appeared golden brown, similar in appearance to conventionally baked biscuit products.

EXAMPLE 3

CAKE

Because Pillsbury microwave yellow cake is a batter system, the browning system (a 1:1:2, by weight, soy protein:xylose:shortening mixture) was applied to the cooking vessel such that it would be in contact with the outer surface of the batter throughout the microwave cooking cycle. This was accomplished in two manners: 1) By manually applying browning system to the interior of the microwave cake pan (surface area = 531.4 cm^2) prior to the addition of cake batter, and 2) By dusting a dry 1:1 mixture of browning ingredients (e. g., soy protein and xylose) to a cake pan pregreased with shortening.

After the cake batter was prepared (per the instructions on the package), it was poured directly into a pretreated cake pan, and microwaved for 7 minutes (oven power set on "high"). A Litton Generation II microwave oven Model #2492 (power step 1) was used in

all of the cake experiments described herein. Upon completion of the microwave cooking cycle, the cake was immediately inverted and removed from its pan.

The color and textural properties of the microwave prepared browned cake closely approximated those of a conventionally prepared cake. A golden brown dehydrated crust developed.

EXAMPLE 4

SHELF LIFE

The shelf life performance of the microwave browning system of the present invention was evaluated in the buttermilk biscuit dough model system as described in Example 1. Throughout a seven-week study period, biscuit dough sample packages were periodically removed from refrigerated storage, microwaved, and evaluated via Gardner colorimetric analysis. Gardner L and a_L values remained virtually unchanged while b_L values varied slightly (no more than 15%) throughout the seven-week study (see Figures 16 and 17). In addition, the browning system browned to the same relative extent upon microwave preparation regardless of refrigeration storage time.

EXAMPLE 5

COPARTICULATE

Enhancing browning through prereaction may be accomplished by suspending the browning agents in water and drying them in such a manner as to yield dry solids (coparticulates). For example, a suspension was made by mixing 25 grams of albumin and 25 grams of xylose in 100 grams of water. This suspension was freeze dried for three days in a small laboratory freeze drier and the

resultant coparticulate was evaluated versus the initial reactants in a shortening matrix on microwave biscuits. In each evaluation, nine samples were each coated with 1.7 grams of the browning system, placed in a microwaveable baking vessel inside a steam retaining pouch, and cooked on high in a Litton Generation II microwave oven for 2 minutes. The system was allowed to sit an additional 2 minutes after microwaving prior to opening the pouch. Eight of the nine biscuits microwaved in each run were evaluated using a Milton Roy spectrophotometer. Table 9 shows the averages of the resultant L a_L b_L color values:

TABLE 9

Sample Type	Solids/Shortening Ratio	Gardner Color Value L	a_L	b_L
xylose/albumin control 1	1:2	81.1	-2.0	34.2
xylose/albumin control 2	1:1	70.1	7.4	53.2
xylose/albumin coparticulate	1:2	70.7	7.6	54.7

The data indicated that by producing the coparticulate, the reactivity of the system has been enhanced, as compared to using non-coparticulate starting materials.

EXAMPLE 6

INCORPORATION OF BROWNING SYSTEM INTO THE CRUMB OF A BREAD PRODUCT BY BLITZING

Two small loaves of microwave bread-like products were made as follows to demonstrate interior

browning. For each loaf, the dry ingredients (see formulas below) were premixed by hand. The shortening and water was then added and mixed in briefly with a spoon. The resultant dough was hand kneaded for 5 minutes and shaped into small loaves. The dough was allowed to proof for 10 minutes and then baked in a Litton Generation II microwave oven for 4 minutes. After this time, the loaves were cut in half and the color of the crumb was compared. The test loaf, containing the browning agents xylose and soy protein, had a browned crumb color whereas the control was white.

Control		Test	
flour	100 grams	flour	100 grams
shortening	7 grams	shortening	10 grams
sucrose	7 grams	xylose	10 grams
GDL	1.5 grams	soy protein	10 grams
soda	1 gram	soda	1 gram
water	60 grams	GDL	1.5 grams
		water	65 grams

EXAMPLE 7

INCORPORATION OF BROWNING SYSTEM INTO THE INTERIOR OF A PRODUCT SYSTEM BY LAMINATION

Approximately 70g of a 1:1:2, by weight, soy protein:xylose:shortening mixture was spread onto one side of an unraveled 152g piece of Pillsbury Pipin'Hot® Loaf dough using a butter knife. The treated loaf was rerolled in such manner that the coated surface remained in the interior of the product. The prepared loaf was then microwave heated in a Litton Generation II microwave oven set on high for 4 minutes. Upon completion of the microwave cooking cycle, browning for

the loaf interior had occurred. The browning coating did not diffuse to any significant extent into the crumb structure of the loaf. Rather it remained isolated on the surface to which it was applied. As a result of laminated application, a brown swirl pattern developed within the treated loaf. No observable browning occurred in an untreated control sample.

EXAMPLE 8

ELECTROLYTE BROWNING ENHANCEMENT

A browning system comprising of 90% weight basis the formula described in Example 2 and 10% NaCl was prepared as outlined in Example 2. Approximately 2.5g of the browning system described above was applied to two separate Pillsbury Buttermilk Biscuit dough samples. The samples were covered with Saran Wrap and baked in a Litton Generation II microwave oven on high for 90 seconds. Upon completion of the microwave cooking cycle, the samples were allowed to cool for 2 minutes after which time the Saran wrap was removed and Gardner colorimetric values taken. Two control samples were prepared, as described above, using the silicate based browning formula outlined in Example 2 (without the addition of NaCl). Table 10 shows the Gardner L, a_L, and b_L values observed for biscuit samples treated with the two browning systems described above.

TABLE 10

GARDNER L, a_L, AND b_L VALUES

CONTROL VERSUS 10% NaCl BROWNING SYSTEM

	CONTROL	10% NaCl
L	62.3	48.9
a_L	7.5	8.5
b_L	22.6	17.8

As the Gardner values show, the samples coated with 10% NaCl browning system browned to a greater extent than control browning system treated biscuits.

Infrared camera analysis of the surface temperature of the 10% NaCl browning system-treated biscuit samples showed an increase in surface temperature upon exposure to microwave energy when compared to the control browning system-treated biscuit dough samples. One of the advantages of electrolyte (NaCl) addition is that a desired degree of browning may be achieved in a shorter amount of time using smaller amounts of browning agents (e. g., reducing sugars, proteins, and controllers).

EXAMPLE 9

COMPARATIVE SHELF LIFE STUDY

AT VARYING STORAGE TEMPERATURES

Comparative studies were conducted with a browning system in accordance with the present invention and a browning system falling within the scope of U.S. Patent No. 4,448,791 to Fulde, et al., and assigned to Campbell's Soup Company.

The browning system selected from the '791 Campbell patent comprised yeast extract 12.5%, xylose 12.5%, shortening 30%, flour 25%, water 20% (all by weight).

The browning system in accordance with the instant invention, comprised soy protein 25%, xylose 25%, shortening 50% (all by weight).

These two formulations were spreadable formulations and were used to coat the top surface of biscuits. Each biscuit was coated with 1.7 grams of the formulation. Nine biscuits were put into microwave brownie trays and placed in a pouch. The pouch was evacuated and flushed with carbon dioxide to avoid color changes in the dough due to oxidation. The biscuits stored at room temperature were unleavened. The biscuits were then placed in storage at three different temperatures (0, 40, and 70°F). Colorimetric analysis was performed on eight of the nine biscuits in the tray at various time intervals (see Figs. 25, 26, and 27) before microwaving. In these figures, the biscuits treated with the formulation in accordance with this invention, are indicated on the graphs as "P". The biscuits treated with a browning formulation in accordance with the '791 Campbell's patent, are indicated as "C".

These results show that the color of the biscuit samples treated with the '791 Campbell's formulation changed color more than the biscuits treated with formulations in accordance with this invention, over time at 40°F and at 70°F. Both formulations were pretty close at 0°F (as shown in Fig. 25). The graphs show DE vs. days. DE is a parameter which shows "color change" and describes the magnitude of the difference between the color of the biscuits at day 0 and any given day.

At 0°F there is very little difference in DE between the two samples. Both are frozen, and the

reactants should be reactively immobilized in both cases. The change in the first day for both samples appears to indicate that there was some residual oxygen which may have caused the dough to gray slightly. That would normally take about a day. The curves after day 1 for both samples are fairly flat. At 40°F there seems to be a significant difference in DE at day 1 between the two formulations. The formulation in accordance with the '791 Campbell's patent has a definite positive slope, while the formulation in accordance with this invention seems to be unchanging after the second say. The formulations in accordance with the '791 Campbell's patent are browning slightly.

The difference is more significant at 70°F. The formulations in accordance with this invention show the same type of curve as at the other two temperatures. The formulation in accordance with the '791 Campbell's patent is changing much more and shows that the browning reactants are not reactively immobilized.

Embodiments of this invention can provide the advantage of control of color development in a browning system prior to microwave heating, thereby allowing distribution of the treated food products at standard food distribution temperatures, particularly frozen and refrigerated. Embodiments of this invention can also provide for quantitative control of the browning reaction to allow the end point of browning and textural development of the food product to coincide. Embodiments of the invention also allow for the predictability of the development of a coloring effect, and for means of displaying predicted colors using computer technology and color science.

SEE LAB

SeeLab is an interactive computer color display system which allows an operator to invoke:

1. A Triplet Patch Browser which allows one to view colors and colorimetric coordinates within a measured space.

2. A Gauged Browser which allows one to view predicted food product color by selecting and setting browning ingredient variables for a desired product system; based on linear regression of experimental color measurements on actual product.

3. An N by N Color Patch Browser which allows one to view an N by N grid of predicted product color patches generated by: a) selecting a product system; and b) fixing all but two browning system ingredient variables, allowing the remaining two variables to vary over their respective ranges; based on linear regression of experimental color measurements on actual product.

1. <u>The Triplet Patch Browser</u>

The triplet patch browser consists of two main areas: the gauge panel on the left and the color patch on the right. The gauge panel consists of three labeled gauges, each with a label, digital, and analog section. The color patch panel consists of a surround region and a central color display rectangle.

By changing the values of the gauges (e.g., L a_t and b_t values), the displayed color patch is recomputed and displayed. The gauged values can be changed by "dragging" the analog bar which results in a corresponding change in the digital readout or by using the popup menu in the digital gauge to type in a value. Dragging of an analog gauge is accomplished by placing

the cursor in the analog display rectangle, pressing the mouse button and moving the cursor.

An example of the triplet patch browser is shown in Figure 21.

2. The Gauged Browser

The gauged patch browser consists of two main areas: the gauge panel on the top and the color patch panel on the bottom. The gauge panel consists of labeled gauges, one for each independent browning system variable in the regression on the experimental data, each with a label, digital, and analog section. The color patch panel consists of a surround region and a central color display rectangle.

By changing the values of the gauges (e.g., microwave time, sugar to protein ratio, soy protein to albumin ratio, glucose to xylose ratio, and % soda), the displayed color patch is recomputed and displayed. Dragging of an analog gauge is accomplished by placing the cursor in the analog display rectangle, pressing the mouse button and moving the cursor.

An example of the gauge browser on regression is shown in Figure 22.

3. The N by N Color Patch Browser

The N by N color patch browser consists of a single labeled grid of colored rectangles. The number of horizontal and vertical divisions are the same and determined at invocation time. The horizontal and vertical independent browning system variables are labeled at the bottom and left edges of the grid while the fixed variables and their values are indicated on the top edge of the grid.

What is claimed is:

1. A food product suitable for storage at temperatures of at least 40 degrees Fahrenheit having a browning surface are for developing a desired browning effect during preparation of the food product for consumption, the food product comprising:

(a) a starch based component;

(b) a browning system applied to the starch based component to provide the browning surface area; and

(c) the browning system comprising Maillard browning reactants for developing the desired browning effect during microwave irradiation, the Maillard browning reactants being capable of at least partially reacting prior to exposure to microwave heating, and a carrier system containing the Maillard browning reactants, the carrier system maintaining the Maillard browning reactants in a substantially reactively immobolized state on the food product prior to microwave irradiation and while the food product is at a temperature of at least about 40 degrees F. for about two days, wherein the carrier system is selected from the group consisting of a lipid, water, an adsorptive silicate and mixtures thereof.

2. A process for making food product suitable for storage at temperatures of at least about 40 degrees Fahrenheit which has a browning surface area for developing a desired browning effect during preparation of the food product for consumption by microwave radiation, the process comprising:

(a) selecting a starch based component;

(b) applying a browning system to a browning surface area of the starch based component; and

(c) the browning system comprising Maillard browning reactants for developing a desired browning effect during microwave irradiation, the Maillard browning reactants being capable of at least partially reacting prior to exposure to microwave irradiation, and a carrier system containing the Maillard browning reactants, the carrier system maintaining the Maillard browning reactants in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at a temperature of at least

about 40 degrees F. for at least about two days, wherein the carrier system is selected from the group consisting of a lipid, water, an adsorptive silicate and mixtures thereof.

3. A food product suitable for storage at temperatures of at least about 40 degrees Fahrenheit having a browning surface area for developing a desired browning effect during preparation of the food product for consumption by microwave irradiation, the food product comprising:

(a) a starch based component;

(b) a first Maillard browning reactant applied to the browning surface area of the starch based component;

(c) a second Maillard browning reactant applied to the browning surface area, the second Maillard browning reactant being complementary to the first Maillard browning reactant for reacting therewith to develop the desired browning effect during microwave irradiation, the first and second Maillard reactants being capable of at least partially reacting prior to exposure to microwave irradiation; and

(d) the second Maillard browning reactant being contained in a carrier system for maintaining said second Maillard browning reactant in a substantially reactively immobilized state on the food product prior to microwave irradiation and while the food product is at a temperature of at least about 40.degree. F. for at least about two days, wherein the carrier system is selected from the group consisting of a lipid, water, an adsorptive silicate and mixtures thereof.

4. A food product according to claim 1, in which the carrier system maintains the Maillard browning reactants in a substantially reactively immobilized state while the food product is at temperatures of up to about 70.degree. F. for up to about two days.

5. A food product according to claim 1 or claim 4, in which the carrier system maintains the Maillard browning reactants in a substantially reactively immobilized state for up to at least about four days.

6. A food product according to claim 2, in which the carrier system maintains the Maillard browning reactants in a substantially reactively

immobilized state while the food product is at temperatures of up to about 70.degree. F. for up to several days.

7. A food product according to claim 2 or claim 6, in which the carrier system maintains the Maillard browning reactants in a substantially reactively immobilized state for up to at least about four days.

8. A food product according to claim 1, in which the carrier system maintains the Maillard browning reactants substantially reactively immobilized by maintaining at least one of the reactants isolated from moisture.

9. A food product according to claim 8, wherein the carrier is a lipid.

10. A food product according to claim 8, wherein the adsorptive silicate maintains the Maillard browning reactants or moisture in an adsorbed condition prior to microwave irradiation to thereby maintain the reactants in a substantially reactively immobilized state.

11. A food product according to claim 1, wherein the Maillard browning reactants comprise a reducing sugar and a proteinaceous substance.

12. A food product according to claim 11 wherein the reducing sugar is selected from the group consisting of a triose, tetrose, pentose and hexose.

13. A food product according to claim 11 wherein the reducing sugar is selected from the group consisting of glucose, fructose and xylose.

14. A food product according to claim 11 wherein the proteinaceous substance is selected from the group consisting of soy protein, yeast, protein, albumin, and casein.

15. A food product according to claim 1, wherein the carrier system is a lipid.

16. A food product according to claim 15, wherein the lipid is a shortening.

17. A food product according to claim 16, wherein the shortening comprises one or move vegetable oils.

18. A food product according to claim 1, wherein the Maillard browning reactants comprise a reducing sugar and a proteinaceous substance which have been prereacted under conditions facilitating reactions leading to Maillard browning.

19. A food product according to claim 18, wherein the Maillard browning reactants comprise a reducing sugar and a proteinaceous substance which having been prereacted under conditions facilitating reactions leading to Maillard browning so that substantially colorless Maillard browning precursors have formed.

20. A food product according to claim 1, wherein the Maillard browning reactants include a browning controller.

21. A food product according to claim 20, wherein the browning controller is one or more of the group consisting of a pH elevating agent, a metal ion, and a phosphate salt.

22. A process according to claim 2, which includes the step of storing the food product at a temperature of below about 40.degree. F. before microwave irradiation.

23. A food product according to claim 1, in which the carrier system is free of moisture.

24. A food product suitable for storage at temperatures of at least about 40 degrees Fahrenheit having a browning surface area for developing a desired browning effect during preparation of the food product for consumption, the food product comprising:

(a) a starch based component;

(b) a browning system applied to the starch based component to provide the browning surface area;

(c) the browning system comprising Maillard browning reactants for developing the desired browning effect during microwave irradiation,

the Maillard browning reactants being capable of at least partially reacting prior to exposure to microwave irradiation, and a carrier system containing the Maillard browning reactants, the carrier system maintaining the Maillard browning reactants in a PG,302 reactively immobilized state on the food product at temperatures of at least about 40 degrees Fahrenheit prior to microwave irradiation, wherein the carrier system is selected from the group consisting of a lipid, water, an adsorptive silicate and mixtures thereof.

25. A food product according to claim 18, wherein the Maillard browning reactants comprise a reducing sugar and a proteinaceous substance which have been prereacted under conditions facilitating reactions leading to Maillard browning so that substantially colorless in situ Maillard browning precursors have formed.

26. A method of forming a food product having a region of a preselected color comprising:

(a) selecting at least one parameter from a group consisting of color producing agent, heating time value, color producing agent concentration value, final food color value, and substrate color value, each selected parameter defining an input parameter;

(b) inputting each selected input parameter into a programmed computer means, the computer means programmed with a functional relationship between the selected input parameter and at least one other parameter included in the group, the computer means capable of providing output information, the output information defined as at least one of the parameters in the group other than the selected parameter;

(c) and making a food product suitable for microwave heating according to the output information so that when the food product is exposed to microwave radiation, a food product of the desired color is formed.

27. The method of claim 26 wherein the selected parameter is selected from the group consisting of a color producing agent, heating time value, and color producing agent concentration value, and the output information includes final food product color value including hue and chroma.

28. The method of claim 26 wherein the selected parameter is final food product color value including hue and chroma, and the output information includes at least one of the following group including the color producing agent, heating time value, and color producing agent concentration value.

29. The method of claim 26 wherein the programmed computer means comprises color graphics output means, and the method further comprises:

(a) adjusting the food product color on the computer graphics output means until a desired color is achieved; and

(b) outputting data from said computer means relating to the output information.

30. The method of claim 26 wherein the output information includes final food color value and the input parameter further includes at least one of the following:

(a) a browning agent selected from the group consisting of a mixture of proteins and reducing sugars and a mixture of prereacted browning intermediates;

(b) controllers selected from the group comprising metal ions, pH adjusting agents, and carriers; and

(c) microwave exposure time for the product.

31. A process of forming a browning composition for application to a surface of a food, the composition causing the surface of the food to brown upon exposure to microwave radiation, comprising:

(a) forming a solution comprising water, a reducing sugar and a proteinaceous substance, the ratio of reducing sugar to proteinaceous substance being effective to produce browning when applied to a surface of the food and when exposed to microwave radiation; and

(b) prereacting the solution to react to a point prior to substantial coloration by means of heating or adjusting the pH of the solution or both, prior to applying the solution to a surface of the food to be browned and prior to exposure to microwave radiation.

32. The process of claim 31 and further comprising the step of dehydrating the prereacted solution to form a coparticulate browning composition.

33. The process of claim 32 and further comprising the step of combining the coparticulate browning composition with a carrier, forming a browning system.

34. The process of claim 33 wherein the carrier is a lipid.

35. The process of claim 34, wherein the lipid comprises about 50 percent of the browning system.

36. The process of claim 31 wherein the solution further comprises a lipid.

37. The process of claim 31 wherein the prereaction step comprises mixing the water, the reducing sugar and proteinaceous substance.

38. The process of claim 31 wherein the prereaction step further comprises cooling the solution after heating.

39. The process of claim 37 wherein the prereaction step comprises dehydrating the solution after mixing.

40. A process of forming a food product which upon exposure to microwave radiation results in surface browning, the process comprising:

(a) providing a food product prepared for exposure to microwave radiation; and

(b) applying a prereacted browning solution to a surface of the food product prior to exposure to microwave radiation, the browning solution comprising water, a reducing sugar and a proteinaceous substance, the ratio of reducing sugar to proteinaceous substance being effective to produce browning when applied to a surface of the food and when exposed to microwave radiation, wherein the browning solution is reacted to a point prior to substantial coloration by means of heating or adjusting the pH of the browning solution or both, prior to application to the food product and prior to exposure to microwave radiation.

41. A process of forming a food product which upon exposure to microwave radiation results in surface browning, the process comprising:

(a) providing a food product prepared for exposure to microwave radiation; and

(b) applying a coparticulate browning composition to a surface of the food product prior to exposure to microwave radiation, the coparticulate browning composition formed from a browning solution comprising water, a reducing sugar and a proteinaceous substance, the ratio of reducing sugar to proteinaceous substance being effective to produce browning when applied to a surface of the food and when exposed to microwave radiation, wherein the browning solution is prereacted to a point prior to substantial coloration by means of heating or adjusting the pH of the browning solution or both, and the browning solution is dehydrated, forming the coparticulate browning composition.

42. A process of forming a food product which upon exposure to microwave radiation results in surface browning, the process comprising:

(a) providing a food product prepared for exposure to microwave radiation; and

(b) applying a browning system to a surface of the food product prior to exposure to microwave radiation, the browning system formed by forming a browning solution comprising water, a reducing sugar and a proteinaceous substance, the ratio of reducing sugar to proteinaceous substance being effective to produce browning when applied to a surface of the food and when exposed to microwave radiation, prereacting the browning solution to a point prior to substantial coloration by means of heating or adjusting the pH of the browning solution or both, dehydrating the browning solution to form a coparticulate browning composition, and combining the coparticulate browning composition with a carrier.

43. A food product formed according to the process of claim 42.

44. The process of claim 40, and further comprising the step of storing the product prior to exposure to microwave radiation.

45. The process of claim 41, and further comprising the step of storing the product prior to exposure to microwave radiation.

46. The process of claim 42, and further comprising the step of storing the product prior to exposure to microwave radiation.

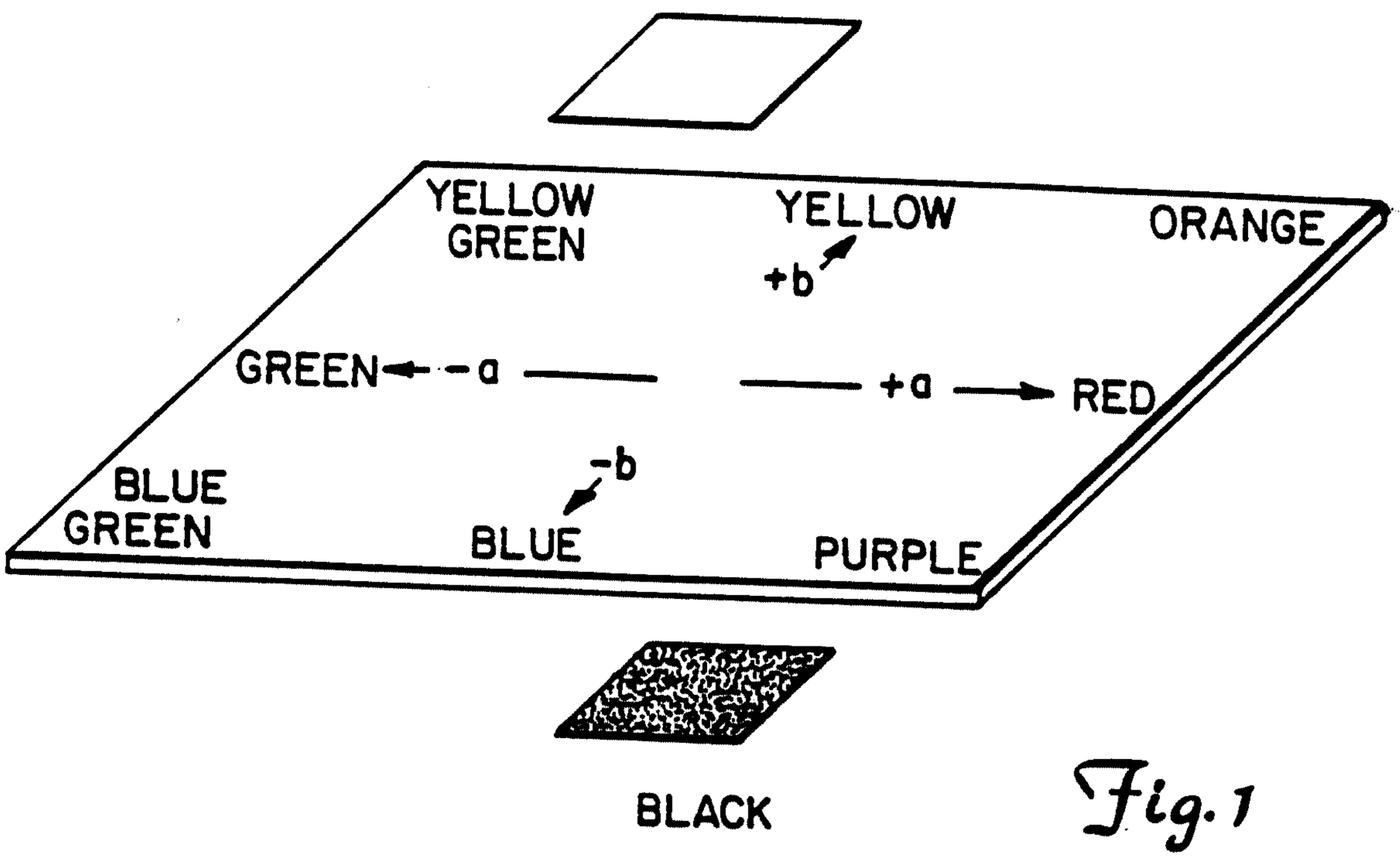

L
WHITE
YELLOW GREEN
YELLOW
+b
ORANGE
GREEN
-a
+a
RED
BLUE GREEN
-b
BLUE
PURPLE
BLACK

Fig. 1

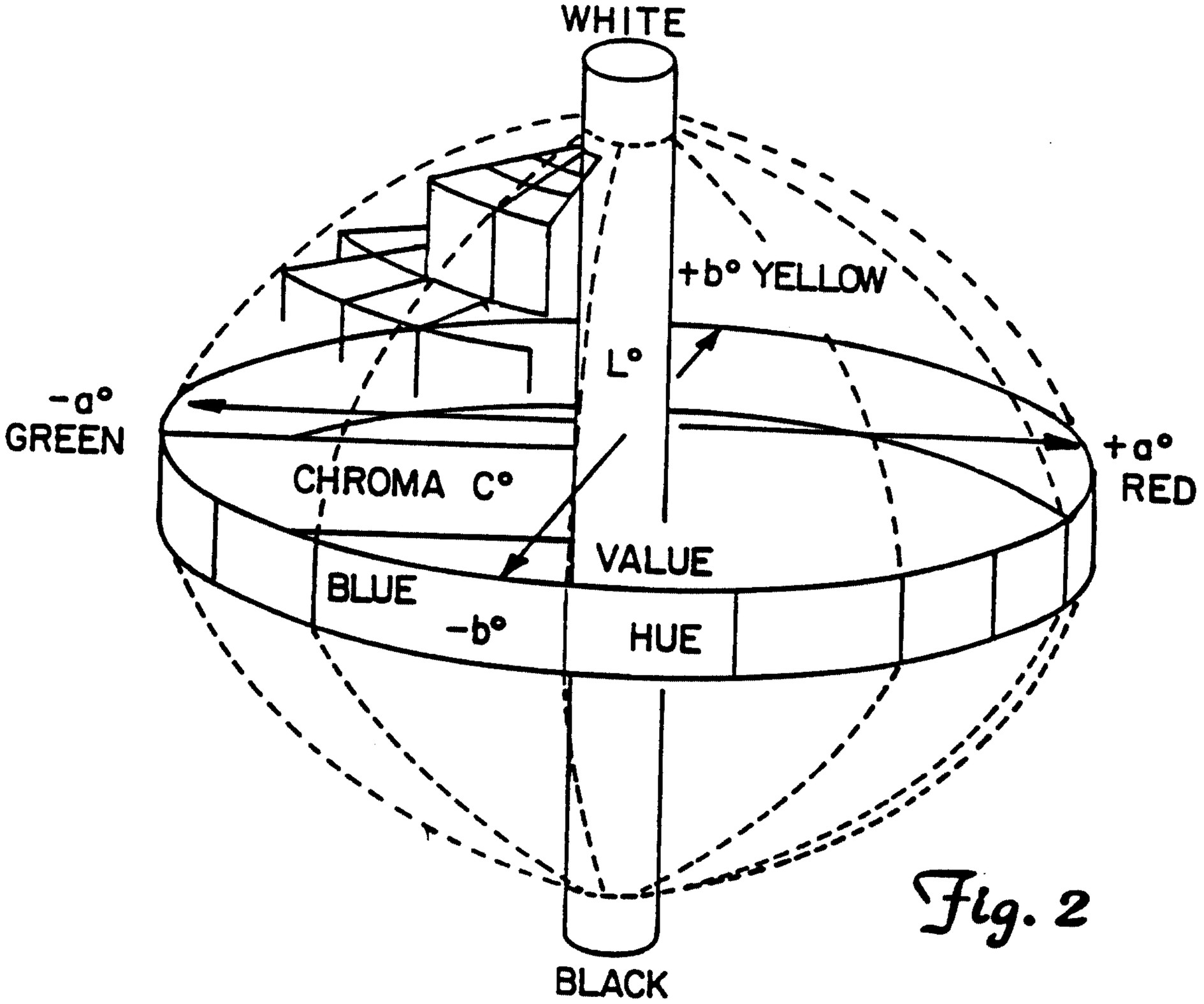

WHITE
+b° YELLOW
L°
-a°
GREEN
+a°
RED
CHROMA C°
VALUE
BLUE
-b°
HUE
BLACK

Fig. 2

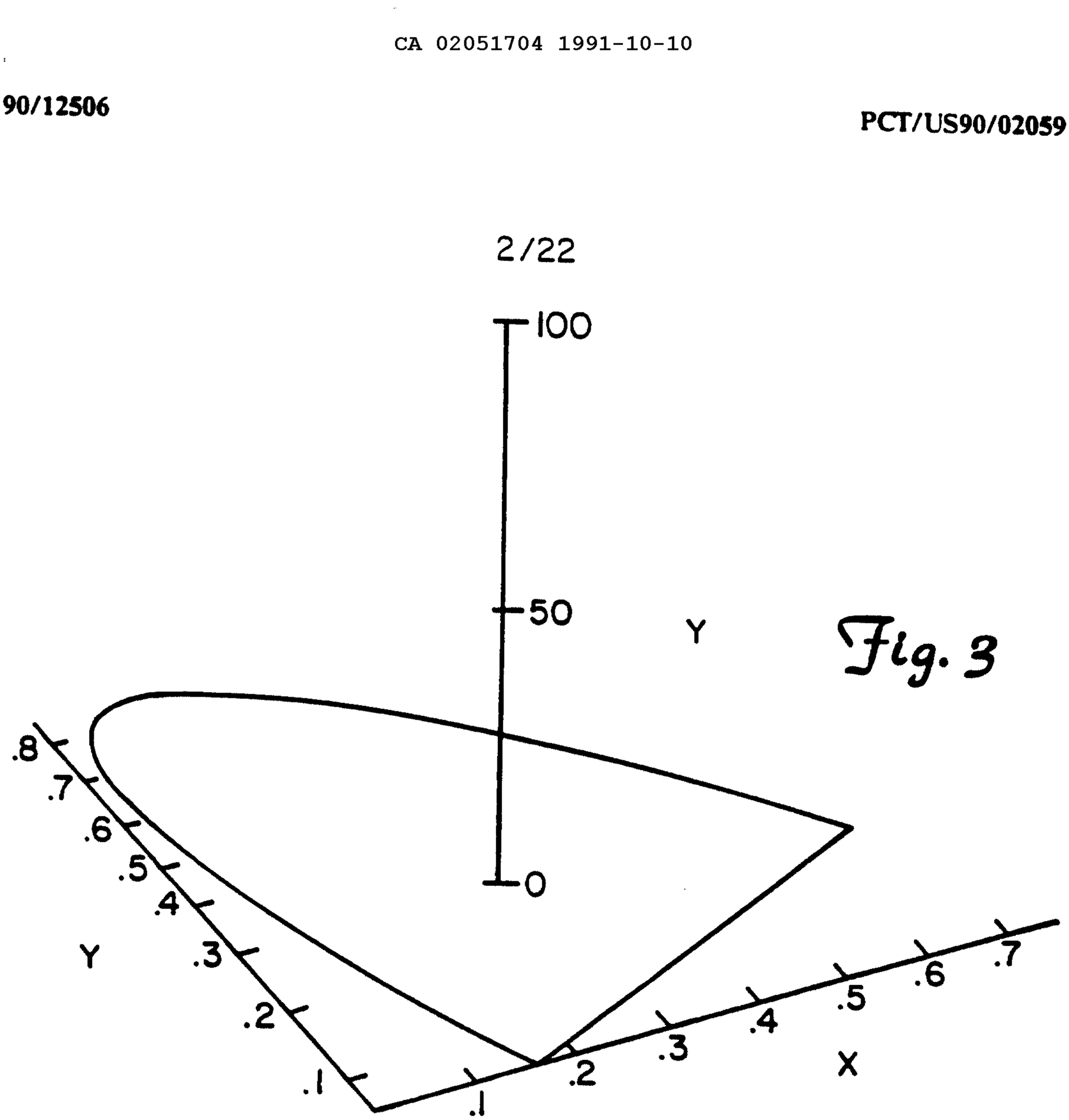

100
50
Y
0
.8
.7
.6
.5
.4
Y
.3
.2
.1
.1
.2
.3
.4
.5
.6
.7
X

Fig. 3

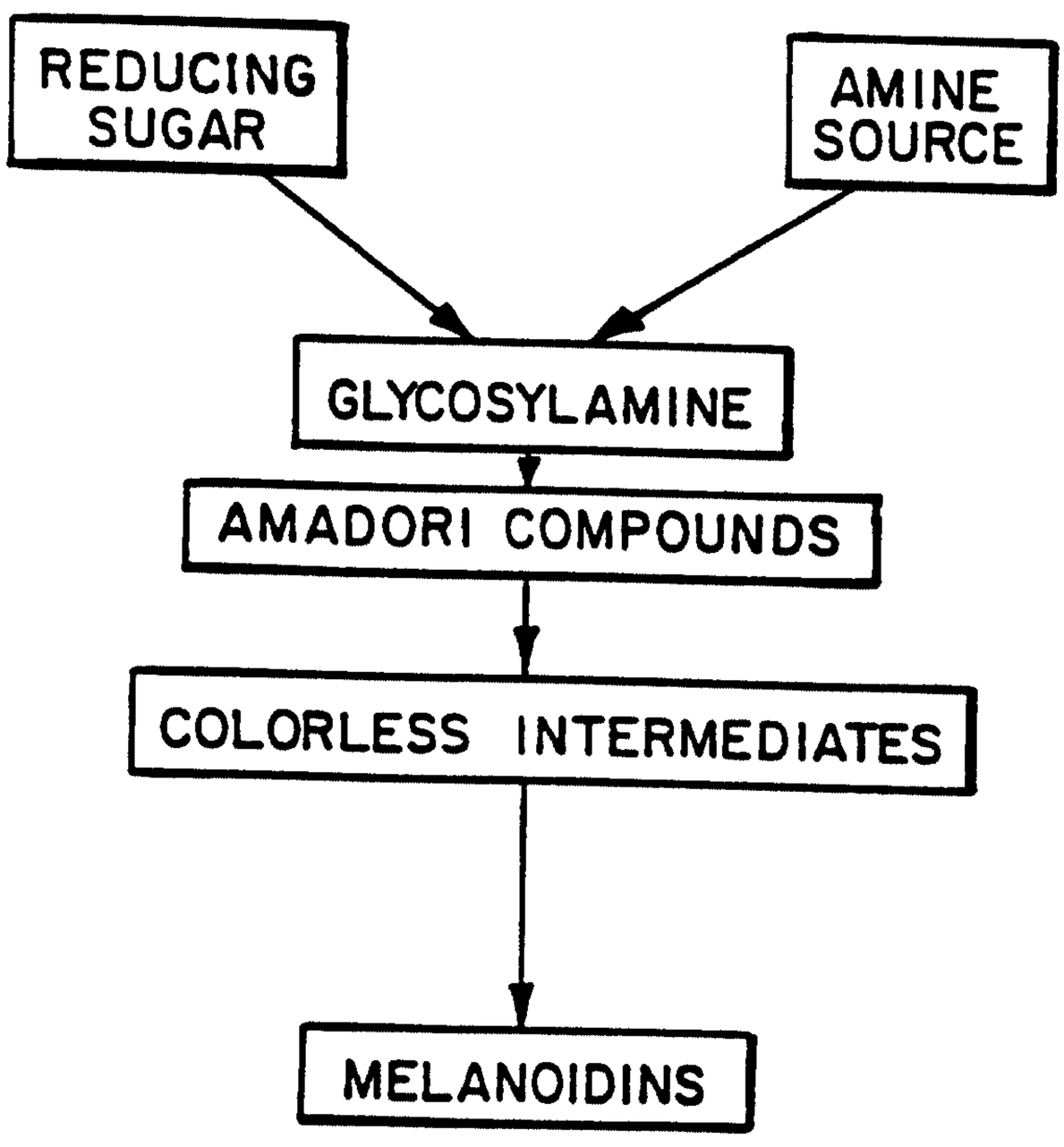
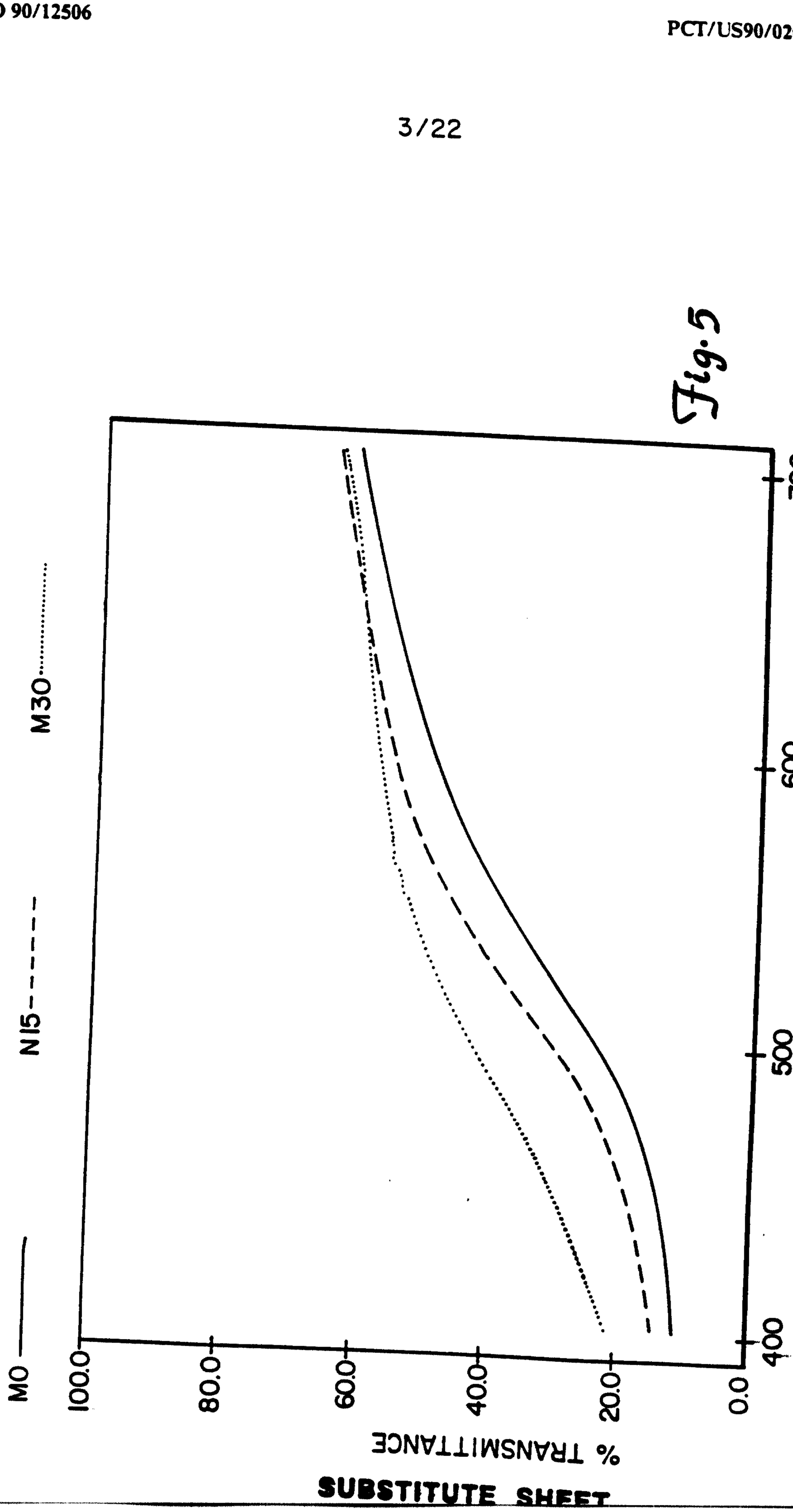

REDUCING SUGAR
AMINE SOURCE
GLYCOSYLAMINE
AMADORI COMPOUNDS
COLORLESS INTERMEDIATES
MELANOIDINS

Fig. 4

Fig. 5


M0
M15
M30
M0
100.0
80.0
60.0
40.0
20.0
0.0
% TRANSMITTANCE
400
500
600
700
WAVELENGTH (NM)

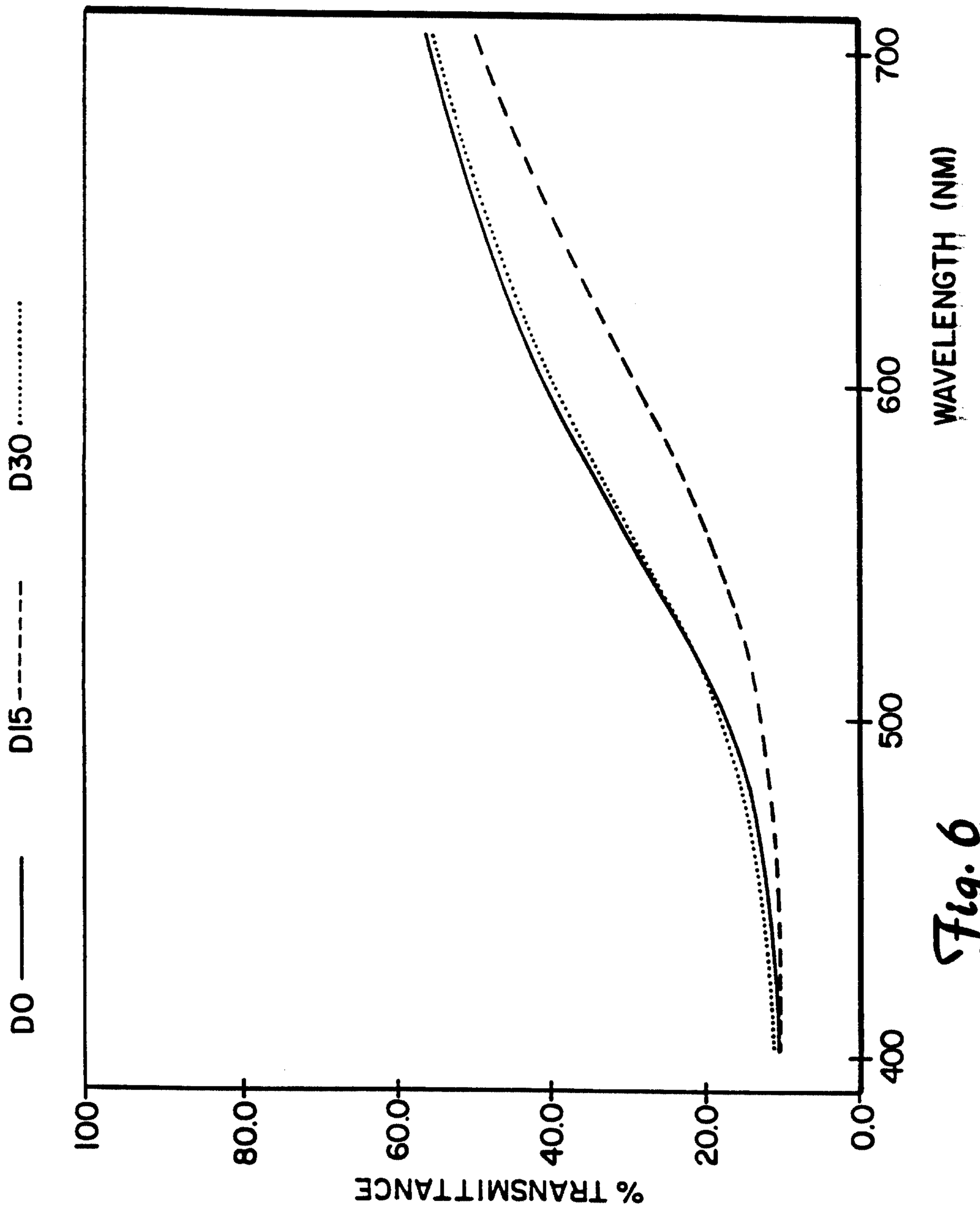

D0
D15
D30
100
80.0
60.0
40.0
20.0
0.0
% TRANSMITTANCE
400
500
600
700
WAVELENGTH (NM)

Fig. 6

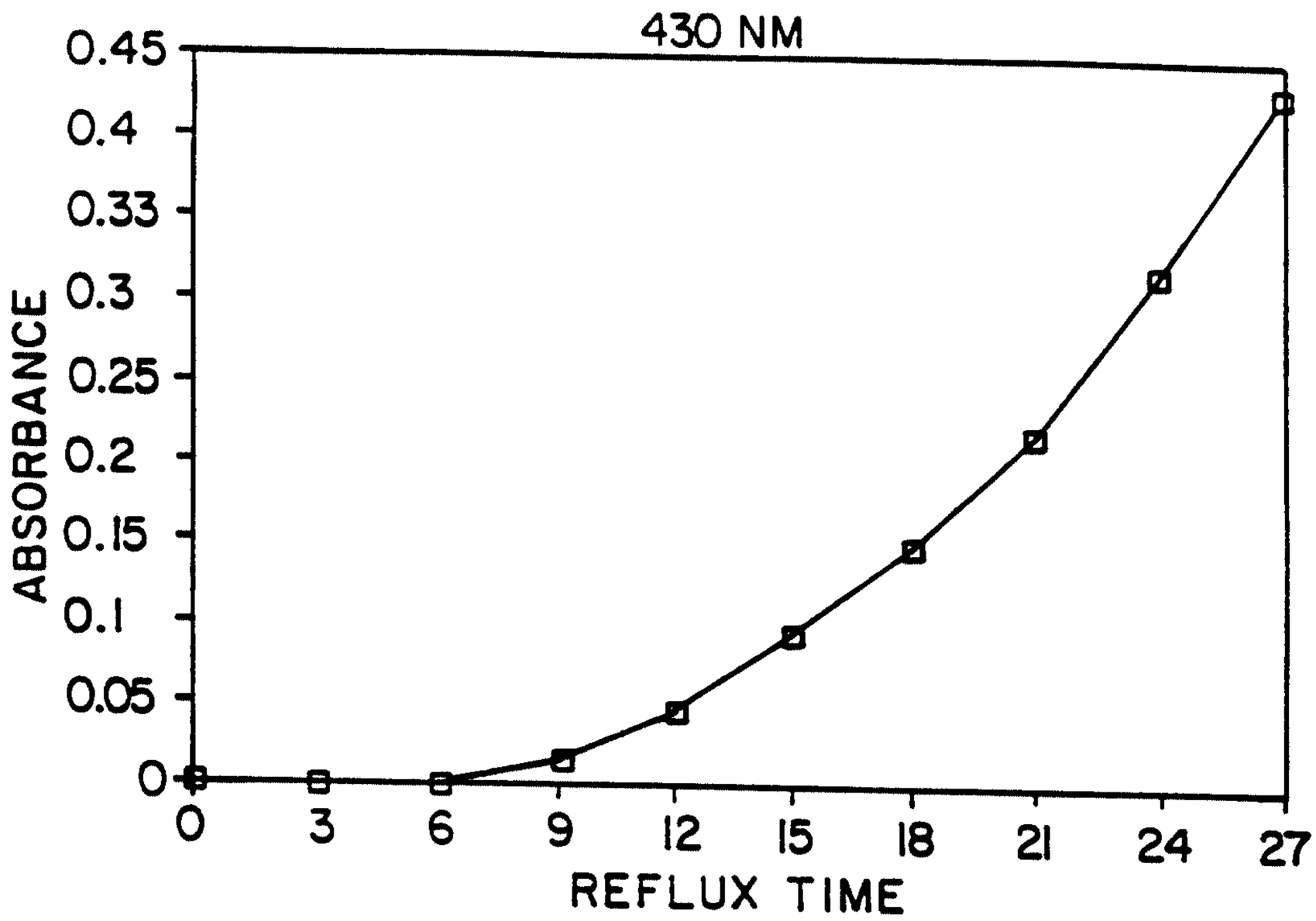

430 NM
ABSORBANCE
0.45
0.4
0.33
0.3
0.25
0.2
0.15
0.1
0.05
0
0
3
6
9
12
15
18
21
24
27
REFLUX TIME

Fig. 7

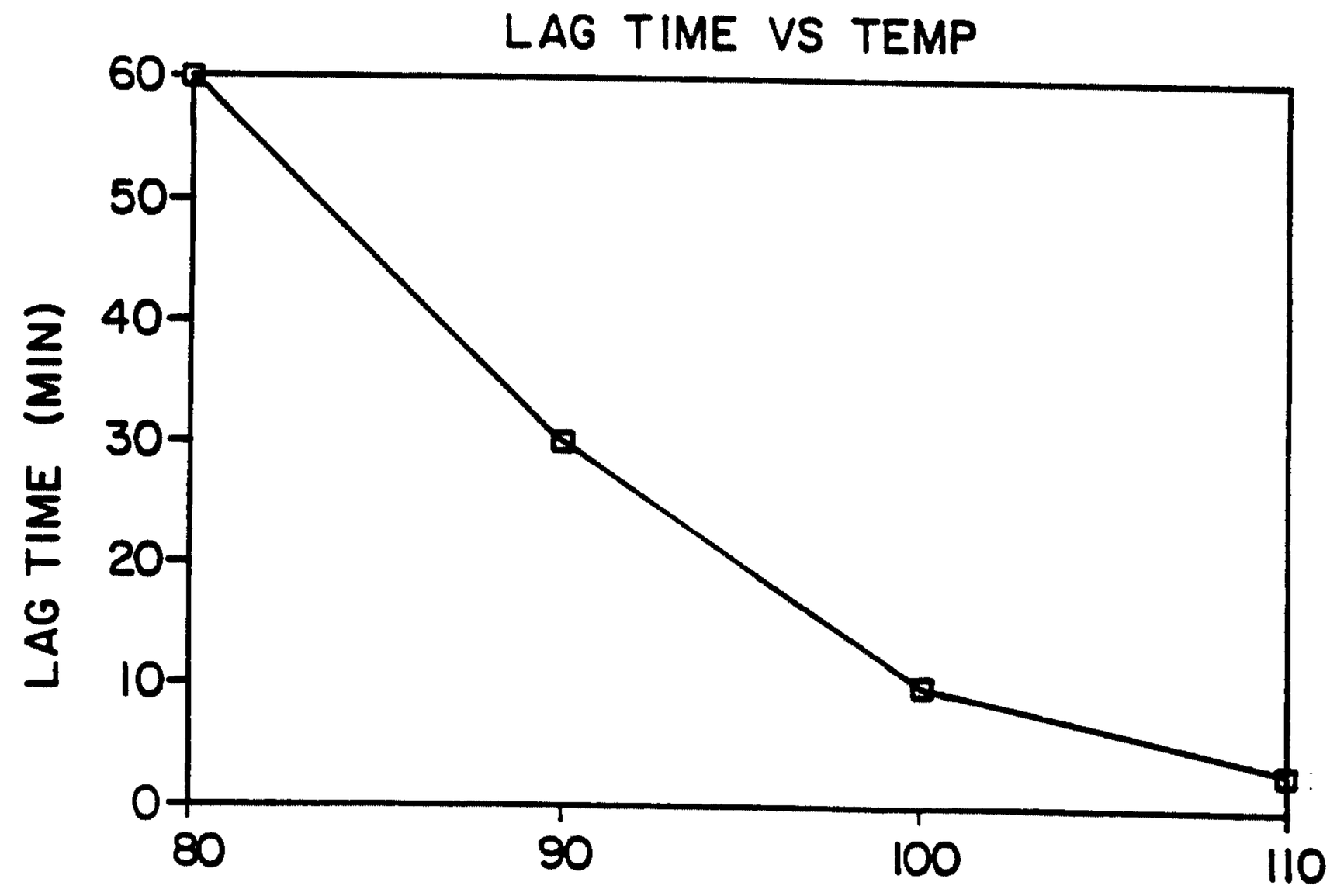

LAG TIME VS TEMP
LAG TIME (MIN)
60
50
40
30
20
10
0
80
90
100
110
TEMP (C)

Fig. 8

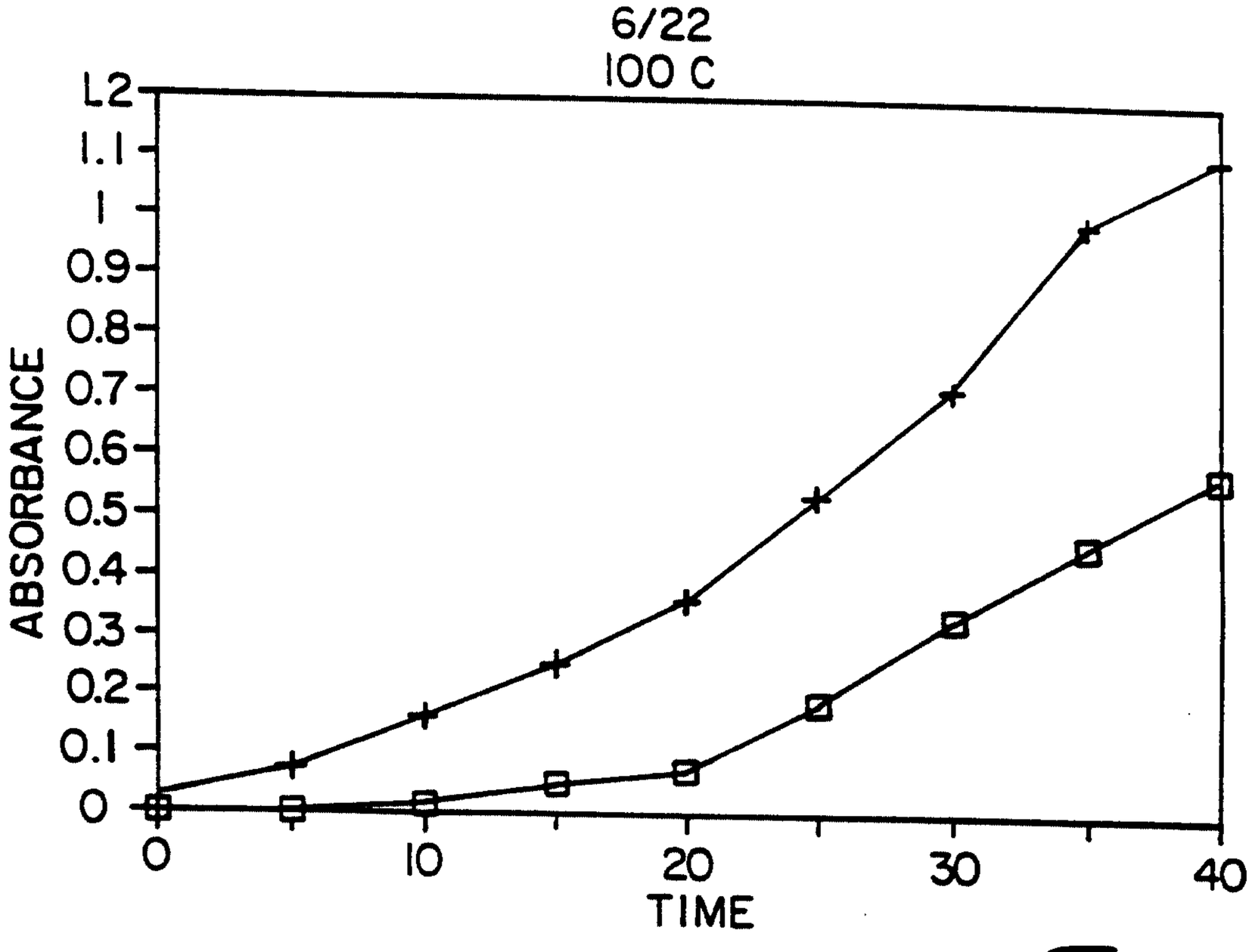

6/22
100 C
ABSORBANCE
L2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
TIME
□ REACTANTS
+ INTERMEDIATES

Fig. 9

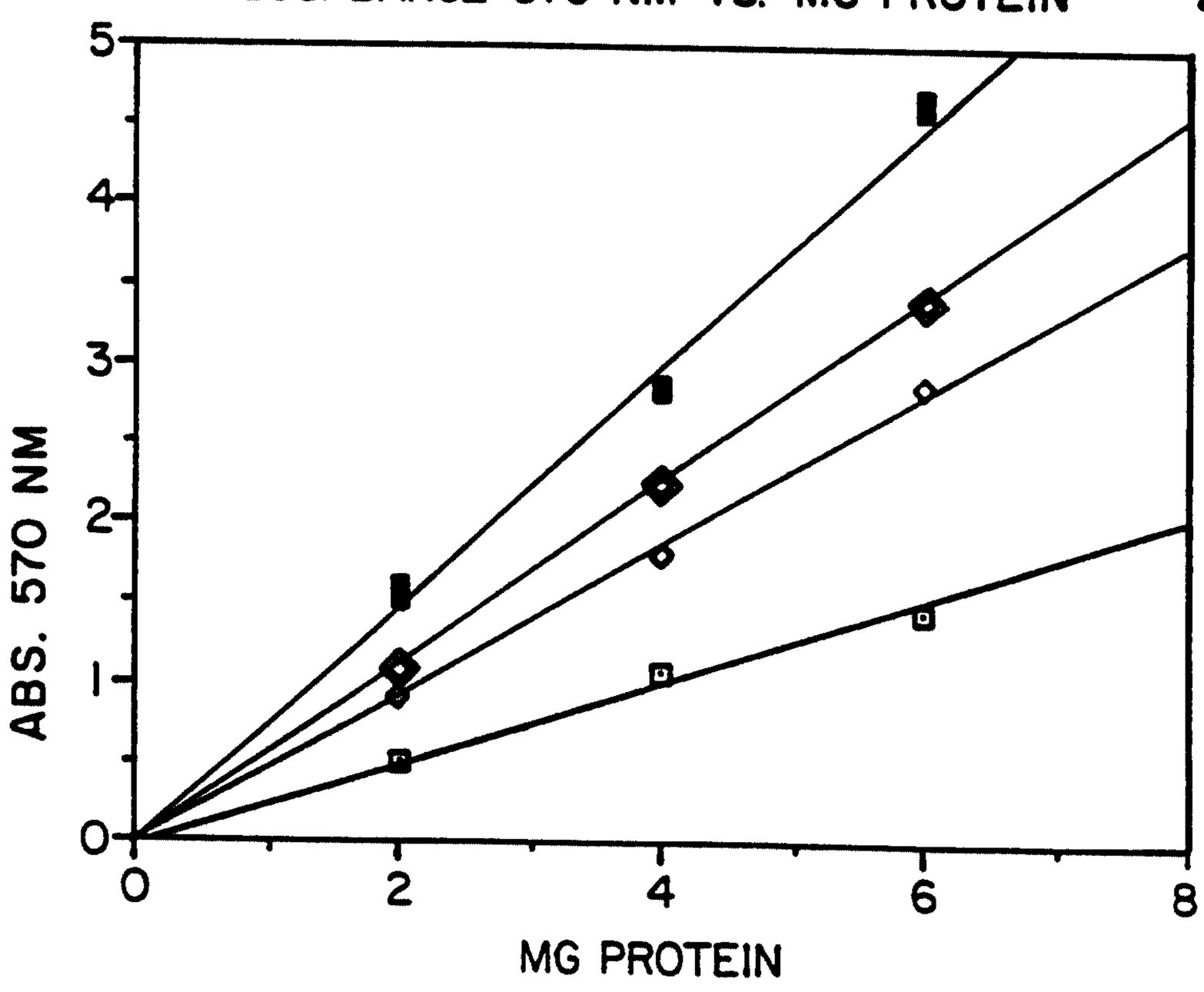

ABSORBANCE 570 NM VS. MG PROTEIN
ABS. 570 NM
5
4
3
2
1
0
0
2
4
6
8
MG PROTEIN
⊡ABS GLUTEN
◈ABS SOY
■ABS ALBUMIN
◇ABS WHEY
■ABS CASEINATE

Fig. 10

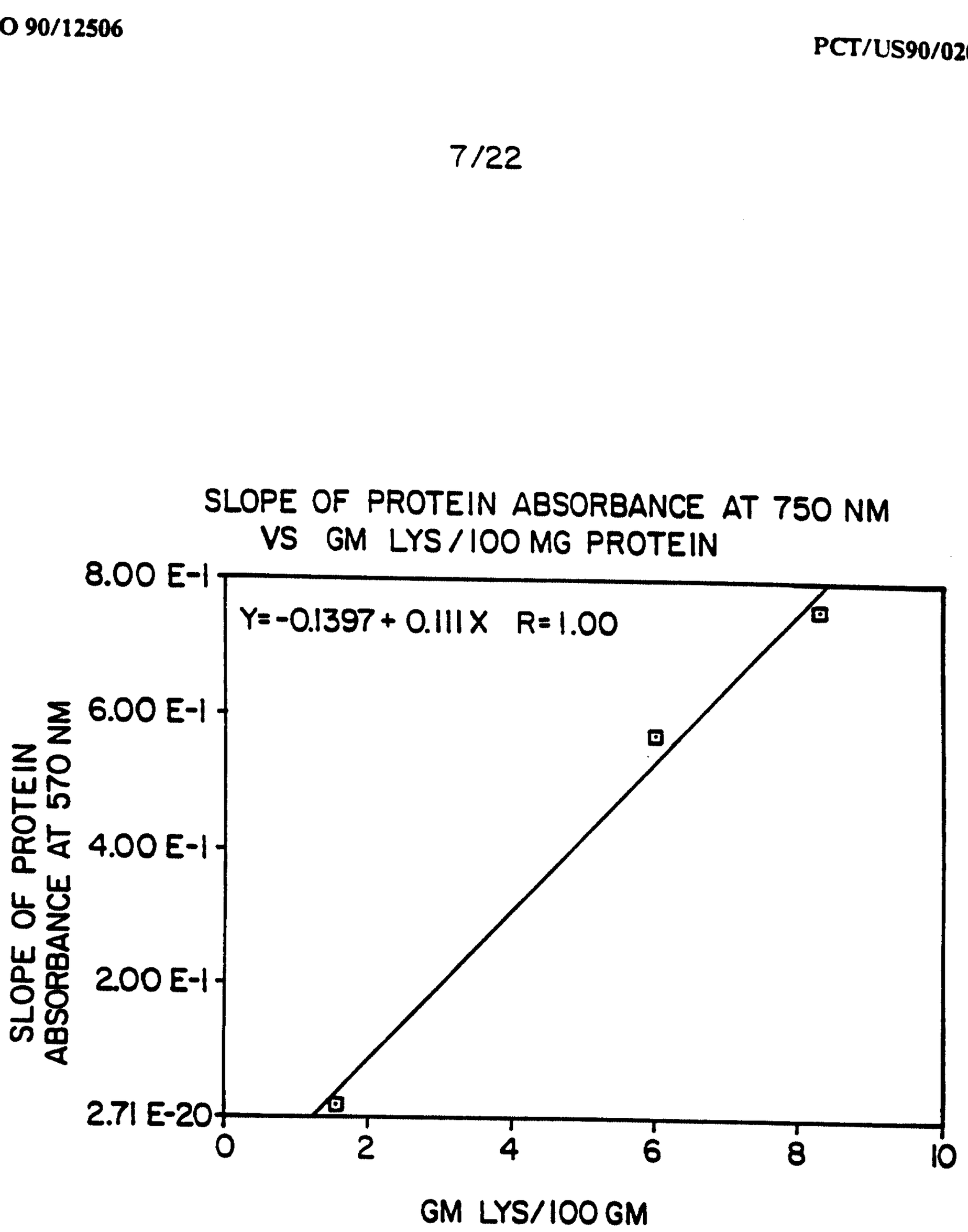

SLOPE OF PROTEIN ABSORBANCE AT 750 NM
VS GM LYS / 100 MG PROTEIN
Y= -0.1397 + 0.111 X R= 1.00
8.00 E-1
6.00 E-1
4.00 E-1
2.00 E-1
2.71 E-20
SLOPE OF PROTEIN ABSORBANCE AT 570 NM
0
2
4
6
8
10
GM LYS/100 GM
SLOPE ABS. 570

Fig. 11

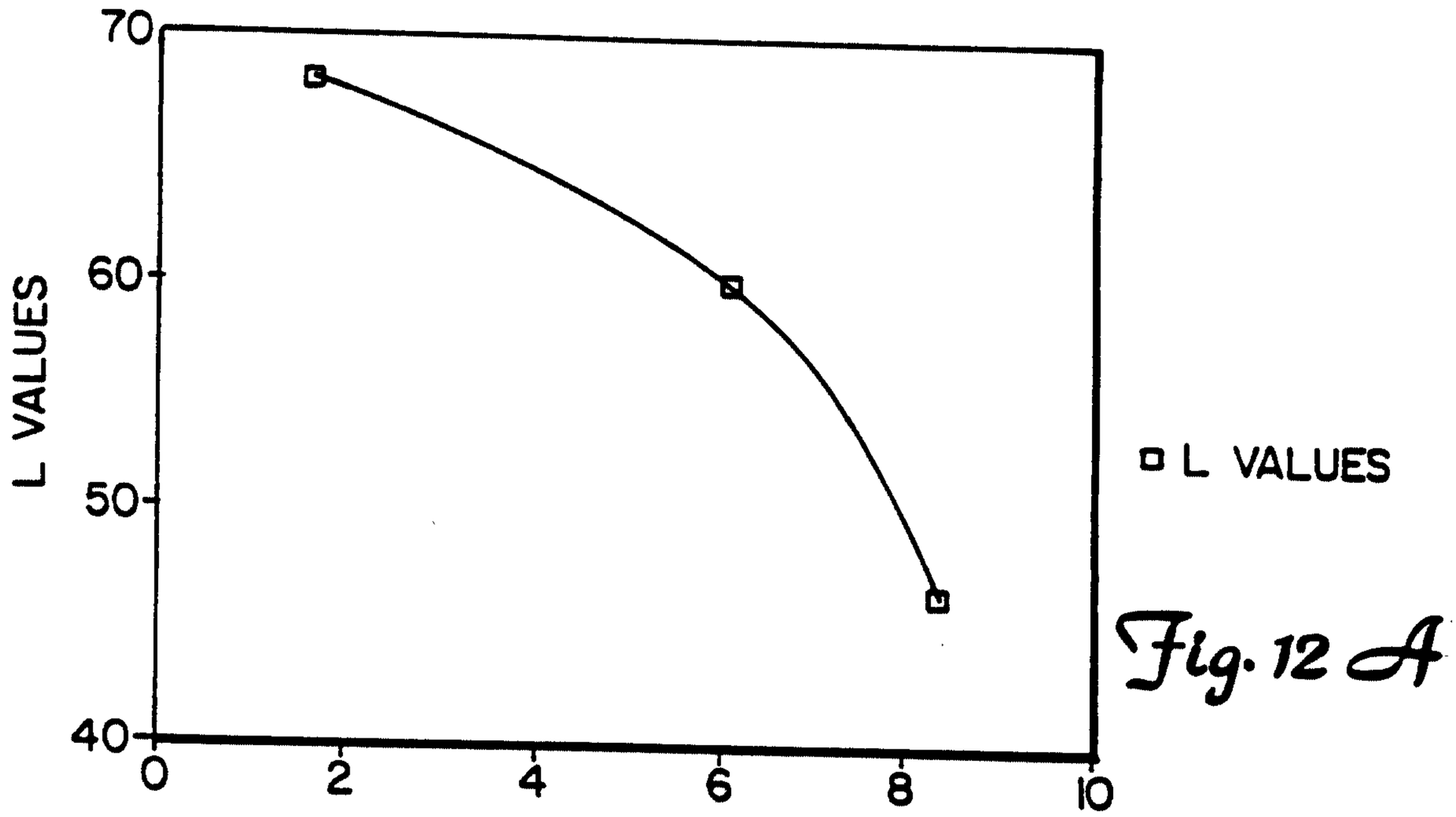


Fig. 12 A

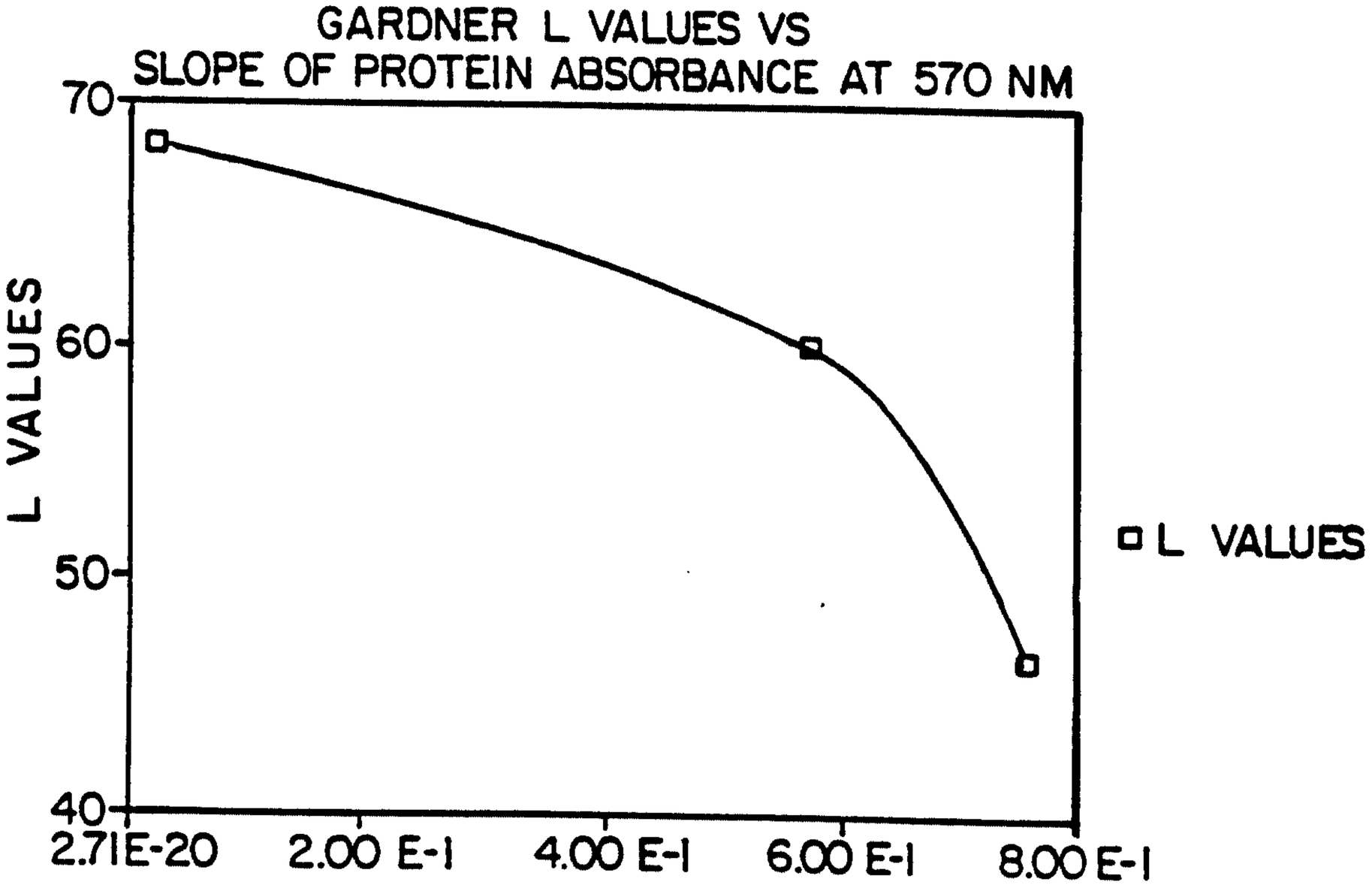


Fig. 12 B

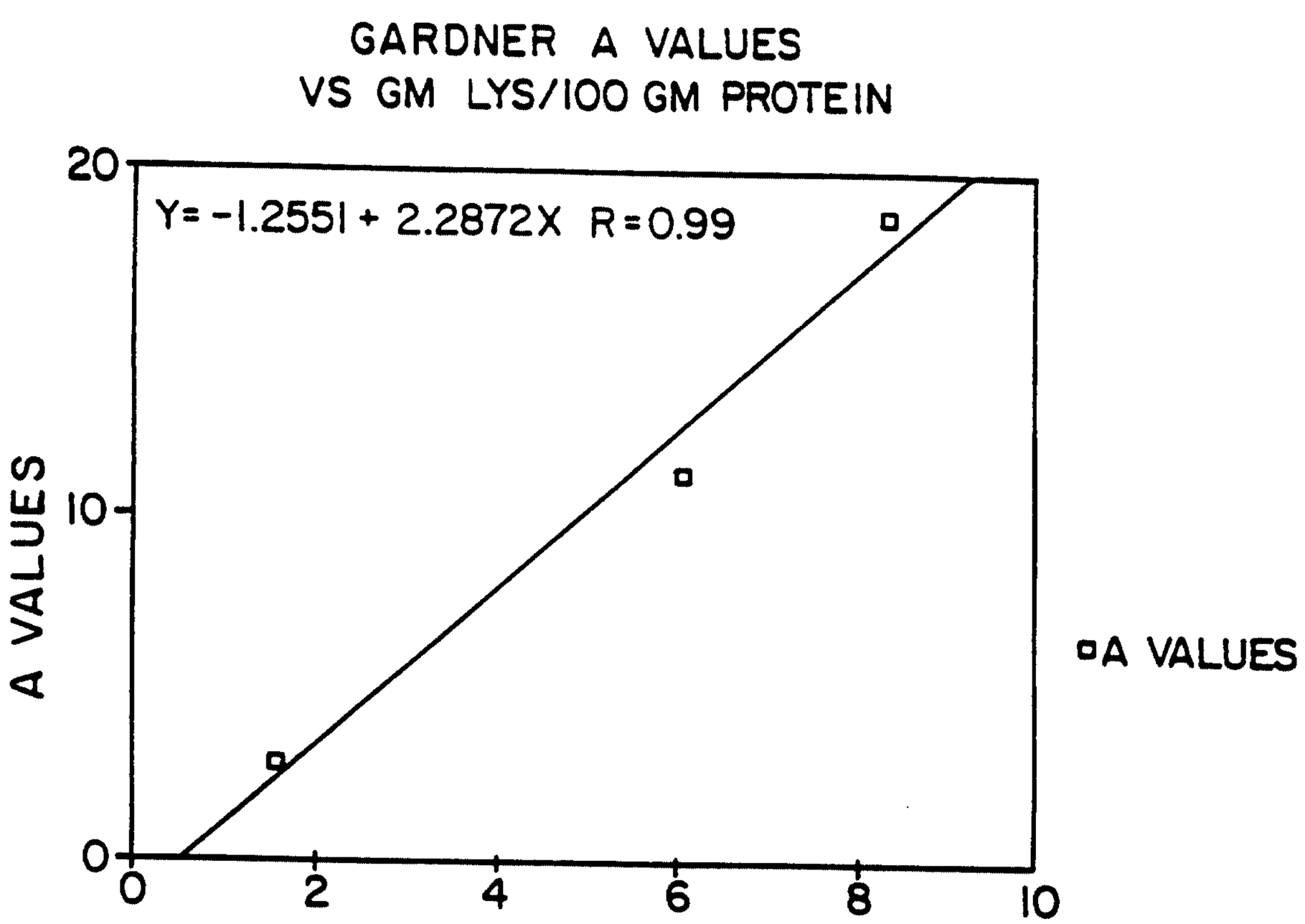


Fig. 12 C

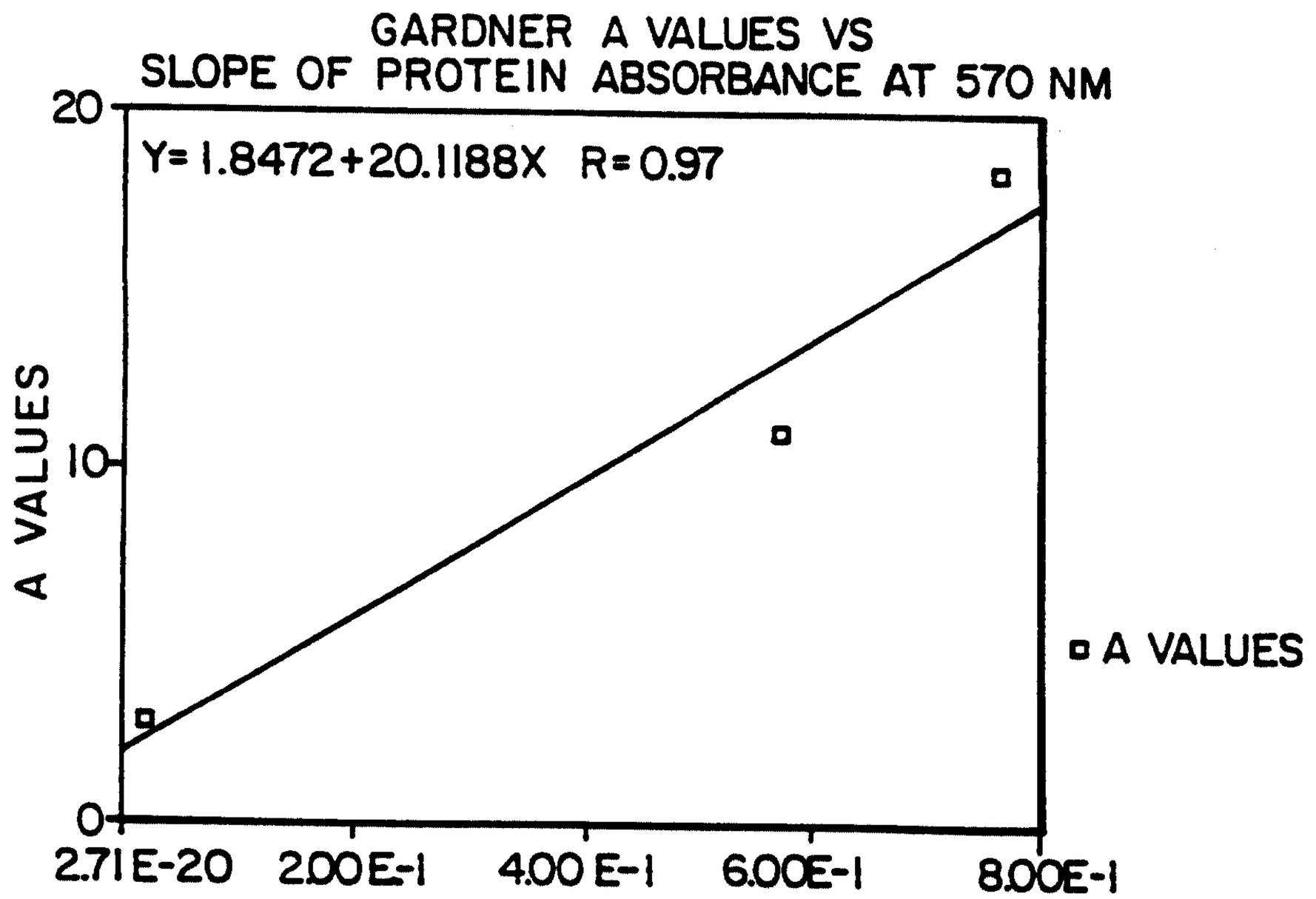


Fig. 12 D

BISCUIT COATING THICKNESS STUDY
SOY PROTEIN / XYLOSE
L VALUES

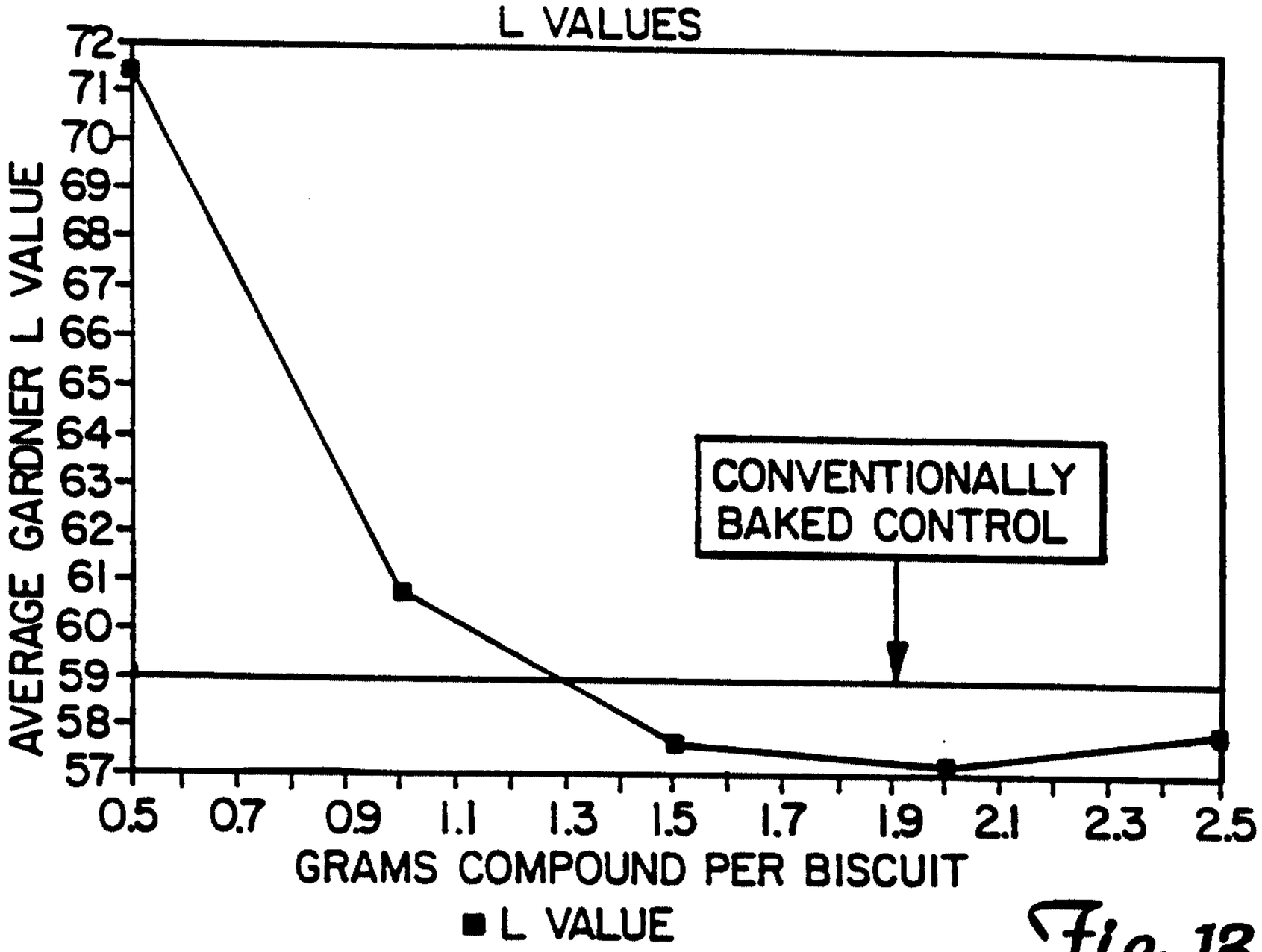


Fig. 13

BISCUIT COATING THICKNESS STUDY
SOY PROTEIN/XYLOSE
A AND B VALUES

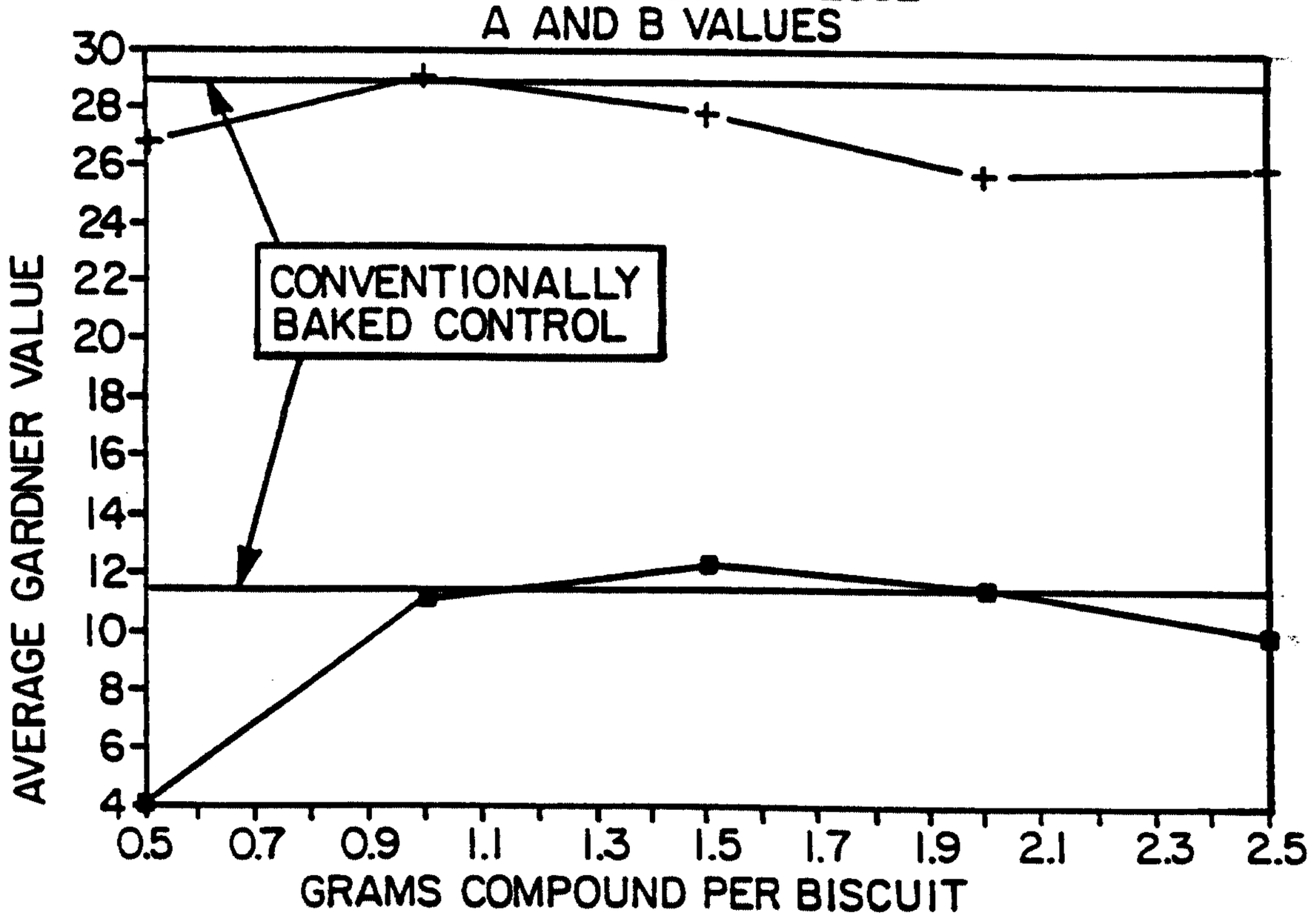
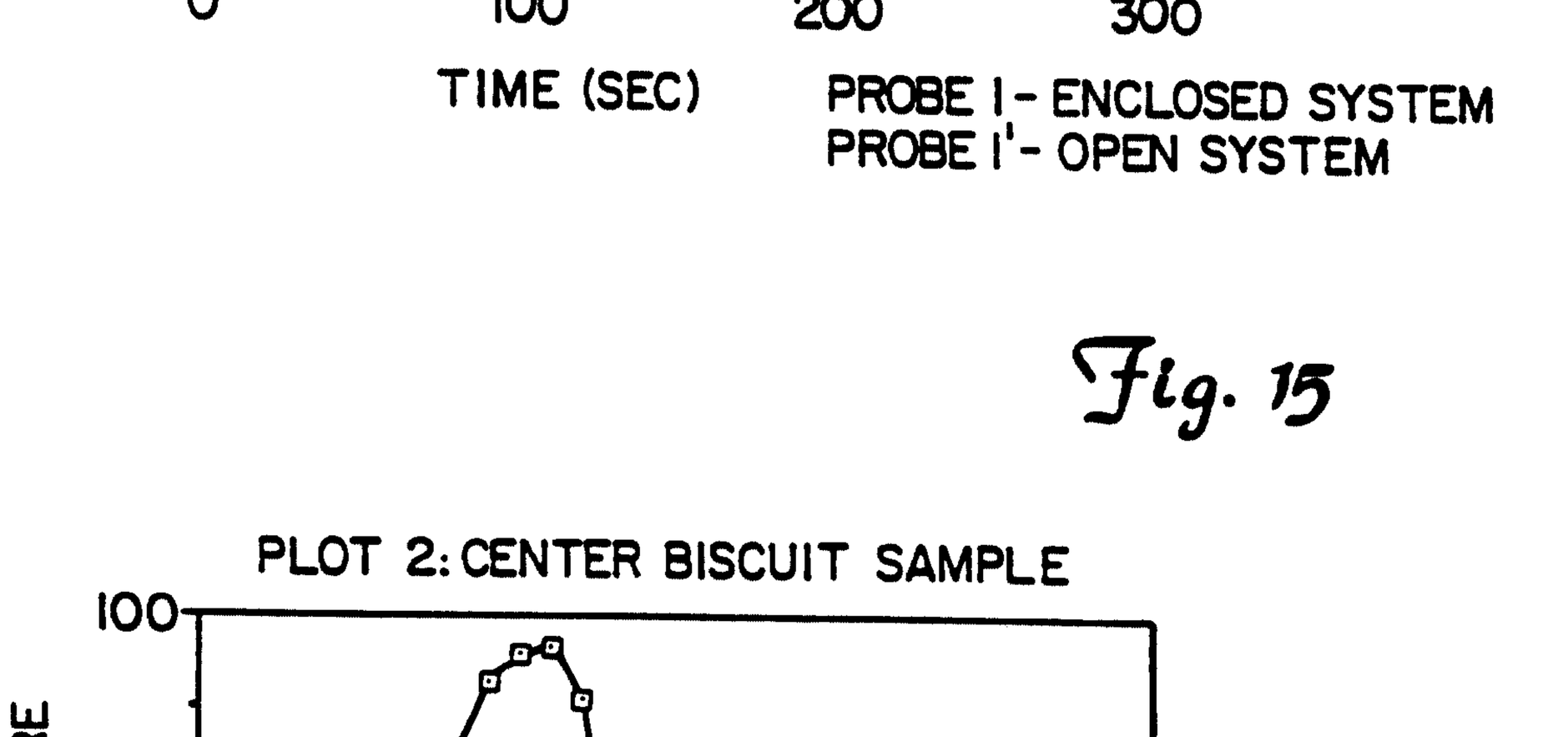


Fig. 14

BISCUIT SURFACE ATMOSPHERE
TEMPERATURE VS TIME

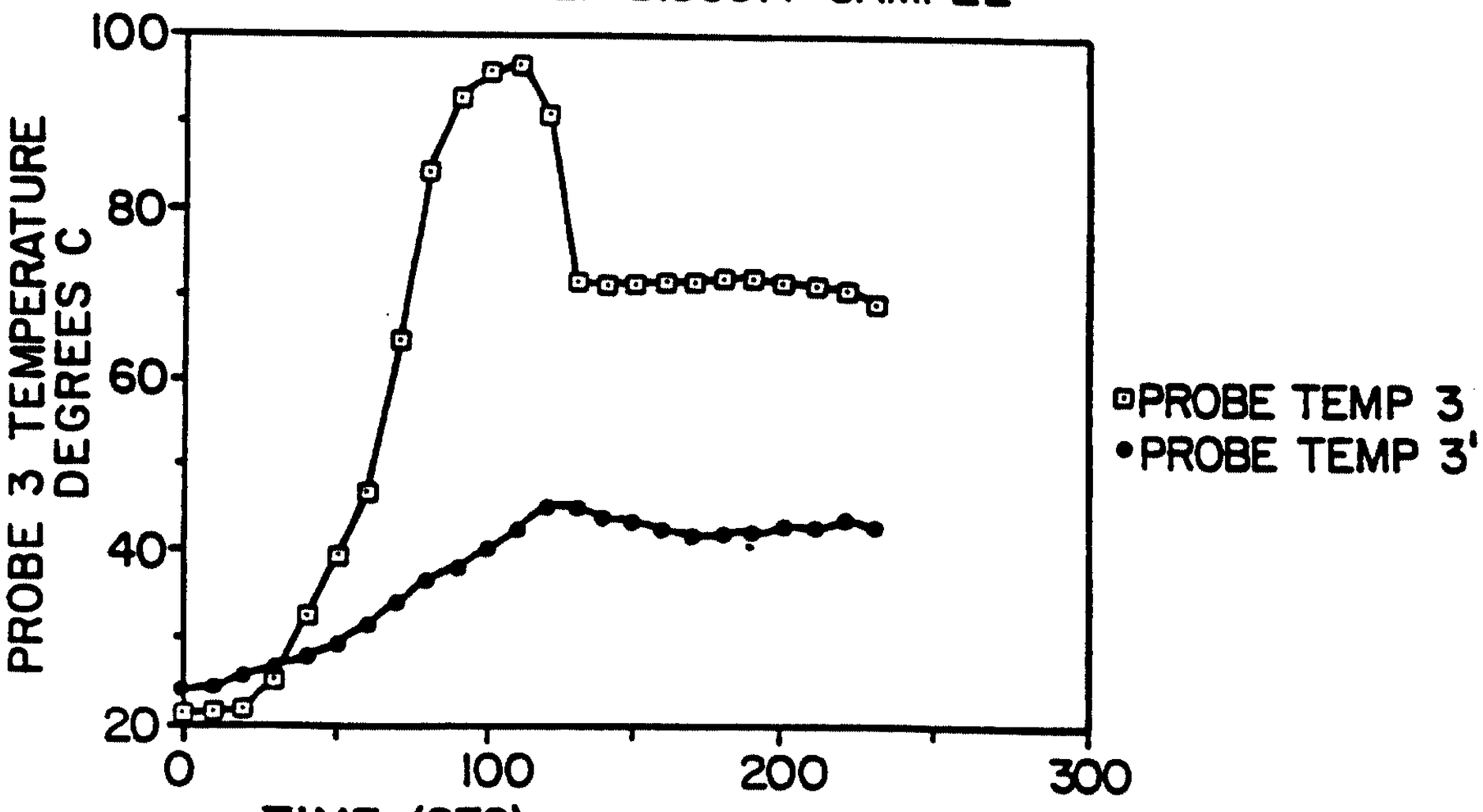
PLOT 1: EDGE BISCUIT SAMPLE



PROBE I - ENCLOSED SYSTEM
PROBE I'- OPEN SYSTEM

Fig. 15

PLOT 2: CENTER BISCUIT SAMPLE



PROBE 3-ENCLOSED SYSTEM
PROBE 3'-OPEN SYSTEM

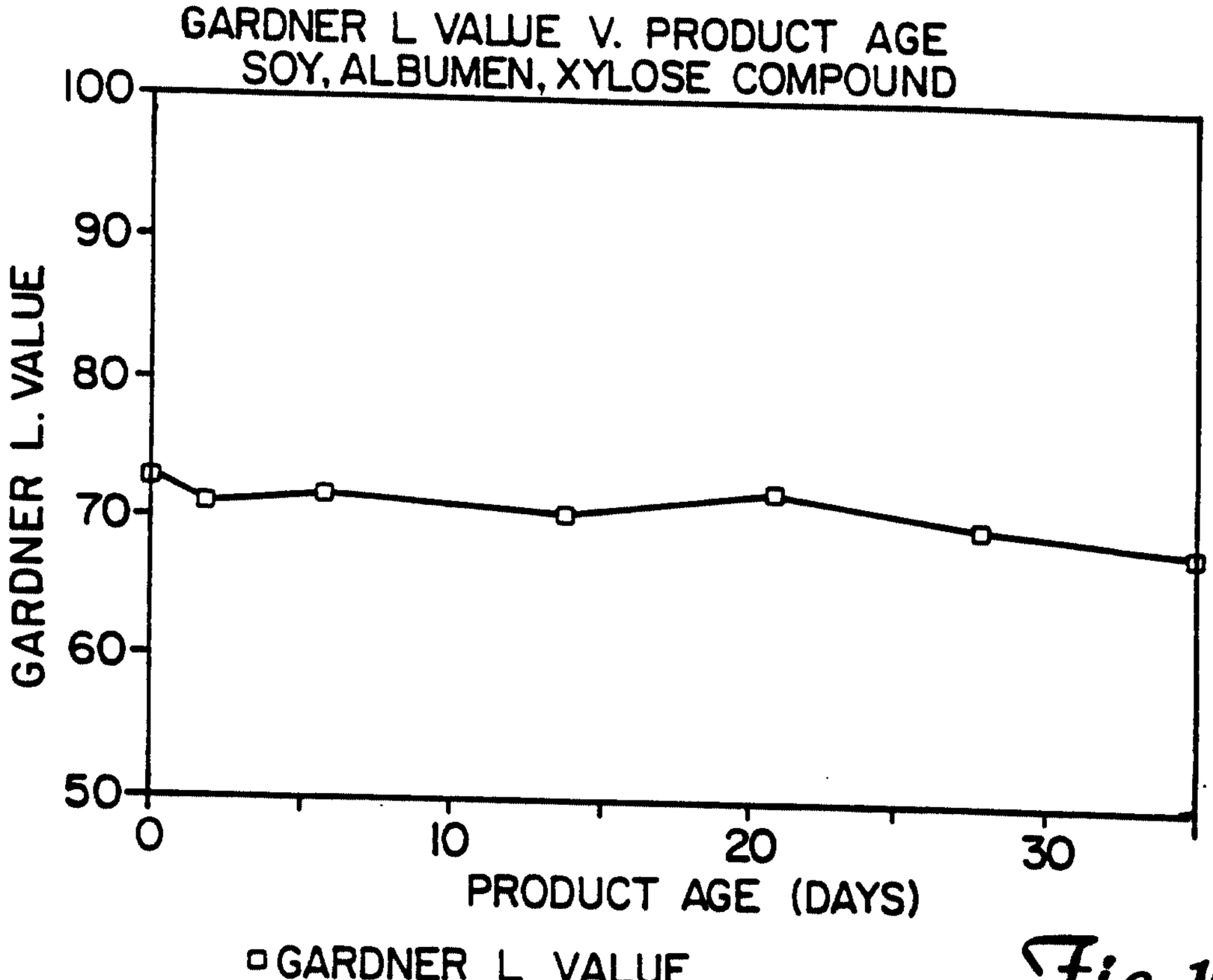

GARDNER L VALUE V. PRODUCT AGE
SOY, ALBUMEN, XYLOSE COMPOUND
GARDNER L. VALUE
100
90
80
70
60
50
0
10
20
30
PRODUCT AGE (DAYS)
GARDNER L VALUE

Fig. 16

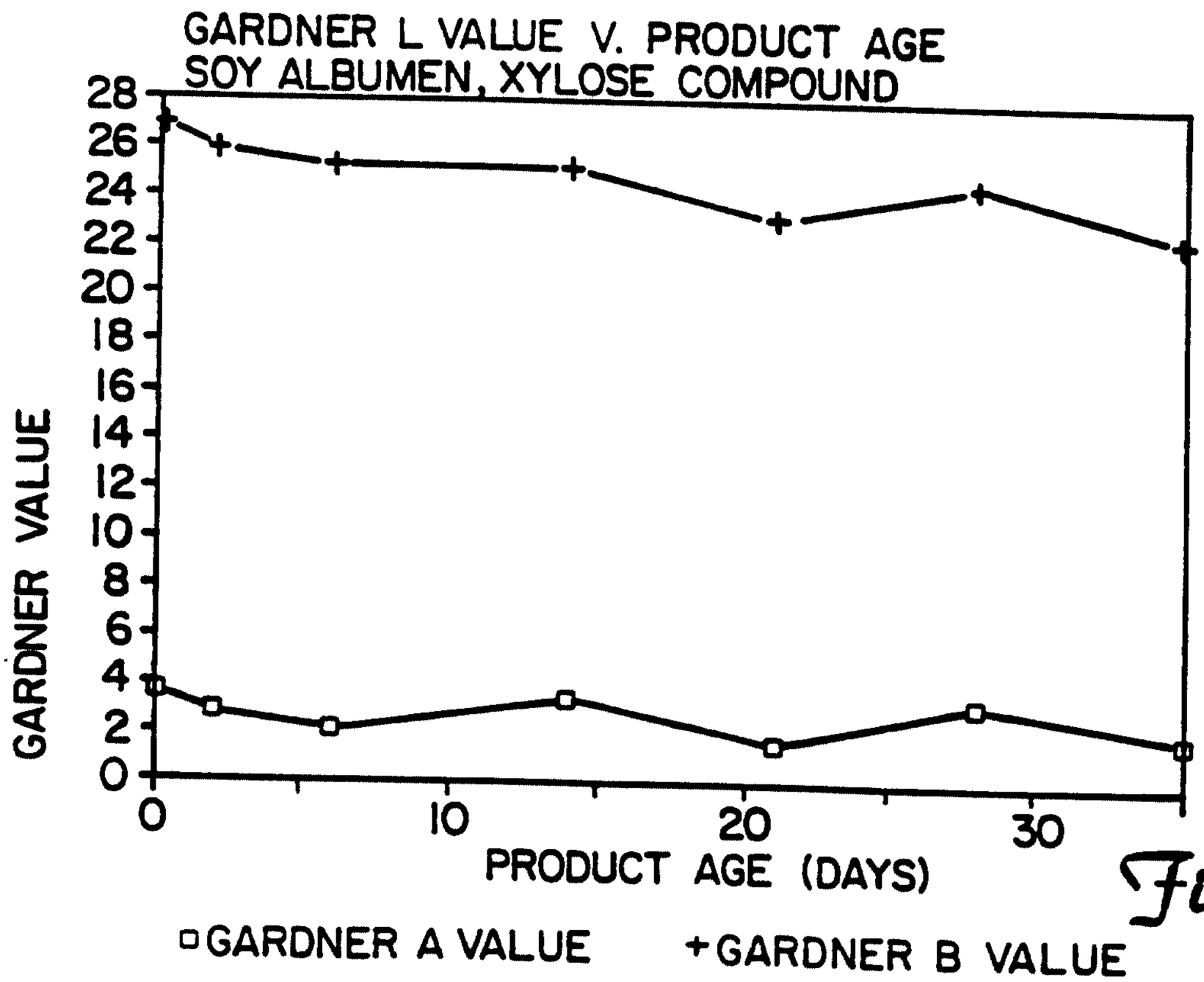
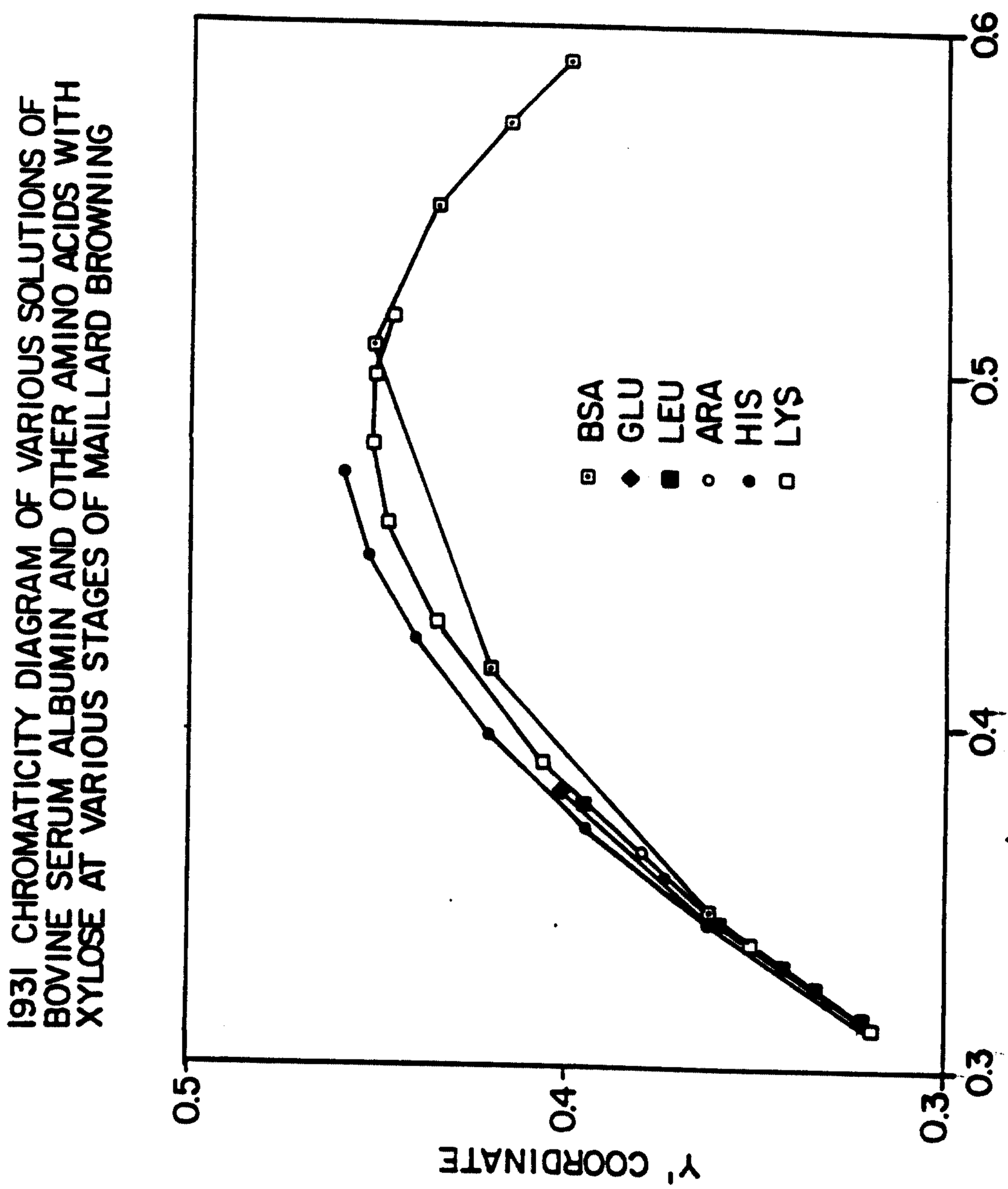

GARDNER L VALUE V. PRODUCT AGE
SOY ALBUMEN, XYLOSE COMPOUND
GARDNER VALUE
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
PRODUCT AGE (DAYS)
GARDNER A VALUE
GARDNER B VALUE

Fig. 17

Fig. 18


1931 CHROMATICITY DIAGRAM OF VARIOUS SOLUTIONS OF
BOVINE SERUM ALBUMIN AND OTHER AMINO ACIDS WITH
XYLOSE AT VARIOUS STAGES OF MAILLARD BROWNING
BSA
GLU
LEU
ARA
HIS
LYS
0.6
0.5
0.4
0.3
X' COORDINATE
Y' COORDINATE

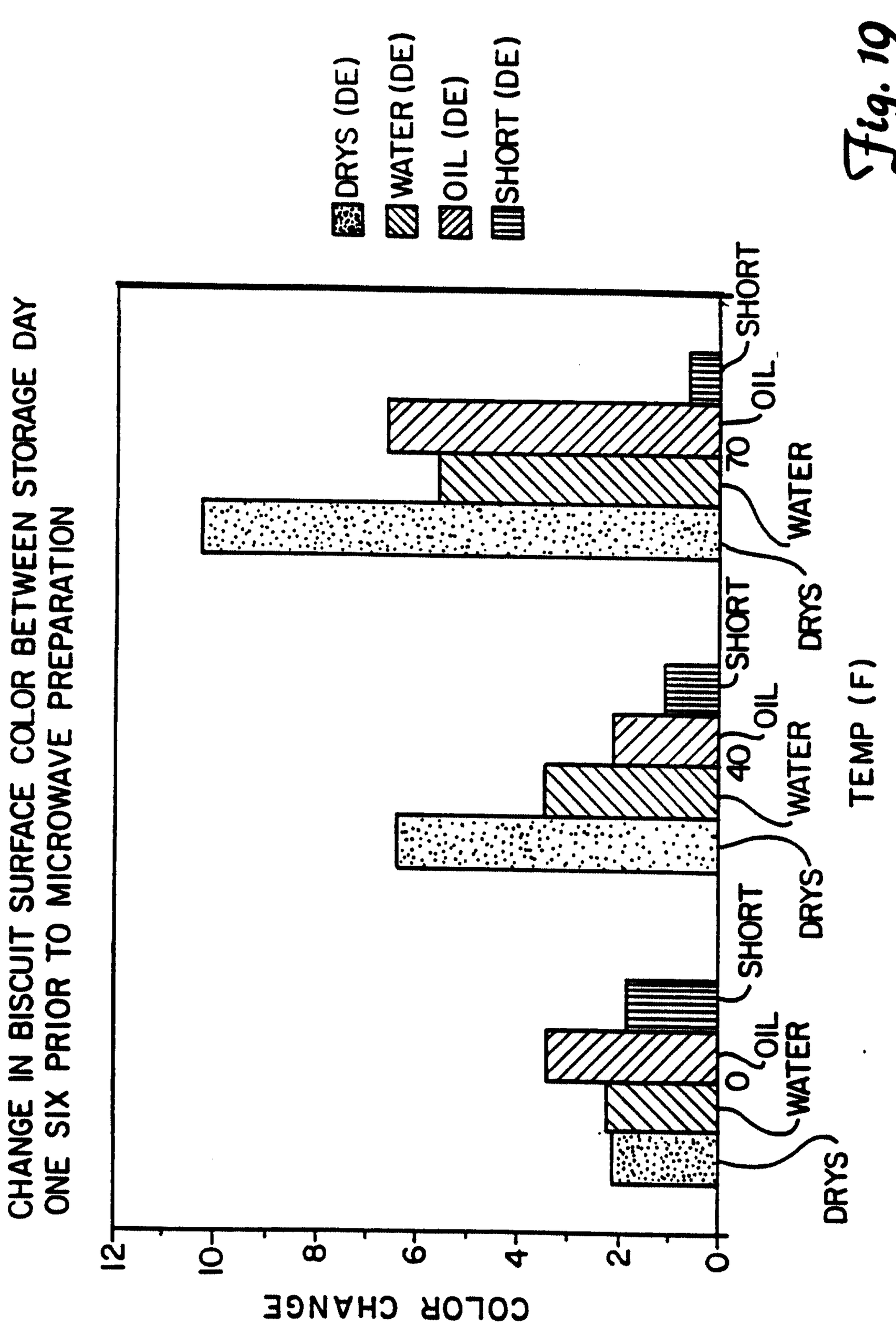

CHANGE IN BISCUIT SURFACE COLOR BETWEEN STORAGE DAY ONE SIX PRIOR TO MICROWAVE PREPARATION
COLOR CHANGE
0
2
4
6
8
10
12
TEMP (F)
DRYS (DE)
WATER (DE)
OIL (DE)
SHORT (DE)
SHORT
OIL
WATER
DRYS
70
40
0

Fig. 19

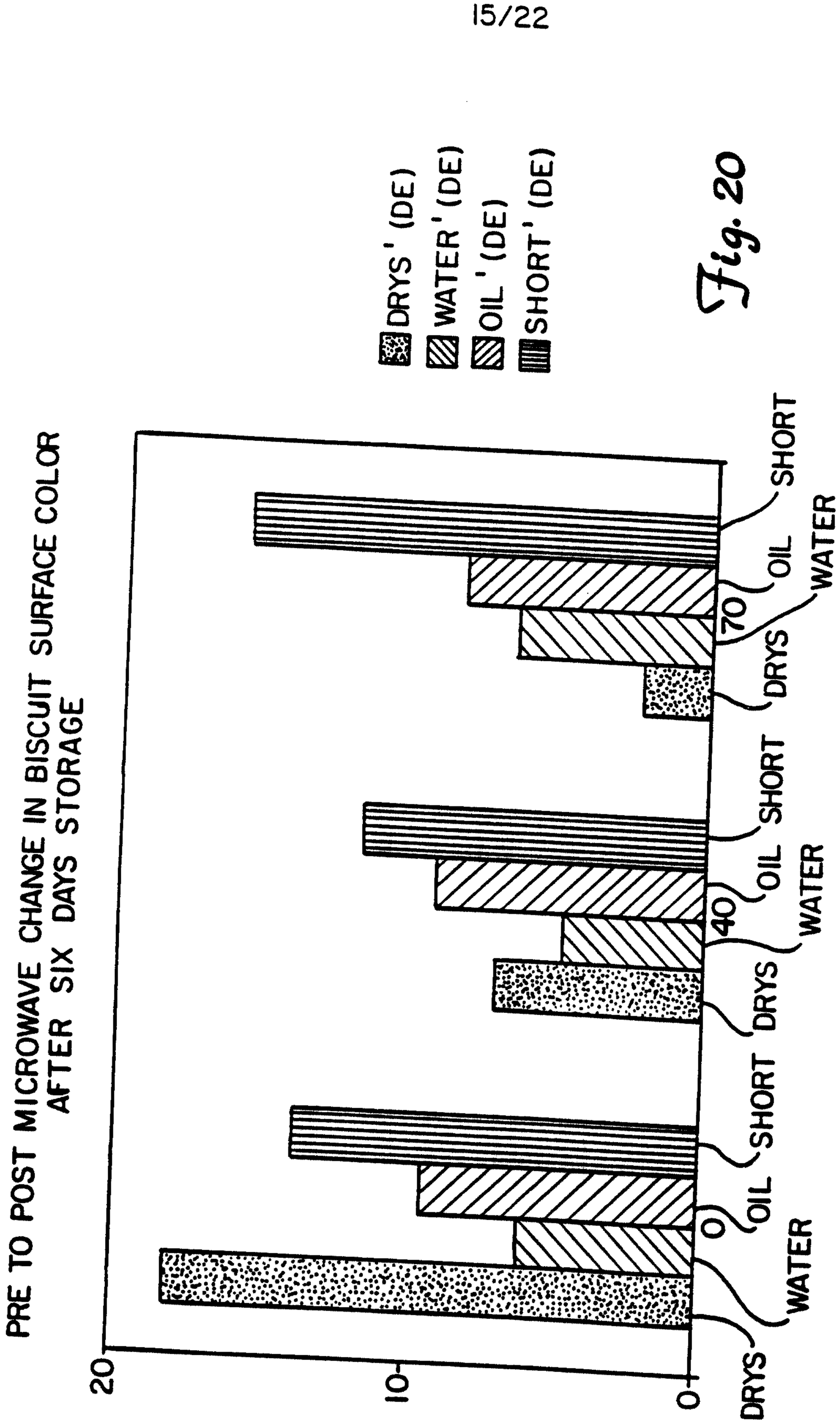

PRE TO POST MICROWAVE CHANGE IN BISCUIT SURFACE COLOR
AFTER SIX DAYS STORAGE
20
10
0
COLOR CHANGE
DRYS
WATER
OIL
SHORT
70
DRYS
OIL
WATER
SHORT
40
DRYS
OIL
WATER
SHORT
0
DRYS
OIL
WATER
SHORT
TEMP (F)
DRYS' (DE)
WATER' (DE)
OIL' (DE)
SHORT' (DE)

Fig. 20

Fig. 21

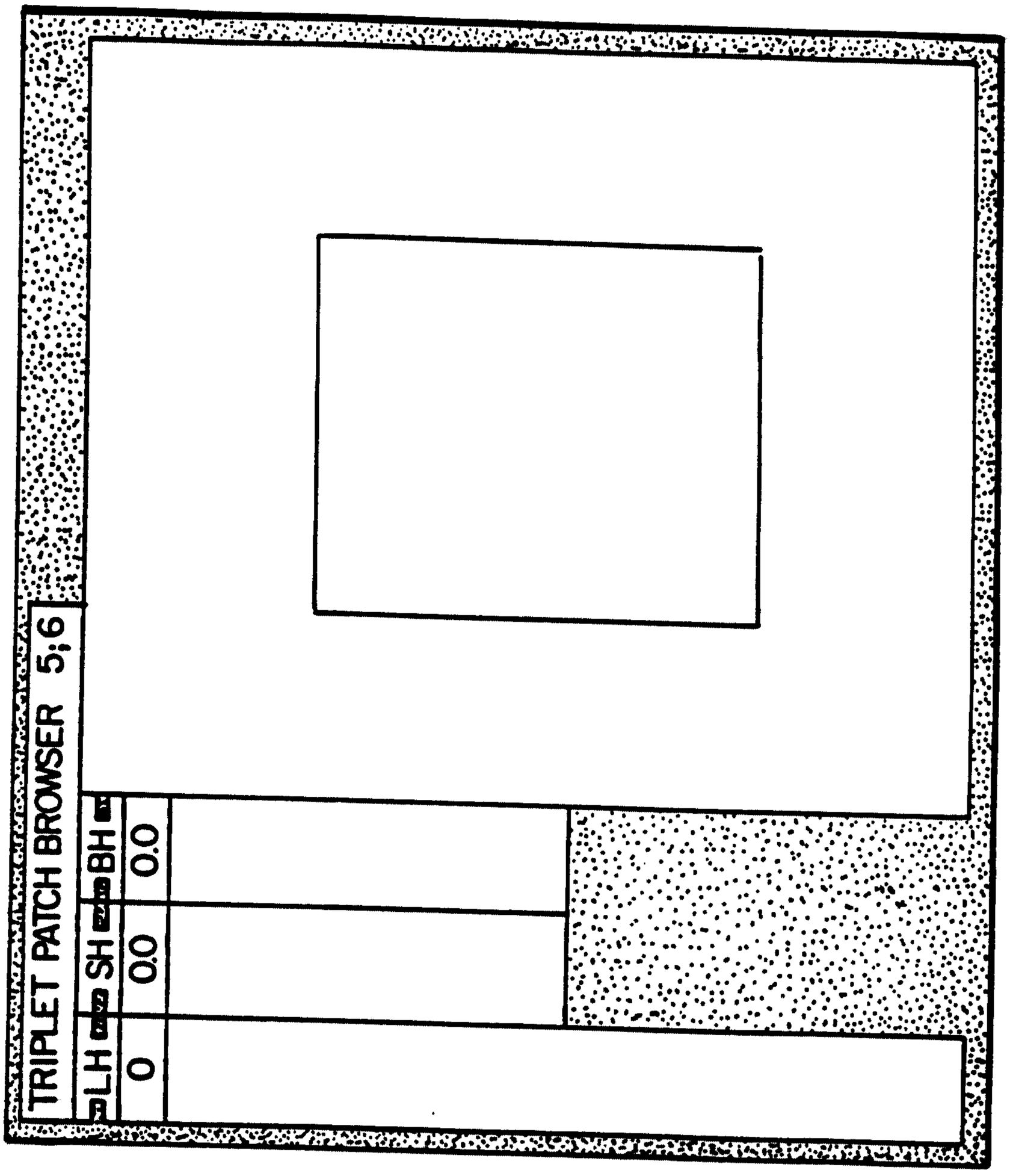


Fig. 22

EP 120 RESPONSE SURFACE EXPERIMENT 3:4
SUGAR/PROTEIN
TIME
80.0
0.917381
SOY/ALBUMIN
PERCENT
50.0
50.0
50.0
GLUCOSE/XYLOSE
PERCENT
SODA %
2.5

SCREENDUMP:

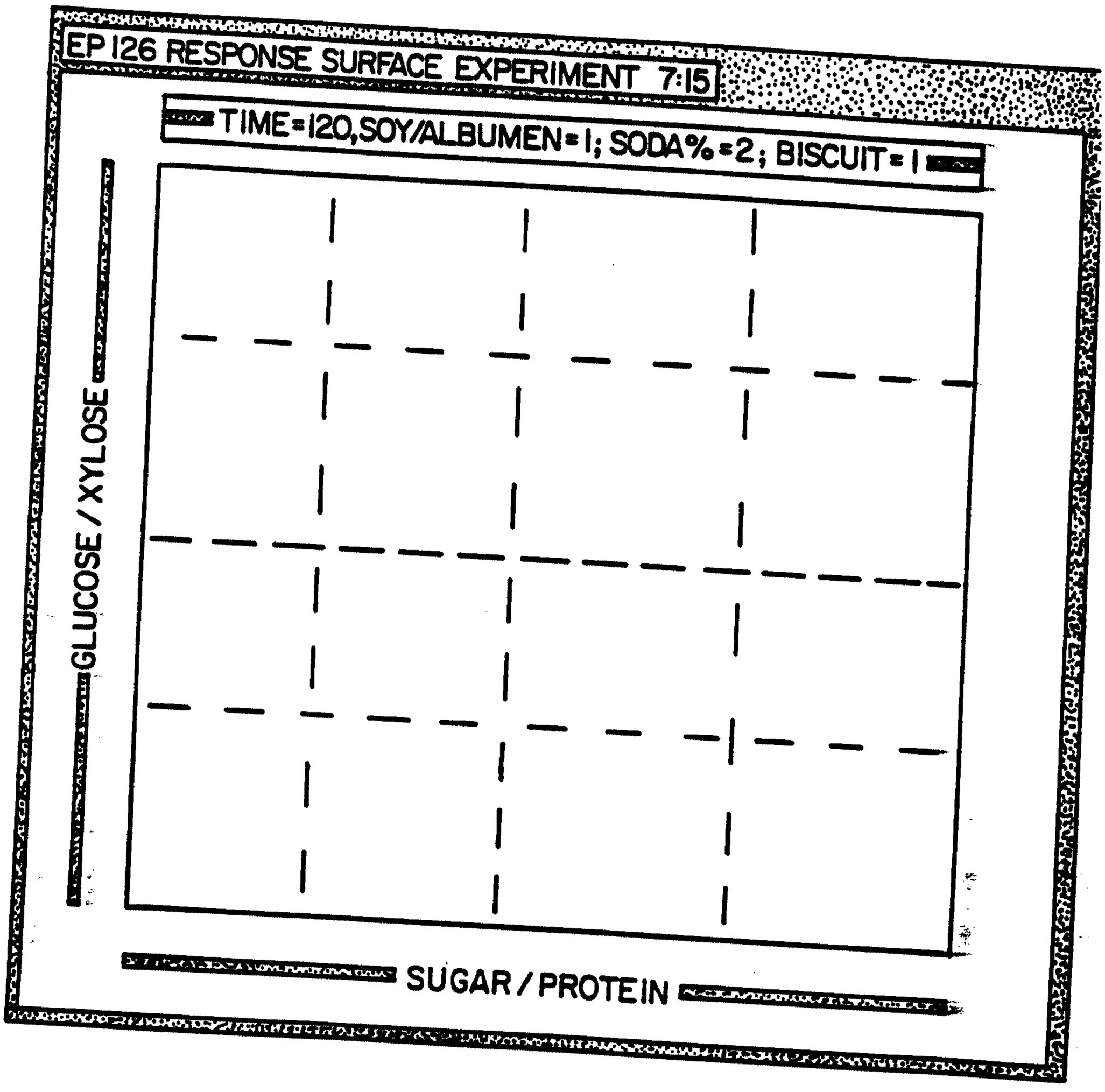


Fig. 23

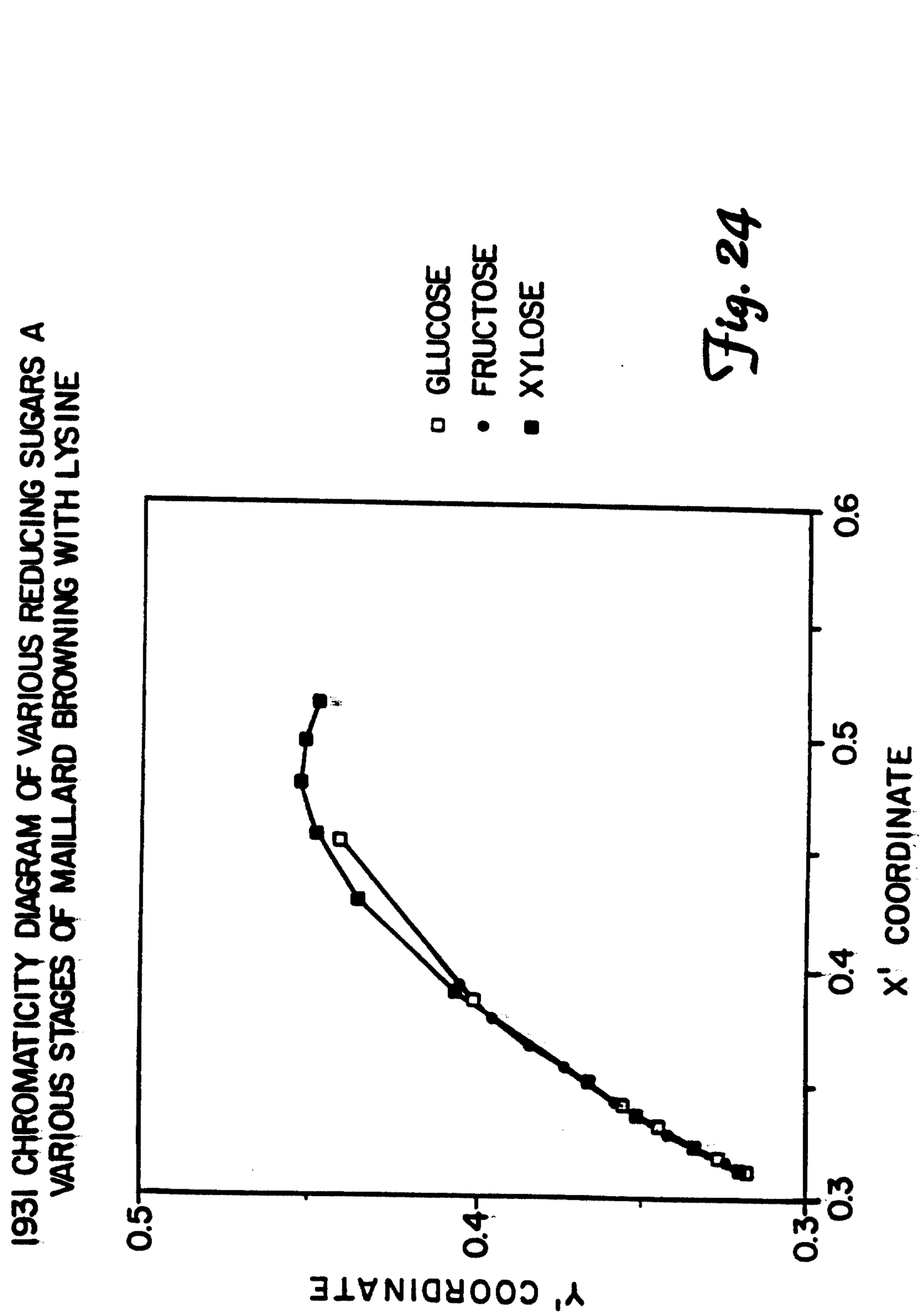

1931 CHROMATICITY DIAGRAM OF VARIOUS REDUCING SUGARS A
VARIOUS STAGES OF MAILLARD BROWNING WITH LYSINE
GLUCOSE
FRUCTOSE
XYLOSE
0.5
0.4
0.3
Y' COORDINATE
0.3
0.4
0.5
0.6
X' COORDINATE

Fig. 24

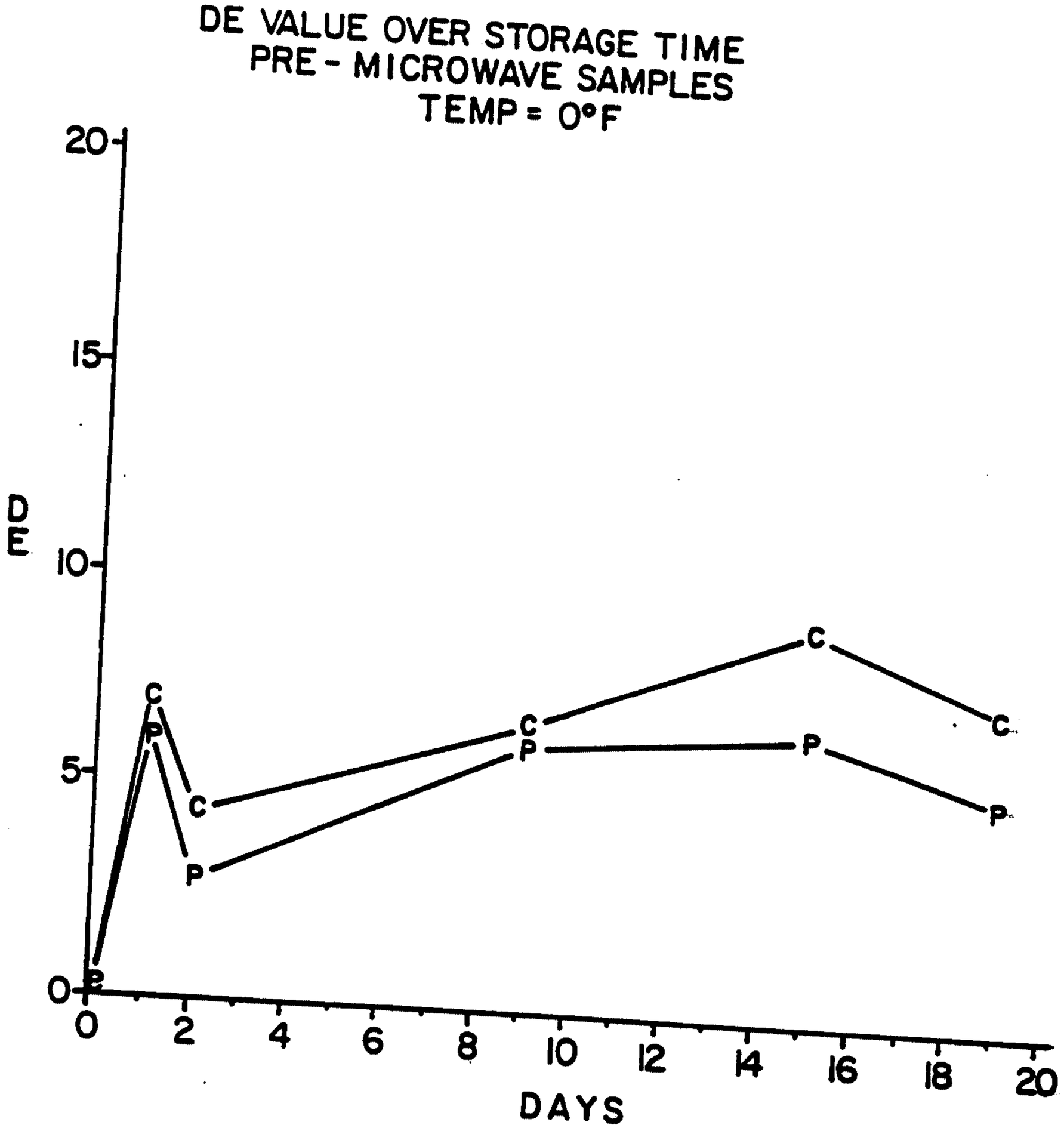

DE VALUE OVER STORAGE TIME
PRE - MICROWAVE SAMPLES
TEMP = 0°F
DE
20
15
10
5
0
C
P
0
2
4
6
8
10
12
14
16
18
20
DAYS

Fig. 25

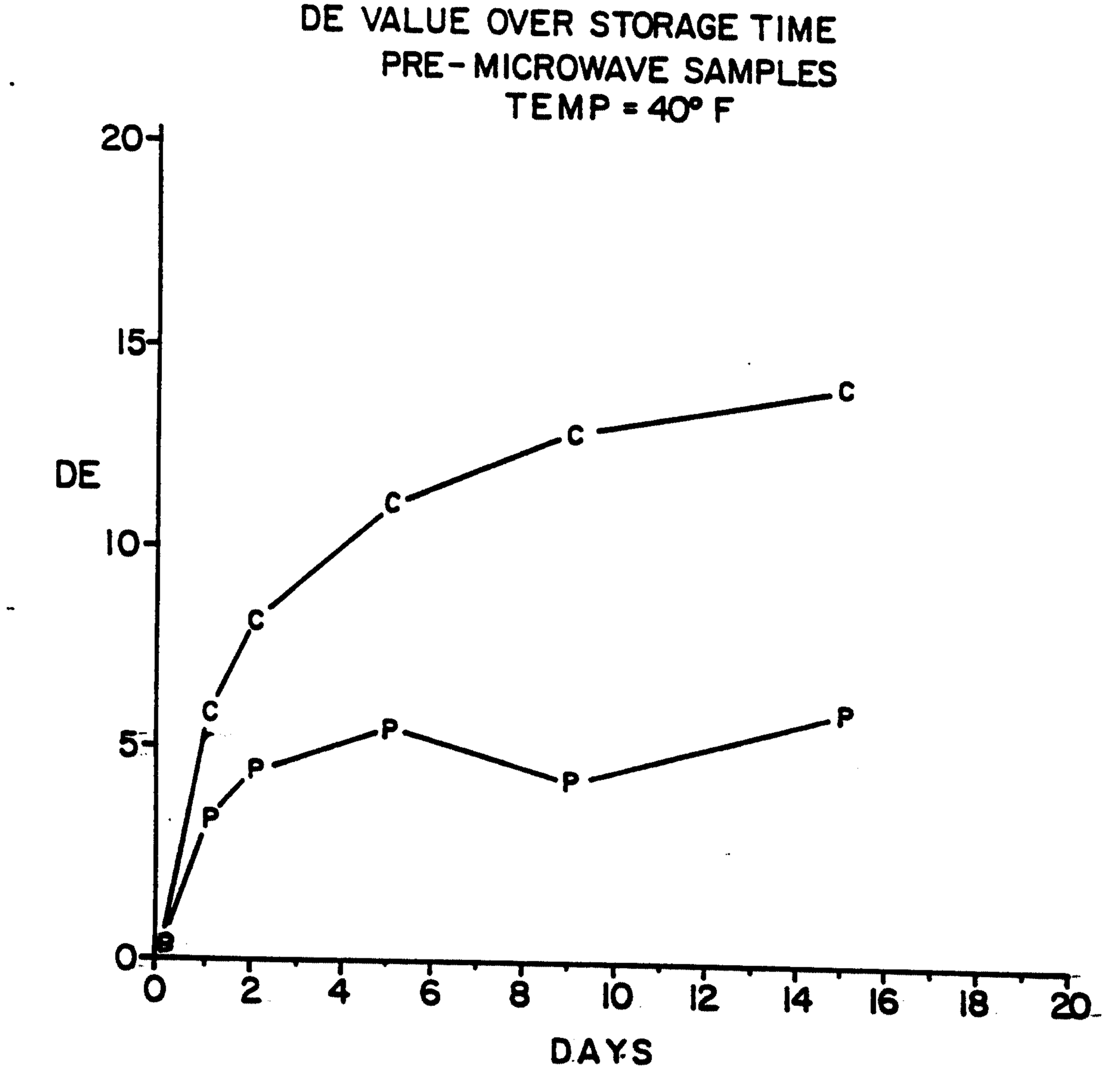

DE VALUE OVER STORAGE TIME
PRE-MICROWAVE SAMPLES
TEMP = 40° F
DE
DAYS
0
5
10
15
20
0
2
4
6
8
10
12
14
16
18
20
C
P

Fig. 26

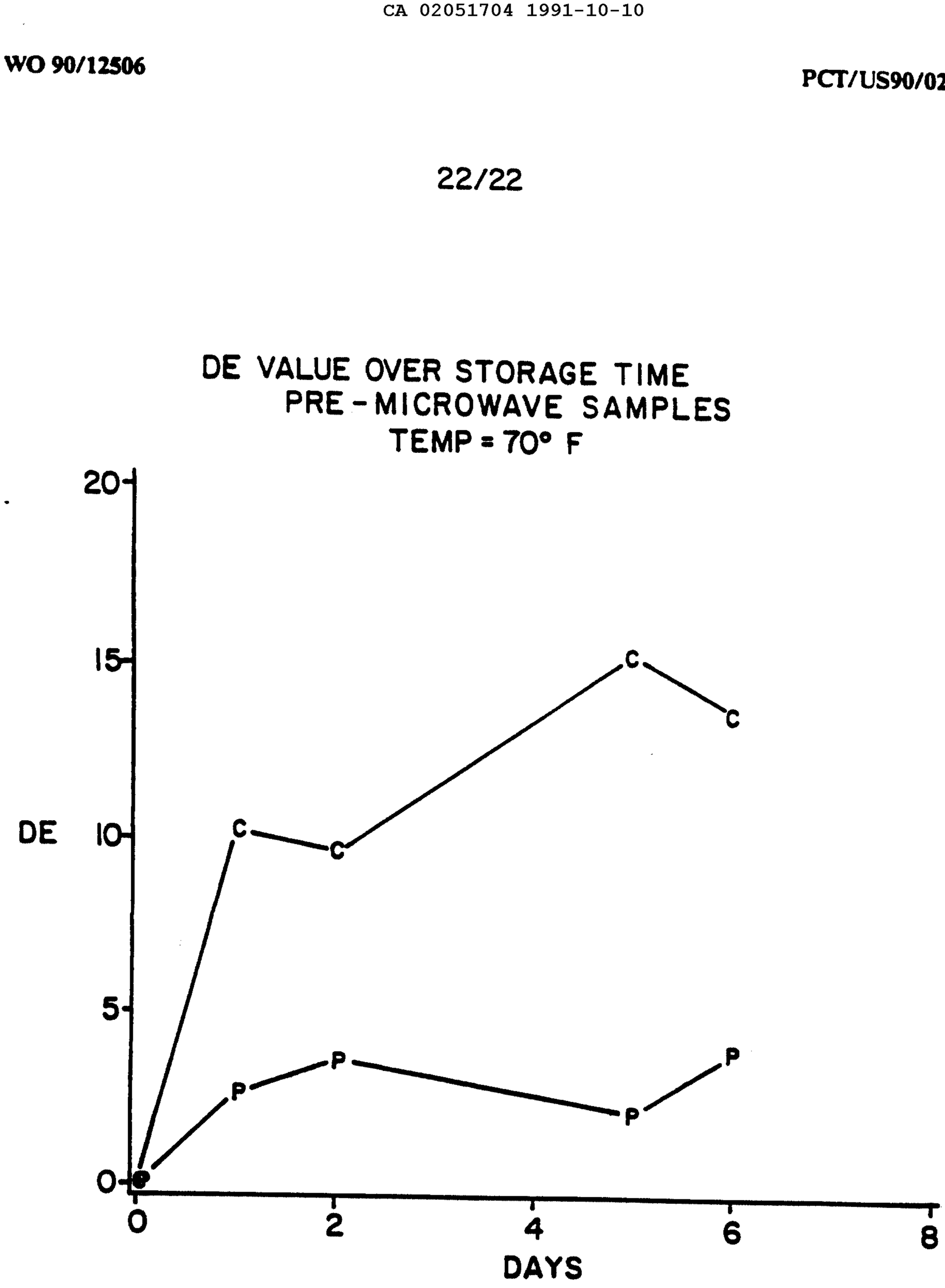
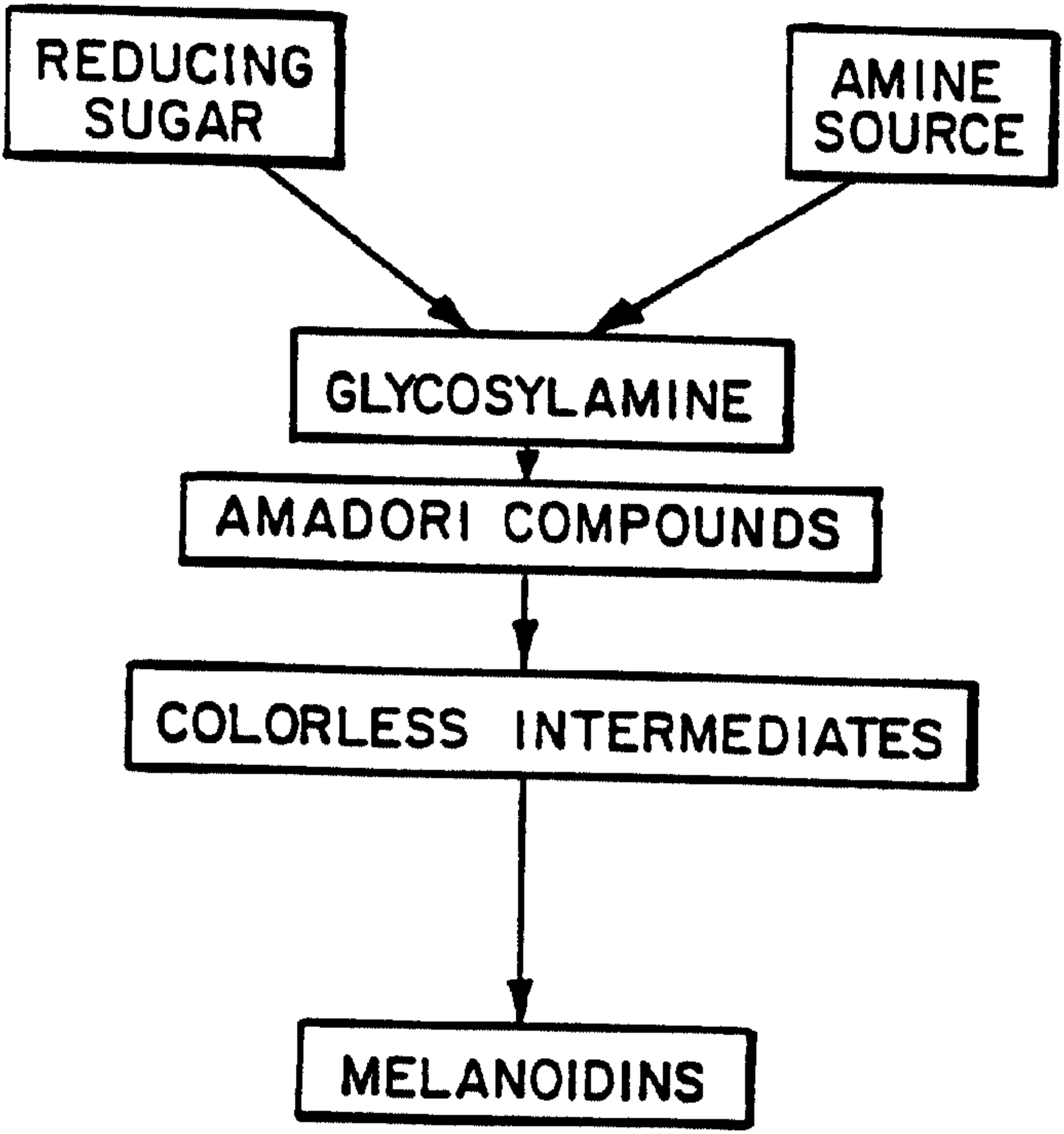

DE VALUE OVER STORAGE TIME
PRE-MICROWAVE SAMPLES
TEMP = 70° F
DE
20
15
10
5
0
C
P
0
2
4
6
8
DAYS

Fig. 27


REDUCING SUGAR
AMINE SOURCE
GLYCOSYLAMINE
AMADORI COMPOUNDS
COLORLESS INTERMEDIATES
MELANOIDINS