DISCRIMINATION METHOD AND APPARATUS THEREFOR

The present invention relates to a method of and apparatus for discriminating a specific substance or object from among a plurality of objects. More particularly, the present invention pertains to a discrimination method wherein objects for discrimination are irradiated with light and a specific substance or type of object is selected from among the objects on the basis of light having a specific wavelength among the various rays of light reflected from the objects. The present invention is also concerned with an apparatus which may be effectively employed in the above-described selection method.

In the case where the colour, reflectivity or the like of a specific substance among a mixed group of objects is different from that of the others in the group, it is general practice to employ a method of selecting the specific substance or type of object on the basis of the light reflected from the objects.

For example, the reflectivity of the shells of nuts is markedly different from that of their kernels in the near infrared region. So nuts, shell and kernel can be discriminated from each other on the basis of this difference in reflectivity. More specifically, in the case of almonds, for example, the shell generally reflects more light than the kernel in the near infrared region. Reflected light having a specific wavelength within the

near infrared region is therefore monitored, and when the quantity of reflected light with the specific wavelength exceeds a predetermined reference value, the object is judged to be a shell whereas, when the reflected light quantity is below the reference value, the object is judged to be a kernel, thus allowing selection to be effected.

Incidentally, the configurations of objects for selection are not uniform and therefore the quantity of reflected light depends on the direction in which each object is observed, which may affect the judgement upon which selection is based.

The observation section of a typical selection apparatus is arranged as exemplarily shown in Figure 1 of the accompanying drawings. Each object 2 which drops from a chute 1 is illuminated by illuminators 3 at an observation position P, and the light reflected from the object 2 is observed from a predetermined direction. As the object 2 drops, the observed surface changes as shown by the reference numerals i.e. (1) - (2) - (3). Since the configurations of objects are not uniform, as described above, while the observed surface changes as the object 2 drops, the quantity of the reflected light which is being monitored also changes. There are cases where, as a matter of course, although the object is a shell, the observed surface thereof reflects only a small quantity of light in the same manner as in the case of kernel. In the

conventional selection apparatus, selection is effected on the basis of the quantity of light reflected from a specific observed surface which is limited to a relatively narrow area. For this reason, the prior art involves a risk of erroneous selection.

In addition, objects for selection have a variety of sizes and this may also affect the judgement enabling selection. More specifically, in general, the larger the object, the greater is the quantity of reflected light; the smaller the size, the less reflected light there is. In the case of a small shell, therefore, the quantity of light reflected therefrom is small so that it may be impossible to distinguish it from a kernel. In the prior art selection apparatus, a uniform reference level is set and selection is effected on the basis of whether or not the reflected light quantity exceeds that reference level. There has therefore been a risk of erroneous selection with regard to objects of irregular size.

According to one aspect of the present invention, there is provided a method of discriminating between different objects including the steps of applying light to the objects while they pass an observation position, detecting light reflected from the object and having a particular wavelength or a range of wavelengths, and discriminating between the objects on the basis of an integrated value obtained by integrating the light reflected from the object during its transit of the observation position by means of an integrating circuit.

A second aspect of the invention provides apparatus for discriminating between different objects by applying light

to the objects while they pass an observation position, and detecting light of a particular wavelength or range of wavelengths reflected from the objects as they pass the observation position, the apparatus including an integrating circuit for calculating an integral of the light reflected from an object during its transit of the observation position, and judging means for discriminating between the objects on the basis of the final result of the integration value output by said integrating circuit after said object has passed said observation position.

More specifically, while each object for selection is passing the observation position, an electrical signal is formed from the reflected light using a signal converter and is integrated by the integration circuit to obtain a quantity representing the amount of light reflected from the entire observed surface, and selection is effected on the basis of the overall reflected light quantity. Thus, it is possible to effect selection independently of variations in the reflected light quantity due to changes in the observed surfaces.

Preferably, with the first and second aspects of the present invention each of various kinds of light of said different wavelength is converted into the electrical signal using respective signal converters, the electrical signal being integrated by said integrating circuit to form said integrated value.

Thus, the reflection characteristics of each object for selection are obtained from the two or more different kinds of reflected light respectively having specific wavelengths, and selection is effected on the basis of those reflection

characteristics. Accordingly, it is possible to effect selection independently of relative changes in the reflected light quantity due to variations in the size of objects for selection.

According to a further aspect, the present invention provides a method of discriminating between different objects including the steps of applying light to the objects while they pass an observation position, detecting light of at least two different wavelengths reflected from the objects, obtaining for each wavelength one integral of the light reflected from each object during its transit of the observation position, obtaining reflection characteristics of said object with respect to each different wavelength of light on the basis of the final results of integration after said object has passed said observation position, and discriminating between the objects on the basis of the reflection characteristics.

A fourth aspect of the present invention provides apparatus for discriminating between different objects by applying light to the objects while they pass an observation position, and detecting light reflected from the objects, the apparatus including means for detecting light of at least two different wavelengths reflected from the objects, an integrating circuit for calculating for each wavelength an integral of the light reflected during its transit of the observation position, means for measuring for each object reflection characteristics at two different wavelengths on the basis of the final result of integration after the object has passed the observation position, and judging means for discriminating between the objects on the basis of the measurements.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiment thereof, taken in conjunction with the accompanying drawings, in which like reference numerals denote like elements, and of which:

Fig. 1 is a block diagram showing changes in the observed surface of an object for selection as it drops from a chute;

Fig. 2 is a block diagram schematically showing the arrangement of the selection apparatus according to the present invention;

Fig. 3 is a graph showing the respective values of reflectivity of the shell, mesocarp and kernel of almonds;

Fig. 4 shows one example of a combinational logic circuit which may be employed in the selection apparatus shown in Fig. 2 to remove the shell and mesocarp of almonds;

Fig. 5 shows one example of a combinational logic circuit which may be employed in the selection apparatus shown in Fig. 2 to select the kernel of almonds;

Fig. 6 is a block diagram showing a specific embodiment of the selection apparatus according to the present invention;

Fig. 7 is a perspective view showing the arrangement of the background box employed in the selection apparatus shown in Fig. 6;

Fig. 8 is a block diagram showing a specific arrangement of the spectroscope employed in the selection apparatus shown in Fig. 6; and

Fig. 9 is a timing chart used to describe the operation of the selection apparatus shown in Fig. 6.

One embodiment of the present invention will be described hereinunder more specifically with reference to the accompanying drawings.

Prior to describing the embodiment, the basic idea of the present invention will be explained for the purpose of facilitating understanding.

Fig. 3 is a graph showing the respective values of reflectivity of the shell A, mesocarp B and kernel C of almonds in the near infrared region.

Considering the reflections of the shell A, mesocarp B and kernel C at three different wavelengths, namely 1000 nm, 1200 nm and 1450 nm, which can be designated respectively as: Ax, Ay, Az; Bx, By, Bz; and Cx, Cy, Cz, it will be clear from the graph that the following conditions hold:

$$Ax/Ay<Bx/By \quad \ldots (1)$$

$$Ax/Ay<Cx/Cy \quad \ldots (2)$$

Thus, there is a value kl which satisfies the following conditions:

$$Ax/Ay<kl<Bx/By \quad \ldots (3)$$

$$Ax/Ay<kl<Cx/Cy \quad \ldots (4)$$

As will be clear from the graph, the following conditions also hold:

$$Ay/Az<By/Bz \quad \ldots (5)$$

$$Cy/Cz<By/Bz \quad \ldots (6)$$

So there is a value k2 which satisfies the following conditions:

$$Ay/Az<k2<By/Bz \quad \ldots (7)$$

$$Cy/Cz<k2<By/Bz \quad \ldots (8)$$

Assuming that the values of reflectivity with respect to the three different specific wavelengths of 1,000 nm, 1,200 nm and 1,450 nm which are detected for a certain object for selection (irrespective of whether it is shell, mesocarp or kernel) are x, y and z, respectively, the object is identified as shell, mesocarp or kernel on the basis of the above conditions 3, 4, 7 and 8. More specifically, if the following conditions are satisfied:

$$x/y<k1 \text{ and } y/z<k2 \quad \ldots (9)$$

then the object is a shell. If the following conditions are satisfied:

$$k1<x/y \text{ and } k2<y/z \quad \ldots(10)$$

then the object is mesocarp covered. If the following conditions are satisfied:

$$k1<x/y \text{ and } y/z<k2 \quad \ldots(11)$$

then the object is a kernel.

Referring next to Fig. 2, which is a block diagram schematically showing the function of the present invention, the illustrated apparatus is arranged to remove the shell and mesocarp from almonds as objects 2 for selection or to select kernel from among the objects 2. The light reflected from an object 2 for selection at an observation position P is

received by a spectroscope 10. The spectroscope 10 separates the rays of reflected light of the above-described three different wavelengths, i.e., 1,000 nm, 1,200 nm and 1,450 nm, and converts them into electrical signals x', y' and z', respectively, before supplying them to respective integrators 11, 12 and 13. The integrators 11, 12 and 13 integrate the respective electric signals supplied from the spectroscope 10 while the object 2 is passing the observation position P. After the object 2 has passed the observation position P, the integrators 11, 12 and 13 output and supply the respective final integration results x, y and z to comparators 14 and 15. In this case, the integration result x is supplied to the comparator 14, the integration result y to both the comparators 14 and 15, and the integration result z to the comparator 15.

The above-described value k1 is set in the comparator 14 in advance. k1 is a value which is experimentally obtained in advance so as to satisfy both the above-described conditions (3) and (4). On receipt of the integration results x and y, the comparator 14 obtains a ratio of x to y, i.e., x/y, and compares the ratio x/y with the value k1 to check the size relationship therebetween. The comparator 14 ouputs logic signal v in accordance with the result of the size comparison: if x/y<k1, v="0" is output, whereas, if x/y>k1, v="1" is output.

The above-described value k2 is set in the comparator 15 in advance. k2 is a value which is experimentally obtained in advance so as to satisfy both the above-described conditions (7) and (8). On receipt of the

integration results y and z, the comparator 15 obtains a ratio of y to z, i.e., y/z, and compares the ratio y/z with the value k2 to check the size relationship therebetween. The comparator 15 ouputs logic signal w in accordance with the result of the size comparison: if y/z<k2, w="0" is output, whereas, if y/z>k2, w="1" is output.

The logic signals v and w are supplied to a combinational logic circuit 16 which outputs either a removal signal for removing shell and mesocarp or a signal for selecting kernel on the basis of the logic signals v and w.

Fig. 4 shows the arrangement of a combinational logic circuit 16 that outputs a removal signal for removing shell and mesocarp. This circuit outputs a removal signal when v="0" or w="1", that is, when the above-described condition (9) or (10) is satisfied. On the other hand, Fig. 5 shows the arrangement of a combinational logic circuit 16 that outputs a signal for selecting kernel. This circuit outputs a kernel selecting signal when v="1" and w="0", that is, when the above-described condition (11) is satisfied. Selection of either one of the two different types of logic circuit, i.e., the one shown in Fig. 4 and the other one shown in Fig. 5, may be appropriately determinedd according to the particular objective.

In the illustrated apparatus, while the object 2 of selection is passing the observation position 0, the electrical signals output from the spectroscope 10 are integrated to obtain a quantity representing the amount of light reflected from the entire observed surface and the object 2 is distinguished on the basis of the overall

quantity of reflected light. Thus, it is possible to effect selection independently of variations in the quantity of reflected light that are caused by changes in the observed surface. More specifically, since one object shows variations in the quantity of reflected light for each surface observed, it is impossible to judge whether it is a kernel simply by examining one surface. However, if all the quantities of light reflected from various observed surfaces are integrated, the final result of integration reflects the nature of the object for selection and therefore differs in accordance with the kind of object. Since in the apparatus of the present invention the discrimination is made on the basis of the final result of integration, the discrimination accuracy is considerably high.

In the apparatus of the present invention, the electric signals x, y and z which respectively correspond to three different kinds of reflected light respectively having specific wavelengths are divided into two pairs, i.e., (x, y) and (y, z), and value representing the ratio between one electric signal and the other, that is, the ratio between the light quantities of the corresponding reflected rays, is obtained for each pair, and then the kind of object is identified on the basis of the obtained ratio.

Objects for selection are various in size and, as a matter of course, the larger the size, the larger the quantity of reflected light; the smaller the size, the less light is reflected. For this reason, if the kind of object for selection is judged on the basis of an absolute value representing the quantity of reflected light, there is

a risk of erroneous selection. However, it is possible to ascertain the reflection characteristics of each individual object by obtaining a value representing the ratio between the quantities of each pair of reflected rays having specific wavelengths which are adjacent to each other among the three different kinds of reflected light, as described above. Thus, it is possible to identify each individual object from its reflection characteristics without the need to make a comparison with an absolute value as in the case of the prior art, and it is hence possible to effect selection independently of relative changes in the quantity of reflected light due to variations in the size of objects for selection.

Referring next to Fig. 6, which is a block diagram showing the arrangement of one embodiment of the selection apparatus according to the present invention, the reference numeral 100 denotes objects for selection, more specifically, almonds in this case. The reference numeral 100a denotes the kernel of almonds, while the numeral 100b denotes the mesocarp and shell of almonds. These objects 100 for selection drop from a chute (not shown) and pass an observation position P. The observation position P is illuminated by means of a plurality of illuminators 101, for example, halogen lamps or tungsten-filament lamps, which are provided at both the upstream and downstream side of the observation position P.

A background box 102 is installed at the rear of the observation position P. A specific arrangement of the background box 102 is shown in Fig. 7. More specifically, a window 102a is formed in the front of the background box 102

and the interior of the box 102 is arranged to absorb light. Accordingly, light which enters the background box 102 through the window 102a is absorbed in the interior of the background box 102 and no light comes out of it. As a result, the window 102a, from which no light escapes, looks black when viewed from the outside. In other words, when the observation position P is viewed with the window 102a in the background, it is possible to solely observe the light reflected from an object 100 passing the observation position P. When no object 100 is present at the observation position P, only the pitch-black background is seen.

In front of the observation position P, a lens 103, a slit 104 and a spectroscope 105 are provided forwardly in the mentioned order on the extension of a line which intersects the window 102a of the background box 102 and the observation position P. The lens 103 focuses on the slit 104 the light reflected from an object 100 passing the observation position P. The slit 104 allows only the central portion of the light supplied from the lens 103 to pass. More specifically, the slit 104 limits the observation position P to an area the background of which consists only of the window 102a of the background box 102 and permits passage of light within that limited area only. As a result, when an object 100 passes the observation position P, only the light reflected from the object 100 passes through the slit 104 to enter the spectroscope 105. When no object 100 is present at the observation position P, since no light escapes from the window 102a which constitutes the background, no

light passes through the slit 104 and hence no light enters the spectroscope 105.

A specific arrangement of the spectroscope 105 is shown in Fig. 8. The spectroscope 105 separates the incident light into two or more different kinds of light respectively having specific wavelengths which are to be subjected to discrimination. The spectroscope 105 further selects rays of light having different wavelengths from among the separated light and converts each light ray into an electric signal corresponding to the intensity thereof. Accordingly, the spectroscope 105 has a number of beam splitters 106, filters 107 and sensors 108 which number is equal to the number of different kinds of light respectively having specific wavelengths which are to be subjected to discrimination. In this embodiment, the number of specific wavelengths which are to be subjected to discrimination is n. In the present invention, the number n of specific wavelengths is determined as follows. By observing a certain number of light rays having different wavelengths among the rays of light which are reflected simultaneously, a value representing the ratio between these light rays is obtained to thereby eliminate the difference in intensity of the reflected light between individual objects, that is, objects for selection. As is known, two values are needed to obtain a ratio. Accordingly, to discriminate, for example, two different kinds of object from one other, it is necessary to detect at least two different kinds of light and obtain the ratio between the two. Three or four different kinds of light may, of course, be detected if desired. If three or

four different kinds of light are employed and a plurality of ratios are obtained for predetermined combinations, the degree of detection accuracy may be expected to increase.

To discriminate three different substances A, B and C, it is only necessary to detect at least two different kinds of light having different wavelengths for the combination (A, B) and at least two different kinds of light having different wavelengths for the combination (B, C). In this case, light having a specific wavelength which is to be subjected to detection may be employed in both groups. In this way, the value for n is determined.

As shown in Fig. 8, the spectroscope 105 has a window 105a formed in its rear face, so that the light passing through the slit 104 enters the spectroscope 105 through the window 105a. The beam splitters 106-1 n are disposed within the spectroscope 105 along the path L of the light entering it. Each beam splitter 106 passes one part of the light and reflects the other part thereof perpendicular to the light path L. The light reflected from the beam splitter 106 is supplied to each of the filters 107-1 n which are provided in correspondence with the beam splitters 106-1 n. Each filter only allows the corresponding light having a specific wavelength to pass among those which are to be subjected to discrimination. The light passing through the filter 107 is received by each of the light-receiving elements 108-1 n which are similarly provided in correspondence with the beam splitters 106-1 n, and the received light is converted into an electrical signal in each of the light-receiving elements 108-1 n. As a result, when an object 100 for selection

passes the observation position P, the spectroscope 105 outputs analog signals s1, s2 ... sn which represent the respective intensities of a plurality of kinds of light having different specific wavelengths which are to be subjected to discrimination. When no object 100 is present at the observation position P, the above-described signals are at the zero level because no light escapes from the window 102a.

The electrical signals s1, s2 ... sn output from the spectroscope 105 are amplified in amplifiers 109-1 n and then supplied to integrators 111-1 n through resistors 110-1 n, respectively.

Each integrator 111 comprises an operational amplifier 112 which functions as a principal component and a capacitor 114 which is interposed between the output terminal and the inverting input terminal of the operational amplifier 112. The integrator 111 also has a switch 114 which is interposed parallel with the capacitor 114, the switch 114 turning on/off in accordance with the output state of an OR gate 115. In this case, the switch 114 is arranged such that, when the output of the OR gate 115 is "1", the switch 114 turns off to open the two ends of the capacitor 113, whereas, when the output of the OR gate 115 is "0", the switch 114 turns on to short the ends of the capacitor 113. Accordingly, when the switch 114 is off, the integrator 111 functions as an integrator, that is, integrates the corresponding signal s1, s2 ... sn amplified by the amplifier 109, whereas, when the switch 114 is on, the integrator 111 does not function as an integrator but holds the output at the zero level.

The output of the amplifier 109-n is supplied not only to the corresponding integrator 111-n but also to a first input terminal of a comparator 117 for detection of the passage of an object 100. The comparator 117 is supplied at its second input terminal with a reference voltage v0 which is set so as to be slightly higher than the level of a signal which is output from the amplifier 109-n when the signal output from the spectroscope 105 is at the zero level, that is, when no object 100 is present at the observation position P. Accordingly, the comparator 117 continuously supplies a passage detecting signal of the logic level "1" to both a first input terminal of the OR gate 115 and a monostable multivibrator 118 while the output of the amplifier 109-n is in excess of the reference voltage v0, that is, while an object 100 is passing the observation position P and, hence, the signal sn is being output from the spectroscope 105. When no object 100 is present at the observation position P, the output of the comparator 117 is held at the "0" level.

The monostable multivibrator 118 outputs and supplies a pulse signal to both a second input terminal of the OR gate 115 and a first input terminal of an AND gate 119 at the same time as the output of the comparator 117 falls. Accordingly, the output of the OR gate 115 is "1" during the sum of the period of time when an object 100 is passing the observation position P and the duration of the pulse which is subsequently output from the monostable multivibrator 118. While the output of the OR gate 115 is "1", the integrators 111-1 n integrate with respect to time the respective signals s1, s2 ... sn and supply the

integration results S1, S2 ... Sn to a signal selecting circuit 116.

The signal selecting circuit 116 selects a pair of integration signals corresponding to each pair of adjacent reflected rays of light having specific wavelengths, with one integration signal being permitted to belong to two integration signal pairs which are adjacent to each other, and the circuit 116 outputs and supplies each pair of integration signals to the corresponding signal ratio comparison circuit 120. More specifically, the signal selecting circuit 116 generates and supplies n-1 pairs of integration signals (S1, S2), (S2, S3), (S3, S4) ... (Sn-2, Sn-1) and (Sn-1, Sn) to the corresponding signal ratio comparison circuits 120-1 to 120-n-1.

A total number of n-1 signal ratio comparison circuits 120-1 to 120-n-1 are provided in correspondence with the above-described signal pairs. Each signal ratio comparison circuit 120 compares the ratio of one integration result to the other in the corresponding pair of integration results with a preset constant. More specifically, each signal ratio comparison circuit 120 comprises a variable gain amplifier 121, an adder 122 and a comparator 123. The variable gain amplifier 121 amplifies one integration result and supplies the amplified signal to the adder 122. The adder 122 subtracts the other integration result from the amplified signal and supplies the result of the subtraction to the non-inverting input terminal of the comparator 123, the inverting input terminal thereof being grounded, so that, when the result of the subtraction carried out by the adder 122 is

plus, a logic signal "1" is output from the comparator 123, whereas, when the result of the subtraction is minus, a logic signal "0" is output from the comparator 123. The operation of the signal ratio comparing circuit 120 will be further explained with the pair of integration results (S1, S2) taken as an example. The integration result S1 is supplied to the variable gain amplifier 121 where it is amplified k times and then supplied to the adder 122. The adder 122 subtracts the integration result S2 from the amplified integration result kS1 and supplies the result of the subtraction to the non-inverting input terminal of the comparator 123. More specifically, the integration result S1 is amplified by the variable gain amplifier 121 as follows:

$$k \times S1 = kS1 \quad \ldots(12)$$

The integration result S2 is subtracted from the amplified integration result kS1 as follows:

$$kS1 - S2 \quad \ldots(13)$$

Judgement is then, made by the comparator 123 as to whether the result of the subtraction is plus or minus. When the following condition is satisfied:

$$kS1 - S2 > 0 \quad \ldots(14)$$

i.e.,

$$k > S2/S1 \quad \ldots(15)$$

a logic signal "1" is output from the comparator 123. On the other hand, when the following condition is satisfied:

$$kS1 - S2 < 0 \quad \ldots(16)$$

i.e.,

$$k < S2/S1 \quad \ldots(17)$$

a logic signal "0" is output from the comparator 123. The amplification factor k of the variable gain amplifier 121 is equivalent to the constants k1 and k2 shown in the aforementioned expressions 3, 4, 7 and 8. The factor k is experimentally obtained in advance so as to satisfy predetermined conditions (conditions which are equivalent to 3 and 4, or 7 and 8).

The comparator 123 of each signal ratio comparison circuit 120 supplies the result of the comparison to a combinational logic circuit 124. The combinational logic circuit 124 is a TTL circuit such as that shown in Fig. 4 or 5. The combinational logic circuit 124 is arranged such that, when a shell or mesocarp passes the observation position P, the circuit 124 outputs a logic signal "1", whereas, when a kernel passes the observation position P, the circuit 124 outputs a logic signal "0". The logic signal output from the combinational logic circuit 124 is supplied to a second input terminal of the AND gate 119.

The first input terminal of the AND gate 119 is supplied with the output of the monostable multivibrator 118, as described above. Accordingly, the output of the combinational logic circuit 124 is gated and output from the AND gate 119 in accordance with the output of the monostable multivibrator 118.

The output of the AND gate 119 is supplied to a monostable multivibrator 125 which extends the width of the pulse output from the AND gate 119 for the time required to remove shell or mesocarp and supplies the signal to a delay circuit 126. The delay circuit 126 delays the signal output

from the monostable multivibrator 125 for a period of time stating at the instant a dropping object 100 passes the observation position P until the moment it reaches the removal position Q, and the circuit 126 supplies the delayed signal to a drive circuit 127. When supplied with the signal from the delay circuit 126, the drive circuit 127 supplies an ejector drive signal to an ejector 128 for a period of time which corresponds to the pulse width of the signal supplied from the circuit 126. The ejector 128 is installed at the above-described removal position Q. When supplied with the ejector drive signal from the drive circuit 127, the ejector 128 blows compressed air on an object 100 passing that position to blow it away.

The following is a description of the operation of the selection apparatus having the foregoing arrangement.

As shown in Fig. 6, objects 100 for selection which are discharged from the chute (not shown) pass the observation position P and then reach the removal position Q. The objects 100 are a mixture of kernels 100a and others 100b including shell- and mesocarp-covered almonds.

The observation position P is illuminated by the illuminators 101, so that, when each object 100 passes the observation position P, the light reflected from the object 100 enters the spectroscope 105 through the lens 103 and the slit 104. It should be noted that, when no object 100 is present at the observation position P, no light enters the spectroscope 105 because no light escapes from the window 102a of the background box 102.

The light entering the spectroscope 105 is split into a plurality of light rays having different wavelengths by means of the corresponding beam splitters and these light rays are supplied to the respective filters 107 provided in correspondence with the beam splitters 106. In the filters 107, light rays having different wavelengths which are to be subjected to discrimination are taken out and supplied to the sensors 108 provided in correspondence with the filters 107. In the sensors 108, the light rays that have passed through the corresponding filters 107 are converted into electrical signals s1, s2 ... sn which are then supplied to the corresponding amplifiers 109. In the amplifiers 109, the supplied signals are amplified and then supplied to the corresponding integrators 11.

Fig. 9 is a timing chart used to describe the operation of the selection apparatus shown in Fig. 6. As shown in Fig. 9(a), the amplifiers 109 amplify and output electrical signals s1, s2 ... sn for a period of time t1 from the time T1 when the lower end of an object 100 reaches the observation position P until the time T2 when the upper end of the object 100 has passed the observation position P. The electrical signal sn is supplied to the passage detecting comparator 117, so that, while the electrical signal sn is above the reference voltage v0, that is, during a period of time which is substantially equal to the period t1 from the time T1 to T2, a passage detecting signal such as that shown in Fig. 9(b) is output. In response to the output of this passage detecting signal, the output of the OR gate 115 is set to "1", so that the switch 114 in each integrator 111

turns off. As a result, integration of the output of the amplifier 109 is commenced in each integrator 111. More specifically, as shown in Fig. 9(e), integration of the electrical signals s1, s2 ... sn is commenced from the time T1 and the integration results S1, S2 ... Sn, which increase gradually, are output from the respective integrators 111.

At the time T2, at which time the upper end of the object 100 has passed the observation position 0, the electrical signals s1, s2 ... sn are lowered to the zero level, thus completing the integration with respect to time. In response to the fall of the output of the passage detecting comparator 117 at the time T2, the output of the monostable multivibrator 118 rises, and a pulse signal with a pulse width t2 is output from the monostable multivibrator 118. Thus, even after the output of the comparator 117 has fallen, the output of the OR gate 115 is held in the state "1" for the period of time t2, that is, from the time T2 to the time T3, so that each integrator 111 continuously functions as an integrator during the period from the time T1 to the time T3. As a result, during the period from the time T2 to the time T3, the respective outputs of the integrators 111 are constantly held at the values S1, S2 ... Sn obtained as the final results of integration. Then, at the time T3, the output of the OR gate 115 is lowered to "0" and the respective outputs of the integrators 111 are also lowered to the zero level.

During the period from the time T1 to the time T3, the integration signals S1, S2 ... Sn are supplied to the signal selecting circuit 116 where a pair of integration signals corresponding to each pair of reflected rays having specific

wavelengths which are adjacent to each other are selected, with one integration signal being permitted to belong to two integration signal pairs which are adjacent to each other, and n-1 pairs of integration signals (S1, S2), (S2, S3), (S3, S4) ... (Sn-2, Sn-1) and (Sn-1, Sn) are output to the corresponding signal ratio comparison circuits 120.

In each signal ratio comparison circuit 120, one integration signal is multiplied by a value k which is experimentally obtained in advance in the variable gain amplifier 121. Then, the other integration signal is subtracted from the result of the multiplication in the adder 122, and the result of the subtraction is supplied to the non-inverting input terminal of the comparator 123. Judgement is made in the comparator 123, as to whether the result of the calculation carried out in the adder 122 is plus or minus, and when the calculation result is plus, a logic signal "1" is output from the comparator 123, whereas, when the result is minus, a logic signal "0" is output from the comparator 123. The logic signal output from the comparator 123 is supplied to the combinational logic circuit 124.

In the combinational logic circuit 124, the object 100 is judged on the basis of the outputs of the signal ratio comparison circuits 120, and the result of this judgement is supplied to the AND gate 119. When the object 100 is judged to be a kernel, the output of the combinational logic circuit 124 is "0", whereas when the object 100 is judged to be shell or mesocarp, the output of the circuit 124 is "1". Since the configurations of the observed surfaces of objects 100 are not uniform, as described above, there is a risk of erroneous

selection if an object 100 is identified on the basis of the light reflected from a part of the observed surface. The output of the combinational logic circuit 124 therefore lacks reliability before completion of the integration of the ray reflected from the entire observed surface.

More specifically, during the period from the time T1 to the time T2, the signal ratio comparison circuits 120 and the combinational logic circuit 124 are operating on the basis of the unstable values S1, S2 ... Sn which increase with the passage of time and therefore the output of the combinational logic circuit 124 during this period cannot be relied upon.

As shown in Figs. 9(f) and 9(g), during the period from the time T2 to the time T3, the signal ratio comparison circuits 120 and the combinational logic circuit 124 are operating on the basis of stable values which are obtained as the final results of integration and it is therefore possible to rely on the output of the combinational logic circuit 124 during this period.

The output of the combinational logic circuit 124 is gated at the AND gate 119 by the output of the monostable multivibrator 118 which is "1" during the period from the time T2 to the time T3, so that only a reliable result of judgement is taken out and supplied to the monostable multivibrator 125.

When the object 100 is judged to be a shell or mesocarp-covered almond, the output of the AND gate 119 is "1" during the period from the time T2 to the time T3 and this output is held for the period t3 by the monostable

multivibrator 125, as shown in Fig. 9(h). The output of the monostable multivibrator 125 is delayed in the delay circuit 126 and then supplied to the drive circuit 127. As a result, when the shell or mesocarp-covered almond reaches the removal position Q, air is blown against it from the ejector 128 and the shell or mesocarp is thereby removed.

When the object 100 is judged to be a kernel, the output of the AND gate 119 is "0" during the period from the time T2 to the time T3. Accordingly, no air is blown from the ejector 128 and the kernel is therefore allowed to pass the removal position Q and received in a receptacle (not shown).

C L A I M S

1. A method of discriminating between different objects including the steps of applying light to the objects while they pass an observation position, detecting light reflected from the object and having a particular wavelength or a range of wavelengths, and discriminating between the objects on the basis of an integrated value obtained by integrating the light reflected from the object during its transit of the observation position by means of an integrating circuit.

2. A method according to claim 1, wherein the reflected light is converted into an electrical signal by a signal converter, the electrical signal being integrated by said integrating circuit to form said integrated value.

3. A method according to claim 1, wherein reflected kinds of light having two or more different wavelengths or ranges of wavelengths are detected.

4. A method according to claim 3, wherein each of the kinds of reflected light of said different wavelength is converted into the electrical signal using respective signal converters, the electrical signal being integrated by said integrating circuit to form said integrated value.

5. A method according to claim 4, wherein the integrated values are divided into pairs of electrical signals, a value is calculated representing the ratio between one electric signal and the other for each pair of electrical signals; and the obtained ratio is compared with a preset value to thereby obtain reflection characteristics of said object with respect to said two or more different wavelengths of light.

* C L M S *

6. Apparatus for discriminating between different objects by applying light to the objects while they pass an observation position, and detecting light of a particular wavelength or range of wavelengths reflected from the objects as they pass the observation position, the apparatus including an integrating circuit for calculating an integral of the light reflected from an object during its transit of the observation position, and judging means for discriminating between the objects on the basis of the final result of the integration value output by said integrating circuit after said object has passed said observation position.

7. Apparatus according to claim 6, wherein the reflected light is converted into an electrical signal by a signal converter, the electrical signal being integrated by said integrating circuit to form said integrated value.

8. Apparatus according to claim 6, wherein reflected kinds of light having two or more different wavelengths are detected and each of the lights is converted into the electrical signal using respective signal converter.

9. Apparatus according to claim 8, further including: dividing means for dividing the integrated values respectively output from said integrating circuits into pairs of electrical signals; comparison means provided for obtaining a value representing the ratio between the two electrical signals for each pair of electrical signals and comparing the obtained ratio with a preset value to thereby obtain reflection characteristics of said object with respect to said two or more different wavelengths of light; and judging means for discriminating the objects on the basis of the result of the

comparison made by said comparing means.

10. A discriminating apparatus according to claim 9, wherein said comparing means includes multiplying means for multiplying one of said pair of electrical signals by said set value, subtracting means for subtracting the other of said pair of electrical signals from the result of the multiplication carried out by said multiplying means, and comparison means for judging whether the result of the subtraction carried out by said subtracting means is plus or minus.

11. A method of discriminating between different objects including the steps of applying light to the objects while they pass an observation position, detecting light of at least two different wavelengths reflected from the objects, obtaining for each wavelength one signal representative of the light reflected, using an integrating circuit to integrate said signals to obtain integrals of the light reflected from each object during its transit of the observation position, obtaining reflection characteristics of said object with respect to each different wavelength of light on the basis of the final results of integration after said object has passed said observation position, and discriminating between the objects on the basis of the reflection characteristics.

12. Apparatus for discriminating between different objects by applying light to the objects while they pass an observation position, and detecting light reflected from the objects, the apparatus including means for detecting light of at least two different wavelengths reflected from the objects, an integrating circuit for calculating for each wavelength an integral of the light reflected during its transit of the

observation position, means for measuring for each object reflection characteristics at two different wavelengths on the basis of the final result of integration after the object has passed the observation position, and judging means for discriminating between the objects on the basis of the measurements.

13. A method according to claim 11 or apparatus according to claim 12, wherein the light reflected at each wavelength is converted into a respective electrical signal and the electrical signal is integrated over the said transit to form the integral.

14. Apparatus for discriminating between different objects constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

15. A method of discriminating between different objects substantially as hereinbefore described with reference to the accompanying drawings.

16. Apparatus for sorting or selecting objects, including discriminating apparatus according to any one of claims 6 to 10, 12 and 14.