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Method for producing compressed body of powder

Abstract

Provided is a method for producing a compressed body of a powder capable of improving a hardness while suppressing a decrease in production efficiency of the compressed body of the powder. A compressed body **14** of a powder is compression molded by compressing a powder supplied into die holes **18** by a lower punch **31** and an upper punch **32**. In the compression molding, a first compression and a second compression following the first compression are performed. In the first compression, the compression is performed at a first compression speed, and in the second compression, the compression is performed at a second compression speed that is lower than the first compression speed.

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Background/Summary

TECHNICAL FIELD

(1) The present invention relates to a method for producing a compressed body of a powder.

BACKGROUND ART

(2) As a compressed body of a powder, a solid milk obtained by compression molding a powdered milk is known (PTL 1). This solid milk is required to have such solubility that it quickly dissolves when placed in warm water. At the same time, transportation suitability, that is, a hardness that prevents breakage such as cracking or collapse from occurring during transportation or carrying, is also required. The solubility of the solid milk can be enhanced by increasing a porosity thereof, but an increase in porosity causes a decrease in hardness. Thus, from viewpoints of solubility and transportation suitability, an optimal porosity has been set. Incidentally, “porosity” means a proportion of the volume occupied by pores in the bulk volume of a powder.

(3) As a tablet press for compression molding a powder including a powdered milk, a rotary tablet press is known (for example, see PTL 2). In addition, a tablet press in which a slide plate having two die hole positions is horizontally reciprocated (see PTL 3) is known. In the tablet press of PTL 3, two discharge zones are provided with a compression molding zone interposed therebetween, and the slide plate reciprocates between a first position where one die hole position is set in the compression molding zone and the other die hole position is set in one discharge zone and a second position where the other die hole position is set in the compression molding zone and one die part is set in the other discharge zone, such that a lower punch and an upper punch are allowed to enter each of a plurality of die holes of the die hole position set in the compression molding zone to compression mold a powder, and a compressed body of the powder obtained by compression molding the powder is extruded from each of the plurality of die holes of the die hole position set in the discharge zone.

CITATION LIST

Patent Literature

(4) PTL 1: WO 2006/004190

(5) PTL 2: JP-A-2000-95674

(6) PTL 3: JP-A-2007-307592

SUMMARY OF THE INVENTION

Technical Problem

(7) In the compressed body of the powder, in a case where the same porosity (which corresponds to compression pressure) is maintained, the higher the compression speed, the lower the hardness. Therefore, in order to increase the hardness of the compressed body of the powder while maintaining a porosity, it is considered to be useful to reduce the compression speed. However, there has been a problem in that the compression of a powder at a reduced compression speed leads to a decrease in the production rate of a compressed body of the powder, resulting in poor production efficiency.

(8) The present invention has been accomplished against the above background, and an object thereof is to provide a method for producing a compressed body of a powder capable of improving hardness while reducing decrease in production efficiency of the compressed body of the powder.

Solution to Problem

(9) A method for producing a compressed body of a powder of the present invention is a method for producing a compressed body of a powder having a solid form obtained by compression molding a powder, the method including a first compression step of compressing the powder at a first compression speed; and a second compression step of compressing the compressed body of the powder compressed in the first compression step at a second compression speed that is lower than

the first compression speed until the compressed body of the powder has a final thickness in a predetermined compression state corresponding to a target thickness of the compressed body of the powder from a state of being compressed in the first compression step.
Advantageous Effects of the Invention
(10) According to the present invention, since the second compression is performed at the second compression speed that is lower than the first compression speed following the first compression performed at the first compression speed, the hardness of the compressed body of the powder can be improved and the decrease in production efficiency of the compressed body of the powder can be reduced as compared to a case where compression is only performed at the first compression speed.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is an explanatory view illustrating a configuration of a tablet press.
(2) FIG. **2** is an explanatory view describing a first compression distance of a first compression and a second compression distance of a second compression.
(3) FIG. **3** is a graph showing a relationship between a compression speed ratio and a hardness ratio of the compressed body of the powder.
DESCRIPTION OF EMBODIMENTS
(4) In FIG. **1**, a tablet press **10** according to an embodiment is provided with a compression molding zone **12**, and removal zones **13***a* and **13***b* on both sides of the compression molding zone **12**. The compression molding zone **12** is a zone in which a powder is compression molded into a compressed body **14** of the powder having a solid form (hereinafter, simply referred to as a compressed body). Each of the removal zones **13***a* and **13***b* is a zone in which the compressed body **14** compression molded in the compression molding zone **12** is removed to a recovery tray **15**. FIG. **1** schematically illustrates a configuration of the tablet press **10**.
(5) For example, a powdered milk is used as the powder, and a solid milk as the compressed body **14** is compression molded by the tablet press **10**. The tablet press **10** and the compression molding technique are also useful in a case where the compressed body **14** is produced from a powder other than the powdered milk. The powder is not particularly limited, but examples thereof can include an inorganic compound such as a metal, a catalyst, or a surfactant, an organic compound such as sugar, powdered oil, or protein, and a mixture thereof. In addition, the compressed body **14** to be produced is not particularly limited, but a compressed body as a food or a pharmaceutical, a compressed body as an industrial product, or the like can be used.
(6) In the tablet press **10**, a slide plate **17** is provided so as to be slidable in a horizontal direction (left and right direction in the drawing). The slide plate **17** has a first die part **17***a* provided on one end side (left side in the drawing) in a sliding direction of the slide plate **17** and a second die part **17***b* provided on the other end side (right side in the drawing). In each of the first die part **17***a* and the second die part **17***b*, a plurality of die holes **18** penetrating the slide plate **17** in a thickness direction (vertical direction) are arranged in a matrix form.
(7) As illustrated in the drawing, the slide plate **17** is slid by a slide mechanism (not illustrated) to a first slide position where the first die part **17***a* and the second die part **17***b* are set in the compression molding zone **12** and the removal zone **13***b*, respectively, and a second slide position where the second die part **17***b* and the first die part **17***a* are set in the compression molding zone **12** and the removal zone **13***a*, respectively.
(8) In the compression molding zone **12**, a lower punch part **21** is arranged below the slide plate **17** and an upper punch part **22** is arranged above the slide plate **17**. In addition, extrusion parts **24***a* and **24***b* are respectively arranged in the removal zones **13***a* and **13***b* above the slide plate **17**. The

lower punch part **21** is vertically moved by an actuator **26**. The upper punch part **22** and the extrusion parts **24***a* and **24***b* are connected by a connecting member so as to be integrally and vertically moved by an actuator **27**.

(9) The lower punch part **21** is provided with a plurality of lower punches **31** at an upper portion thereof, and the upper punch part **22** is provided with a plurality of upper punches **32** at a lower portion thereof. The lower punches **31** and the upper punches **32** are arranged in a matrix form corresponding to a plurality of die holes **18** of the die parts. Therefore, the lower punches **31** and the upper punches **32** are respectively fitted and inserted into the die holes **18** of any one of the first die part **17***a* and the second die part **17***b* set in the compression molding zone **12**. As described later, in the die hole **18**, the powder is compression molded into the compressed body **14** between an upper end face of the fitted and inserted lower punch **31** and a lower end face of the fitted and inserted upper punch **32**.

(10) Each of the actuators **26** and **27** is, for example, a servomotor whose drive is controlled by a controller **34** so as to allow the lower punch part **21** and the upper punch part **22** to be vertically moved. In this example, a speed of the servomotor as each of the actuators **26** and **27** is changed to change a compression speed at the time of compression molding, that is, a moving speed of each of the lower punch **31** and the upper punch **32**, as described later in detail. Each of the actuators **26** and **27** is not limited to a servomotor, and the technique to change the moving speeds of the lower punch part **21** and the upper punch part **22** is not limited thereto. For example, it is also possible to use an oil hydraulic cylinder or the like. In addition, in this example, at the time of compression molding, both the lower punch **31** and the upper punch **32** are moved in a direction to approach each other, or it is also possible that one side is fixed and only the other side is moved.

(11) The tablet press **10** is provided with a funnel **36** supplying the powder to the die holes **18**. The funnel **36** is arranged so that a bottom face thereof is close to an upper face of the slide plate **17**. The bottom face of the funnel **36** is provided with a silt-shaped bottom opening extending in a width direction (a direction orthogonal to the sliding direction) of the slide plate **17**. The funnel **36** reciprocates above the die part set in the compression molding zone **12** prior to compression molding by the lower punch **31** and the upper punch **32**. During the reciprocation, the powder is supplied from a hopper (not illustrated) in the funnel **36**, such that a certain amount of the powder is supplied into the die holes **18** through the bottom opening. As described above, the funnel **36** constitutes a powder supply part together with the hopper. At the time of compression molding, the funnel **36** is moved to a position not interfering with the descending upper punch part **22** and the extrusion parts **24***a* and **24***b*. Incidentally, when the powder is supplied into the die holes **18**, the lower punch **31** is fitted and inserted into the die holes **18**. In addition, the bottom face of the funnel **36** may slide on the upper face of the slide plate **17**.

(12) A plurality of extrusion members **38** are provided below each of the extrusion parts **24***a* and **24***b*. Similarly to the upper punch **32**, the extrusion members **38** of the extrusion parts **24***a* and **24***b* are arranged in a matrix form corresponding to each of the plurality of die holes **18** of the die part. In a state where the slide plate **17** is moved to the first slide position, the extrusion member **38** of the extrusion part **24***b* is inserted into the die hole **18** of the second die part **17***b*, and in a state where the slide plate **17** is moved to the second slide position, the extrusion member **38** of the extrusion part **24***a* is inserted into the die hole **18** of the first die part **17***a*. Therefore, the compressed body **14** compression molded from the die holes **18** by the extrusion member **38** is extruded and removed to the recovery tray **15**.

(13) A shape of the compressed body **14** produced by the tablet press **10** is not particularly limited. Examples of the shape of the compressed body **14** can include a disk shape, a lens shape, a cube shape, and a shape in which a concave portion or a convex portion is provided on a surface of a cube.

(14) A compression molding procedure of the compressed body **14** by the tablet press **10** is as follows. The slide plate **17** is moved to, for example, the first slide position. After the movement of

the slide plate **17**, the actuator **26** is driven to allow the lower punch part **21** to ascend, each of the lower punches **31** is inserted into the die hole **18** corresponding to the first die part **17***a*, and the lower punch part **21** is stopped in a state where the bottom of the die hole **18** is blocked. Thereafter, the funnel **36** reciprocates so as to be moved from one end of the first die part **17***a* to the other end (in this example, a left end from a right end) of the first die part **17***a* and then return to the one end. Then, the powder is supplied to the funnel **36** at this time, such that a certain amount of the powder is supplied into the die holes **18** through the bottom opening of the funnel **36**.
(15) Subsequently, the actuator **27** is driven to allow the upper punch part **22** and the extrusion parts **24***a* and **24***b* to descend. Therefore, each of the upper punches **32** of the upper punch part **22** is fitted and inserted into each of the die holes **18** of the first die part **17***a*. Thereafter, the upper punch part **22** continues to descend, and the lower punch part **21** starts to ascend again. Therefore, in each of the die holes **18**, the powder is compressed between the upper end face of the lower punch **31** and the lower end face of the upper punch **32**. At the time of the compression, the compression speed at which the upper end face of the lower punch **31** and the lower end face of the upper punch **32** approach to each other is changed (switched). That is, a first compression is first performed at a first compression speed V.sub.1, and, following the first compression, a second compression is performed at a second compression speed V.sub.2. In the tablet press **10**, the second compression speed V.sub.2 is lower than the first compression speed V.sub.1.
(16) The powder is compressed by the lower punch **31** and the upper punch **32** to form the compressed body **14**. When the compression by the lower punch **31** and the upper punch **32** is released, a thickness (length in the vertical direction) of the compressed body **14** expands more than in a compressed state. Therefore, in the tablet press **10**, a distance between the upper end face of the lower punch **31** and the lower end face of the upper punch **32** at the time of completion of the compression, that is, a final thickness of the compressed body **14** in a state where the compression is maintained is determined based on a target thickness of the compressed body **14** that is a final molded body in a state where the compression is released (hereinafter, referred to as a target thickness) in consideration of the expansion of the compressed body **14** when the compression is released.
(17) After the completion of the compression, the lower punch part **21** descends and the upper punch part **22** ascends to pull out each of the lower punches **31** and each of the upper punches **32** from the die holes **18**. At this time, the compressed body **14** remains in the die holes **18**.
(18) Next, the slide plate **17** is moved to the second slide position from the first slide position, and the second die part **17***b* is set in the compression molding zone **12**. In the compression molding zone **12**, the compressed body **14** is compression molded from the powder in each of the die holes **18** using the second die part **17***b* in the same procedure as in the compression molding of the powder using the first die part **17***a*.
(19) On the other hand, the slide plate **17** is moved to the second slide position, such that the first die part **17***a* is set in the removal zone **13***a* together with the compressed body **14** in the die holes **18**. Since the extrusion parts **24***a* and **24***b* descend integrally with the upper punch part **22**, when the compressed body **14** is compression molded using the second die part **17***b* as described above, the extrusion member **38** is inserted into each of the die holes **18** of the first die part **17***a*. Therefore, the compressed body **14** in each of the die holes **18** of the first die part **17***a* is extruded onto the recovery tray **15** from the die holes **18** by the extrusion member **38**. The recovery tray **15** is moved after the compressed body **14** is extruded, and a new recovery tray **15** is set in the removal zone **13***a*.
(20) As described above, when the compression molding using the second die part **17***b* and the removal of the compressed body **14** from the first die part **17***a* are completed, the slide plate **17** is moved to the first slide position. After the movement, according to the same procedure as described above, the compression molding using the first die part **17***a* is performed, and the compressed body **14** is also extruded onto the recovery tray **15** from each of the die holes **18** of the second die part

17*b* set in the removal zone **13***b*.

(21) Thereafter, similarly, the slide plate **17** is moved alternatively between the first slide position and the second slide position, and the compression molding of the powder in the compression molding zone **12** and the removal of the compressed body **14** in the removal zone **13***a* or the removal zone **13***b* are performed.

(22) As described above, in the tablet press **10**, first, the first compression is performed at the first compression speed V.sub.1 and the second compression is performed at the second compression speed V.sub.2. In this example, as illustrated in FIG. **2**(A), the compression distances of the first compression and the second compression are based on the state at the time of the completion of the second compression, that is, at the time of the completion of the entire compression steps. Compression by the lower punch **31** and the upper punch **32** is performed until the punch distance between the upper end face of the lower punch **31** and the lower end face of the upper punch **32** reach the final punch distance L. The final punch distance L is the final thickness of the compressed body **14** in the state of being compressed through the entire compression steps. The final punch distance L is determined in consideration of expansion of the compressed body **14** when the compression is released as described above, and is smaller than the target thickness of the compressed body **14**.

(23) FIG. **2**(B) illustrates a state at the time of the start of the second compression, that is, at the time of the end of the first compression, and FIG. **2**(C) illustrates a state at the time of the start of the first compression. Compression from the state of the punch distance illustrated in FIG. **2**(C) (L+L.sub.1+L.sub.2) to the state of the punch distance illustrated in FIG. **2**(B) (L+L.sub.2) is the first compression. In addition, compression from the state of the punch distance illustrated in FIG. **2**(B) (L+L.sub.2) to the state of the final punch distance L illustrated in FIG. **2**(A) is the second compression.

(24) The first compression distance of the first compression is the distance L.sub.1 that the punch distance decreases in the first compression. The second compression distance of the second compression is the distance L.sub.2 that the punch distance decreases in the second compression. Since the second compression is performed following the first compression without releasing the compression, the second compression distance L.sub.2 is the compression distance from the state where the compressed body **14** is compressed in the first compression to the final thickness (L).

(25) The rate of change in the punch distance in the first compression is the first compression speed V.sub.1, and the rate of change in the punch distance in the second compression is the second compression speed V.sub.2. Incidentally, in a case where the rate of change in the punch distance varies during the first compression or the second compression, the average rate is defined as the first compression speed V.sub.1 or the second compression speed V.sub.2.

(26) When the second compression is performed after the first compression at the second compression speed V.sub.2 that is lower than the first compression speed V.sub.1, as compared with a case where the compression is performed at the same compression speed as the first compression speed V.sub.1 with the same compression distance (L.sub.1+L.sub.2), a hardness of the compressed body **14** can be increased. Moreover, since the second compression is performed continuously to the first compression and the second compression distance L.sub.2 can be shortened, the second compression is performed at the second compression speed V.sub.2 that is lower than the first compression speed V.sub.1, and thus, an increase in compression time is small. Therefore, a decrease in production rate of the compressed body **14** is small.

(27) In this example, in order to efficiently enhance the hardness of the compressed body **14**, the mode of the second compression, that is, the combination of the second compression speed V.sub.2 with the second compression distance L.sub.2, is determined in such a manner to satisfy the second compression conditions under which, upon the compression of the compressed body **14** from the state of being compressed in the first compression, the compressed body **14** is compressed to such a state that the rate of change in the hardness of the compressed body **14** relative to the compression

distance decreases.
(28) The inventors have examined compressed bodies obtained from various combinations of the first compression speed V.sub.1, the first compression distance L.sub.1, the second compression speed V.sub.2, and the second compression distance L.sub.2. As a result, they have found that when the second compression speed V.sub.2 is set to be lower than the first compression speed V.sub.1, there exists a specific point at which the rate of change in the hardness of a compressed body (increase rate) relative to change in the second compression distance L.sub.2 decreases (hereinafter, referred to as “hardness specific point”). In addition, the inventors have also found that the second compression distance L.sub.2 corresponding to the hardness specific point changes with the first compression speed V.sub.1 and is also affected by the second compression speed V.sub.2.
(29) The hardness specific point exists presumably because of the change from a compression state where the rearrangement of particles of the powder in the inner part of the compressed body is dominant to another compression state where plastic deformation in the inner part of the compressed body is dominant. In addition, presumably, because an increase in the first compression speed V.sub.1 increases the energy required for plastic deformation in the inner part of the compressed body, the second compression distance L.sub.2 corresponding to the hardness specific point changes according to the first compression speed V.sub.1, and also such a second compression distance L.sub.2 is affected by the second compression speed V.sub.2.
(30) Based on the above findings, the second compression is performed so as to satisfy the second compression conditions, whereby the hardness of the compressed body **14** is efficiently and significantly improved while suppressing an increase in the compression time. Incidentally, the change of the compression state of the compressed body as described above occurs in various powders described above, and thus, it is useful to perform the second compression so as to satisfy the second compression conditions when the compressed body is compression molded from various powders.
(31) It is also preferable that the compression speed ratio (=V.sub.1/V.sub.2), which is the ratio of the first compression speed V.sub.1 to the second compression speed V.sub.2, is set to 5 or more. When the compression speed ratio is set to 5 or more, the hardness of the compressed body **14** can be significantly increased.
(32) The configuration of the tablet press **10** described above is an example, and the configuration is not limited as long as compression can be performed at different compression speeds between the first compression and the second compression. In addition, although compression to the final thickness is performed in the second compression in this example, it is also possible to perform further compression at a rate changed from the second compression speed following the second compression. In this case, the compressed body **14** is compressed to the final thickness by the compression later than the second compression.
EXAMPLES
(33) Experiments 1 to 110 for compression molding the compressed bodies **14** were performed in various combinations of the first compression speed V.sub.1, the first compression distance L.sub.1, the second compression speed V.sub.2, and the second compression distance L.sub.2 to evaluate the hardness of each of the compressed bodies **14** produced in Experiments 1 to 110. The first compression speed V.sub.1 was set to 1 mm/sec, 10 mm/sec, or 100 mm/sec, the first compression distance L.sub.1 was set to 5 mm or 10 mm, the second compression speed V.sub.2 was set to 0.25 mm/sec, 1 mm/sec, 2 mm/sec, 10 mm/sec, or 50 mm/sec, and the second compression distance L.sub.2 was set to 0.2 mm, 0.4 mm, 0.8 mm, or 1.6 mm. In each of Experiments 1 to 110, in addition to the example in which the second compression speed V.sub.2 is lower than the first compression speed V.sub.1, an example in which the first compression speed V.sub.1 and the second compression speed V.sub.2 are equal to each other and an example in which the second compression speed V.sub.2 is higher than the first compression speed V.sub.1 are included. In addition, the production conditions of each of the compressed bodies **14** were equal to

each other, except that the first compression speeds V.sub.1, the first compression distances L.sub.1, the second compression speeds V.sub.2 and the second compression distances L.sub.2 were different from each other.

(34) Combinations of the first compression speed V.sub.1, the first compression distance L.sub.1, the second compression speed V.sub.2, and the second compression distance L.sub.2 in each of Experiments 1 to 110 are shown in Table 1-1 to Table 1-3.

(35) TABLE-US-00001 TABLE 1-1 First compression Second compression First First Second Second compres- compres- compres- compres- Exper- sion sion sion sion iment distance L.sub.1 speed V.sub.1 distance L.sub.2 speed V.sub.2 Hardness No. [mm] [mm/s] [mm] [mm/s] evaluation 1 5 1 0.2 0.25 A 2 10 1 0.2 0.25 A 3 5 100 0.2 0.25 C 4 10 100 0.2 0.25 C 5 5 1 0.4 0.25 A 6 10 1 0.4 0.25 A 7 5 10 0.4 0.25 A 8 10 10 0.4 0.25 A 9 5 100 0.4 0.25 A 10 10 100 0.4 0.25 A 11 5 1 0.8 0.25 A 12 10 1 0.8 0.25 A 13 5 10 0.8 0.25 A 14 10 10 0.8 0.25 A 15 5 100 0.8 0.25 A 16 10 100 0.8 0.25 A 17 5 1 1.6 0.25 A 18 10 1 1.6 0.25 A 19 5 10 1.6 0.25 A 20 10 10 1.6 0.25 A 21 5 100 1.6 0.25 A 22 10 100 1.6 0.25 A 23 5 1 0.2 1 A 24 10 1 0.2 1 A 25 5 100 0.2 1 C 26 10 100 0.2 1 C 27 5 1 0.4 1 A 28 10 1 0.4 1 A 29 5 10 0.4 1 A 30 10 10 0.4 1 A 31 5 100 0.4 1 A 32 10 100 0.4 1 A 33 5 1 0.8 1 A 34 10 1 0.8 1 A 35 5 10 0.8 1 A 36 10 10 0.8 1 A 37 5 100 0.8 1 A 38 10 100 0.8 1 A 39 5 1 1.6 1 A 40 10 1 1.6 1 A

(36) TABLE-US-00002 TABLE 1-2 First compression Second compression First First Second Second compres- compres- compres- compres- Exper- sion sion sion sion iment distance L.sub.1 speed V.sub.1 distance L.sub.2 speed V.sub.2 Hardness No. [mm] [mm/s] [mm] [mm/s] evaluation 41 5 10 1.6 1 A 42 10 10 1.6 1 A 43 5 100 1.6 1 A 44 10 100 1.6 1 A 45 5 1 0.2 2 A 46 10 1 0.2 2 A 47 5 100 0.2 2 C 48 10 100 0.2 2 C 49 5 1 0.4 2 A 50 10 1 0.4 2 A 51 5 10 0.4 2 B 52 10 10 0.4 2 B 53 5 100 0.4 2 B 54 10 100 0.4 2 B 55 5 1 0.8 2 A 56 10 1 0.8 2 A 57 5 10 0.8 2 A 58 10 10 0.8 2 A 59 5 100 0.8 2 A 60 10 100 0.8 2 A 61 5 1 1.6 2 A 62 10 1 1.6 2 A 63 5 10 1.6 2 A 64 10 10 1.6 2 A 65 5 100 1.6 2 A 66 10 100 1.6 2 A 67 5 1 0.2 10 C 68 10 1 0.2 10 C 69 5 10 0.2 10 C 70 10 10 0.2 10 C 71 5 1 0.4 10 C 72 10 1 0.4 10 C 73 5 10 0.4 10 C 74 10 10 0.4 10 C 75 5 1 0.8 10 C 76 10 1 0.8 10 C 77 5 10 0.8 10 C 78 10 10 0.8 10 C 79 5 100 0.8 10 C 80 10 100 0.8 10 C

(37) TABLE-US-00003 TABLE 1-3 First compression Second compression First First Second Second compres- compres- compres- compres- Exper- sion sion sion sion iment distance L.sub.1 speed V.sub.1 distance L.sub.2 speed V.sub.2 No. [mm] [mm/s] [mm] [mm/s] Hardness 81 5 1 1.6 10 C 82 10 1 1.6 10 C 83 5 10 1.6 10 C 84 10 10 1.6 10 C 85 5 100 1.6 10 C 86 10 100 1.6 10 C 87 5 1 0.2 50 D 88 10 1 0.2 50 D 89 5 10 0.2 50 D 90 10 10 0.2 50 D 91 5 100 0.2 50 D 92 10 100 0.2 50 D 93 5 1 0.4 50 D 94 10 1 0.4 50 D 95 5 10 0.4 50 D 96 10 10 0.4 50 D 97 5 100 0.4 50 D 98 10 100 0.4 50 D 99 5 1 0.8 50 D 100 10 1 0.8 50 D 101 5 10 0.8 50 D 102 10 10 0.8 50 D 103 5 100 0.8 50 D 104 10 100 0.8 50 D 105 5 1 1.6 50 D 106 10 1 1.6 50 D 107 5 10 1.6 50 D 108 10 10 1.6 50 D 109 5 100 1.6 50 D 110 10 100 1.6 50 D

(38) A powdered milk was used as a powder used for a material of the compressed body **14**. As for the composition of the powdered milk, 11.1 g/100 g of proteins, 57.7 g/100 g of carbohydrates, and 26.1 g/100 g of lipids were used. In addition, the powdered milk used in the compression molding was obtained by mixing a powdered milk and granules thereof, a size (particle diameter) of the powdered milk was about 5 μm to 150 μm, and a size of the granule of the powdered milk was about 100 μm to 500 μm.

(39) Similarly to the tablet press **10**, the powdered milk was compression molded between the lower punch and the upper punch in the die holes to produce the compressed body **14**. In each of Experiments 1 to 110, 2.0 g of the powdered milk was compression molded into the compressed body **14**. The shape of the compressed body **14** was a disk shape having a diameter of 20 mm and a thickness (target thickness) of 9.5 mm. The compression molding was performed by setting the final punch distance L (final thickness) to 8.4 mm with respect to the target thickness (9.5 mm).

(40) In addition, as Reference Experiments R1 to R6, compressed bodies (hereinafter, reference compressed bodies) obtained by compression molding without changing the compression speed

during the compression were produced. The compression speed V.sub.0 and the compression distance L.sub.0 in each of Reference Experiments R1 to R6 are shown in Table 2. Incidentally, other production conditions of the reference compressed body are the same as those of the compressed body **14**.
(41) TABLE-US-00004 TABLE 2 Compression Compression Experiment distance speed Hardness No. L.sub.0 [mm] V.sub.0 [mm/s] evaluation R1 5 1 A R2 10 1 A R3 5 10 C R4 10 10 C R5 5 100 D R6 10 100 D
(42) Incidentally, in each of Reference Experiments R2, R4, and R6, the compression distance L.sub.0 is 10 mm, but the compression distance (punch distance) for substantially compressing the powder (powdered milk) is shorter than the compression distance L.sub.0. In addition, in each of Experiments 1 to 110, even though the first compression distance L.sub.1 is 10 mm, the compression distance (punch distance) for substantially compressing the powder (powdered milk) is shorter than the first compression distance L.sub.1. Therefore, the substantial total compression distance in each of Experiments 1 to 110 was evaluated to be equal to the substantial compression distance in each of Reference Experiments R2, R4, and R6.
(43) The hardness of the compressed body **14** produced in each of Experiments 1 to 110 was measured, the hardness of the compressed body **14** was compared with a hardness measured for the reference compressed body produced by compression molding performed so that the compression speed V.sub.0 and the first compression speed V.sub.1 were equal to each other and the compression distances were substantially equal to each other as described above. That is, the hardness of the compressed body **14** in each of Experiments 1, 2, 5, and 6 at which the first compression speed V.sub.1 was 1 mm/sec was compared with the hardness of the reference compressed body in Reference Experiment R2 at which the compression speed V.sub.0 was 1 mm/sec. Similarly, the hardness of the compressed body **14** in each of Experiments 7, 8, 13, and 14 at which the first compression speed V.sub.1 was 10 mm/sec was compared with the hardness of the reference compressed body in Reference Experiment R4 at which the compression speed V.sub.0 was 10 mm/sec, and the hardness of the compressed body **14** in each of Experiments 3, 4, 9, and 10 at which the first compression speed V.sub.1 was 100 mm/sec was compared with the hardness of the reference compressed body in Reference Experiment R6 at which the compression speed V.sub.0 was 100 mm/sec.
(44) In the comparison, the hardness of the compressed body **14** produced in each of Experiments 1 to 110 was higher than the hardness of the compared reference compressed body, the compressed body **14** being obtained by compression molding at the second compression speed V.sub.2 that was lower than the first compression speed V.sub.1. As a result, it can be seen that after the powder was compressed at the first compression speed, the compressed body **14** compressed in the first compression step at the second compression speed that was lower than the first compression speed was further compressed up to the final thickness of the compressed body **14**, such that the hardness of the compressed body **14** can be improved and the hardness of the compressed body **14** can be improved while suppressing the increase in time requiring for the compression molding.
(45) The hardness of the compressed body **14** produced in each of Experiments 1 to 110 was evaluated from the criteria such as breakage separately from the comparison of the hardness. The evaluation results are shown in the section of the hardness evaluation of each of Table 1-1 to Table 1-3. In addition, the evaluation results obtained by similarly evaluating the hardness of the compressed body produced in each of Reference Experiments R1 to R6 are shown in the section of the hardness evaluation of Table 2. The meanings of the evaluation results (A to D) in the evaluation section are as follows.
(46) A: Hard Even when an impact such as gripping by a hand or dropping from a height of about 5 cm is applied, cracking does not occur.
(47) B: Hard to some extent Allowable hardness at which cracking does not occur even when gripped by a hand or transported by a conveyer.

(48) C: Soft to some extent Cracking occurs when being gripped by a hand.
(49) D: Soft Cracking easily occurs when being gripped by a hand.
(50) In a case where the hardness evaluation was performed in four stages as described above, the hardness evaluation of the reference compressed body produced in Reference Experiment R4 in which the compression speed V.sub.0 was 10 mm/sec was “C”, but the hardness evaluation of the compressed body **14** in which the first compression speed V.sub.1 was 10 mm/sec corresponding thereto and the second compression speed V.sub.2 was lower than the first compression speed V.sub.1 was “A” or “B”, which showed that the hardness evaluation of the compressed body **14** was higher than those of the reference compressed bodies. In addition, the hardness evaluation of the compressed body produced in Reference Experiment R6 in which the compression speed V.sub.0 was 100 mm/sec was “D”, but the hardness evaluation of the compressed body **14** in which the first compression speed V.sub.1 was 100 mm/sec corresponding thereto and the second compression speed V.sub.2 was lower than the first compression speed V.sub.1 was “A” to “C”, which showed that the hardness evaluation of the compressed body **14** was higher than those of the reference compressed bodies. Incidentally, regardless of the change of the hardness evaluation is as described above, the fact that all of the hardnesses of the compressed bodies **14** are improved as compared to the compared reference compressed bodies is the same as described above, the compressed body **14** being obtained by compression molding at the second compression speed V.sub.2 that is lower than the first compression speed V.sub.1.
(51) Furthermore, the relationship between the compression speed ratio (=V.sub.1/V.sub.2) and the hardness ratio of the compressed body **14** produced in each of Experiments 1 to 110 was examined. The relationship between the compression speed ratio and the hardness ratio is illustrated in FIG. **3**. The hardness ratio was a ratio (=H/H.sub.0) of the hardness (H) of the compressed body **14** produced in each of Experiments 1 to 110 to the hardness (H.sub.0) of the reference compressed body at which the compression speed V.sub.0 and the first compression speed V.sub.1 were equal to each other and the substantial compression distances were equal to each other.
(52) It can be seen from the graph of FIG. **3** that when the compression speed ratio is “5” or more, a large hardness ratio, that is, a large increase in hardness is obtained. Therefore, it can be seen that the case where the compression speed ratio is set to “5” or more by setting the second compression speed V.sub.2 to be lower than the first compression speed V.sub.1 is useful for significantly increasing the hardness of the compressed body **14**.
REFERENCE SIGNS LIST
(53) **10**: Tablet press **14**: Compressed body of powder **18**: Die hole **31**: Lower punch **32**: Upper punch

Claims

1. A method for producing a compressed body of a powdered milk having a solid form obtained by compression molding the powdered milk, the method comprising: a first compression step of compressing the powdered milk at a first compression speed V.sub.1; and a second compression step of compressing the compressed body of the powdered milk compressed in the first compression step at a second compression speed V.sub.2 that is lower than the first compression speed until the compressed body of the powdered milk has a final thickness L in a predetermined compression state corresponding to a target thickness of the compressed body of the powdered milk from a state of being compressed in the first compression step, wherein a compression speed ratio V.sub.1/V.sub.2 is 5 or more; and the second compression step is performed following the first compression step without releasing a compression.
2. A method for producing a compressed body of a powdered milk having a solid form obtained by compression molding the powdered milk, the method comprising: a first compression step of compressing the powdered milk at a first compression speed V.sub.1; and a second compression

step of compressing the compressed body of the powdered milk compressed in the first compression step at a second compression speed V.sub.2 that is lower than the first compression speed until the compressed body of the powdered milk has a final thickness L in a predetermined compression state corresponding to a target thickness of the compressed body of the powdered milk from a state of L.sub.2+L being compressed in the first compression step, wherein in the second compression step, a combination of a compression distance L.sub.2 from the state L.sub.2+L of being compressed in the first compression step to the final thickness L and the second compression speed V.sub.2 is set so that the compressed body of the powdered milk is compressed to a hardness specific point at which a rate of change in a hardness of a compressed body relative to change in the compression distance L.sub.2 decreases.
3. The method for producing a compressed body of a powdered milk according to claim 2, wherein the second compression step is performed following the first compression step without releasing a compression.
