Study on Drying Processing Techniques for keeping the Quality of Soybeans

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Summary

The production of soybeans increases every year owing to the increase of demand for the domestic soybeans among the consumers in Japan and the rate of use of combine for harvesting soybeans increases because of a labor saving harvesting method. But, drying processing technique for the high moisture content soybeans harvested by combine has been retarded, and the degradation of soybeans and the heavy labor work in the process of drying become a problem. The efficient drying processing technique keeping the quality of soybeans harvested by combine, has been strongly required.

In the drying processing of high moisture content soybeans, there occurs the risk of swelling in soybeans when the air ventilation in the layers is not sufficient. The activity of microorganism or mold increases when the temperature of the air exceeds 80% humidity and over 20℃ temperature. It is necessary to adjust the temperature and humidity of the air ventilation to be out of this dangerous zone. In the meantime, it is necessary also to control the drying rate of soybeans so as to avoid the occurrence of the seed-coat cracking or the wrinkle of soybeans. To develop the effective artificial drying method keeping the quality of soybeans, the investigation on the physical properties of soybeans relating to the drying processing and the analysis of the drying process of soybeans are indispensable. However, the study has been retarded in comparison with the study of rice or wheat.

In this study, the fundamental properties of soybeans relating to the drying and the characteristics of the pressure loss in driers such as flat bed driers equipped with the bucket conveyer or dry stores were clarified and a drying simulation model for analyzing the process of drying was developed and investigated and the mechanism of the generation of coat cracking of soybeans and the effective treatment of the ventilation air to minimize the coat cracking were cleared. Through this study, the fundamental techniques for drying soybeans harvested by combine were developed.

In the first chapter, the significance and objectives of this study were described based on an outline of soybean production and studies on soybean drying...

In the second chapter, the dependence of physical properties as specific volume, bulk volume, rate of volume on moisture content of soybeans(tachinagaha, tamahomare, fukuyutaka, suzuyutaka, enrei

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variety) was theoretically considered and determined as follows with principal properties of specific volume of dry matter V_0, coefficient of rate of volume k of average soybeans.

$$V_m = V_0 + \gamma \cdot m = 0.771 + 0.965m \quad (0.1 < m), \quad V_m = (m^2 + 2V_{0c}m + V_0^2)^{1/2} \quad (0 < m)$$

$$V_m' = V_m/(1-\varepsilon) = 6V_m/k\pi, \quad k = 1.00 - 0.029m$$

values i.e m ; moisture content (d.b. decimal), V_m; specific volume based on dry material($10^{-3}m^3/kg$), V_m' ; specific bulk volume, $1-\varepsilon$; rate of kernel volume, $V_0 = 0.771(10^{-3}m^3/kg)$, $V_{0c} = 0.7460$ Hence, physical properties of soybean for a drying simulation model were shown with principal parameters of V_0, V_{0c}, k.

In the third chapter, the pressure loss of soybeans was examined and the data was analyzed using the non-dimensioned Navier-Stokes equations for forced air in accumulations. And resistance factors or friction factors of soybeans were expressed as the function of Reynolds number, to esteem a pressure loss in air forced layers of soybeans by calculation. We could get an experimental equation of resistance factor that was applied for generally to pressure loss of soybeans, in $40<Re<200$ ranges which is used with usual forced air drying. We could express characteristics of pressure loss of soybeans, as the function of space rate, ratio of surface area and velocity of air by using an experimental equations of the resistance factor or a friction factor. The characteristics of pressure loss of soybeans were able to be approximated with high accuracy.

In the forth chapter accuracy of a simulation model for drying soybeans that takes into account moisture transport in gas and solid phases under an inconstant condition of air flow was investigated. It was found that temperature, humidity of air passing through a deep bed of soybeans and the moisture contents of accumulation layers of soybeans using different soybeans and two different types of experimental dryer were able to be estimated correctly by using values of the fundamental drying properties such as density, specific surface area, space ratio, equilibrium moisture content of soybeans, and specific heat, and mass transfer coefficients of soybeans.

In the fifth chapter,seed-coat cracking of soybeans occurs easily during the process of air drying. In order to determine the relationship between external air temperature/humidity and distortions in seed-coat cracked grains, the rates of seed-coat cracking of soybeans subjected to mono-layer drying were investigated under various air drying conditions of different temperature and humidity combinations, and the critical distortions were estimated. Based on the results, the required temperature and humidity conditions of air passing through deep bed of soybeans for minimizing coat cracking and preventing swelling due to high air temperature were clarified.

に裂皮危険領域にある場合には，気温が下がり裂皮危険領域から自然に外れる夕刻に搬入するなどの方法が考えられる．実際には循環して通風側の表層付近の大豆が20分以上低湿の空気に触れるのを防いだり，間欠的に通風して裂皮や蒸れの発生を抑えながら穀温や内部の湿度の上昇を抑えるなどの方法で対処できる．水分が18％以下になると，平衡相対湿度は，ほぼ80％以下となるので，蒸れの危険も少なく，裂皮限界の平衡水分も下がり，高温・低湿の通風が可能となる．

6．まとめ

大豆の乾燥過程で種皮の収縮による歪み発生の原理を論究した上で，実際の恒温・恒湿条件下で調べた裂皮粒発生割合から種皮の限界歪みの分布を近似的に推定し，裂皮の発生回避に蒸れの発生要因も含めて，水分に対応する通風の適切な温・湿度範囲を提示した．

1）乾燥時の種皮の歪みεを，子実粒の平均水分M_v，種皮の水分M_sと線膨張係数λによって$\varepsilon=(1+\lambda M_v)/(1+\lambda M_s)-1$で表した．

2）上記のM_vを初期水分，M_sを外気に平衡する水分に置き換えて算出した歪みを指標として，裂皮粒発生割合との関係を調べた結果，種皮の裂皮限界の歪みは正規分布に近かった．

3）裂皮粒発生割合が10％と15.9％となる裂皮限界の歪みを水分の関数として推定し，水分の減少につれて小さくなることを確かめた．また，限界平衡水分を求め，これに平衡する通風の温・湿度で表した．さらに，裂皮粒発生割合が10％となる限界平衡水分曲線を単粒層で乾燥速度３％d.b./hとなる直線で表示した．

4）湿り空気線図上に水分を平衡相対湿度に変えて加え，裂皮や蒸れを回避しながら高い速度で乾減するための方法を例示した．

Ⅵ　摘　　要

1）大豆の乾燥制御のためのシミュレーションモデル作成のために，大豆の比容積，見かけ体積，空隙率など乾燥に影響する大豆固有の物性量について理論的考察を行い，これらを基本的な物性量（乾物比容積，充てん係数）と水分の関数として表した．さらに調査した５品種（タチナガハ，タマホマレ，フクユタカ，スズユタカ，エンレイ）の大豆に適合する以下の近似式を得た．

$$V_m=V_0+\gamma\cdot m=0.771+0.965m\quad(0.1<m)$$

$$V_m=(m^2+2V_{0c}\cdot m+V_0^2)^{1/2}\quad(0<m)$$

$$V_m'=V_m/(1-\varepsilon)=6V_m/k\pi$$

ただし，m (d.b. decimal), V_m；乾量基準の比容積($10^{-3}m^3/kg$)，V_m'；見かけ体積，ε；空隙率，$V_0=0.771(10^{-3}m^3/kg)$，$V_{0c}=0.746$，$k=1.00-0.029m$

以上の結果，乾燥シミュレーションに必要な物性値を少ない基本的定数で表すことができるようになった．

2）堆積通風乾燥における圧力損失を計算によって求めるため，材料の抗力係数と摩擦係数をレイノルズ数の関数として表し，通常の堆積通風乾燥で用いられる$40<R_e<200$の範囲において大豆において一般的に成立する実験式を求めた．これにより大豆の通風圧力損失特性を,得られた抗力係数，または摩擦係数の実験式を用いて材料の比表面積と堆積層の空隙率，風速の関数として表し，実際の測定結果と比較した結果，高い精度で圧力損失特性を近似することができた．

3）非定常な条件下での気相中の水分移動を考慮した大豆の通風乾燥シミュレーションモデルを作成し，大豆の真密度，体積比表面積，空隙率，平衡水分，材料比熱や移動係数などの基本的な物性定数を用いて，異なる材料や乾燥試験装置において大豆堆積厚層の水分や材料温度，通風空気の温・湿度変化を精度よく推定することができた．

4）大豆の乾燥過程で生じやすい種皮の裂皮について，外気の温・湿度と種皮における歪みとの関係を論究し，温・湿度の異なる条件下で単粒層の乾燥実験を行い，得られた裂皮粒発生割合から，裂皮発生時の歪みを近似的に推定した．これより，堆積した厚層乾燥での裂皮粒の発生が少なく，さらに蒸れを生じない通風の温・湿度条件を明らかにした．