KOREAN J. FOOD SCI. TECHNOL.
Vol. 9, *No.* 1 (1977)

Development of a Simultaneous Seed Separation and Drying Method of Red Pepper

Part I. Red Pepper Seed Separation Methods and Their Momentum Analysis

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(Received November 29, 1976)

고추의 同時脫種 乾燥方法의 開發에 관한 硏究

제 1 보 고추씨의 分離方法과 運動量의 分析

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(1976년 11월 29일 수리)

Abstract

Seed separation from half-cut red pepper were investigated with free falling, up-and-down shaking and rotating collision methods. The separation rates were related with impact applied and the rotating case was distinguished from the other two methods.

Beside the impact effect, velocity of the pod and tumbling factors were involved. Momentum effectiveness of seed separation were calculated as 2.50×10^{-6}, 2.09×10^{-6}, and 3.94×10^{-8} for free falling, shaking and rotating method on the same velocity basis, respectively. The tendency of separation rate was similar to that of red pepper drying rate against time.

Introduction

Red pepper seed is generally separated or discarded after the drying process step for grinding operation, though some households in this country favor to ground the whole seed-carrying pod for their own use. The amount of seed reached 10,000 M/T per year, equivalent to 10 to 12 per cent of whole pepper production,[1] and it is left without study of its effects on the pepper processing and economical use. In spite of the national important spice, the high cost of dry-

Abbreviation used in this report are as follows: A : Angle (degree), Emv : Momentum effectiveness of seed separation, F : Force, g : Gravitional acceleration (cm/sec^2), M : Actual mass (g), Mo : Initial mass (g), Ms : Seed weight (g), n : Vibration rate (reciprocal strokes/min), S : Distance (cm), t : Time (min), v : Velocity (cm/sec), v_1 : Terminal velocity (cm/sec), v_2 : Vibration velocity (cm/sec), v_3 : Resulting velocity of pepper in drum (cm/sec), v_F : Falling velocity of pepper in drum (cm/sec), v_P : Peripheral velocity of pepper in drum (cm/sec)

ing and the long drying time account for its little industrial application. Investigation on the cut-drying method[2], characteristics and its quality[3,4] showed drastic reduction in drying time and its possibility of application to pepper processing. In relation to the elimination of moisture contained in seed for quick drying, to an easy seed separation process prior to pepper grinding and to collect seed for an edible oil source, seed separation methods and impact involvement were studied and analyzed.

Material and Methods

1. Material

Fully mature red-pepper, *Capsicum annum* var. *longum*, was picked and cut transversely into two parts. The both parts of half-cut pod were used for the seed separation experiments.

2. Methods

The seed separation methods employed were a free falling, up-and-down reciprocal shaking and rotating principles causing an impact to the half-cut pod.

The apparatus were built as shown in Fig 1. and the methods wereas the followings:

(a) Free Falling

As shown in Fig. 1-a, 100 grams of half-cut sample were fallen from 30 to 200cm heights and repeated until the completion of the seed separation. The amount of seed separated upon each falling was weighed.

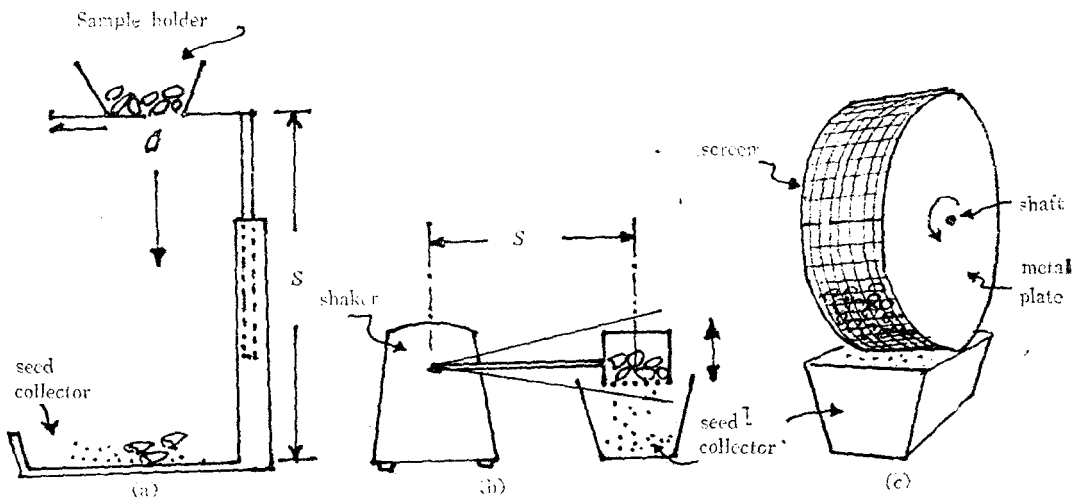

Fig. 1. Seed separation apparatus (a) free falling apparatus, (b) up-and-down reciprocal shaker with seed separater (c) screen-rotary seed separater

(b) Up-and-down Reciprocal Shaking Method

As shown in Fig 1-b, 300 grams of half-cut chili pod were put in sample holder, and shaken at a rate of 110 strokes per minute. The seed separated were weighed at the 10 minute intervals.

(c) Rotating Cylinder Method

A cylindrical rotating screen drum, dia. 44cm, height 20 cm with screen aperture 6mm, as shown in Fig. 1-c, was rotating at various speeds of 12 to 51 revolution per minute. One kg of half-cut pepper was loaded in the screen drum, while rotating seed separated through the screen was collected and weighed at the 10 minute intervals.

3. Analytical Method

Customarily red pepper seed was used to separated with a gentle lashing on dried half-cut pod. This indicates that a certain amount of external force is required to break the binding force of seed to placenta, a seed carrying botanical structure of red pepper. In this experiment, the external force can be supplied with impacts by means of free falling, up-and-down shaking and rotational collision against a stationary hard surface.

By Newton's law[5] the external force on a solid

particle results an impulse, which is equal to the change of momentum,

$$\text{Impulse} = \int_{t1}^{t_2} Fdt = (Mv)_2 - (Mv)_1 \qquad (1\text{-a})$$

where the subscripts 1 and 2 denote the values of mass and velocity at time t_1 and t_2 or before and after impact of pepper. But irregular shape of pepper makes impossible predict and measure the rebound direction and velocity, as is the case of Rugby football. For this reason impact of red pepper may be approximately calculated with the experimentally measurable values of mass and velocity of before impact, or

$$\text{Impact} = Mv \qquad (1\text{-b})$$

where velocity v can be obtained by the various methods as described previously in Method a, b and c, say; for free falling

$$v_1 = (2gS)^{1/2} \qquad (2)$$

for up-and-down reciprocal shaking, assuming that velocity of pepper is equal to that of shaker

$$v_2 = 2nS/60 \qquad (3)$$

for rotating v_3 is obtained by the parallelogram law[6]

$$v_3 = (v_P^2 + v_F^2 - 2v_P v_F \cos A)^{1/2} \qquad (4)$$

where v_P, v_F and angle A were calculated at point "a" as shown in Fig. 2.

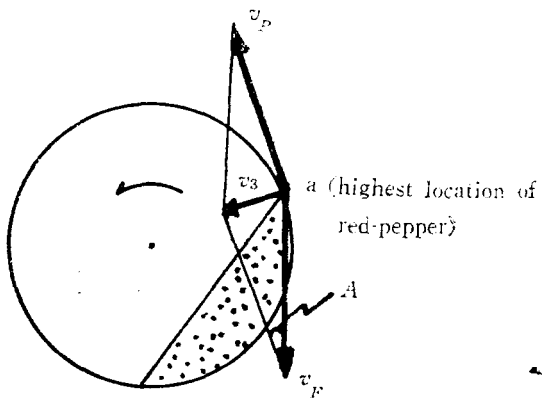

Fig. 2. Schematic representation of the motion of red-pepper in the rotating drum
v_3; resulting velocity

Now Eqn. (1−b) can be written,

$$Mv = \left(Mo - \sum Ms\right)v \qquad (5)$$

And momentum effectiveness of seed separation, *Emv*, may be defined as the actual momentum contributed for seed separation, among the total momentum transferred to the pepper pod, or

$$Emv = \frac{Ms}{\left(Mo - \sum Ms\right)v} \qquad (6)$$

So that, impact effects were analysed on their momentum effectiveness and the mechanism of seed separation of red pepper in this experiment.

Result and Discussion

All seed separation methods employed in this experiments were proved to be effective, but the separation could be characterized upon the method used.

1. Time course seed separation on the methods employed

The time course seed amount separated among the three methods was distinguished in its rate as shown in Fig. 3-a,b.c.

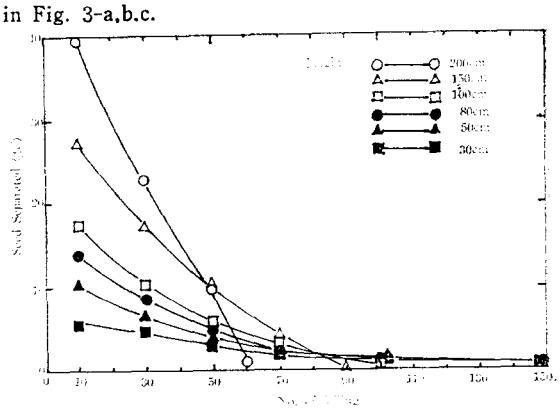

Fig. 3-a Free falling effects on seed separation

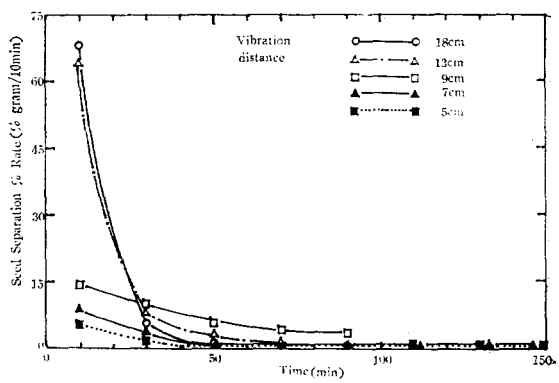

Fig. 3-b Time course seed separation by vibrational motion

In up-and-down shaking, most of seed was separated in the early stage and the rate was suddenly decreased thereafter as is the case in free falling. The result showed that a similar seed separation rate

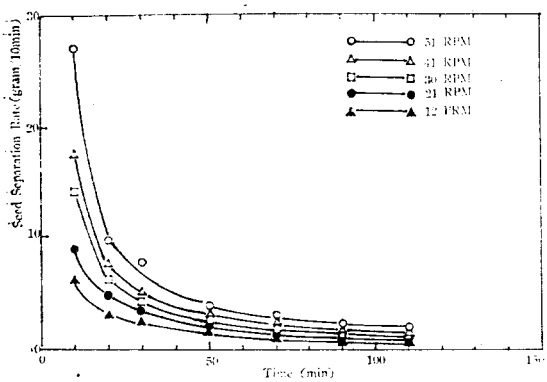

Fig. 3-c Time course seed separation by rotational motion

curve obtained and an enough distance should be prepared to achieve the separation in these systems. On the other hand in the rotating system, a steady decreasing rate of separation to some significent extent could be maintained after the initial high seed recovery. It represents that a progressive seed separation continues even in a low rotational speed, and the more regular separation can be obtained with an effective impact transfer through the shaft of the drum.

2. Effects of Velocity on Seed Separation

The next steps in our analysis were to study on the velocity factors of the different seed separation methods. Table 1 and Fig. 4-a illustrate the relationship between velocity and seed separation, and represent the easier seed recoveries at the higher velocities in the case of free falling method.

Table 1. Terminal or resulting velocities at various seed separation apparatus

Seed Separator	Distance (cm)	Revolution (rev/min)	Velocity (cm/sec)	Note
Free Falling	30		242.5	Eqn.2
	50		313.0	//
	80		396.0	//
	100		442.7	//
	150		542.2	//
	200		626.1*	//
Reciprocal Shaking	5		18.3	Eqn.3
	7		25.7	//
	9		33.0	//
	13		47.7	//
	18		66.0*	//
Rotating		12	216.8	Eqn.4
		21	208.5	//
		30	218.6	//
		41	235.6	//
		51	316.8*	//

* selected for momentum effectiveness of seed separation analysis

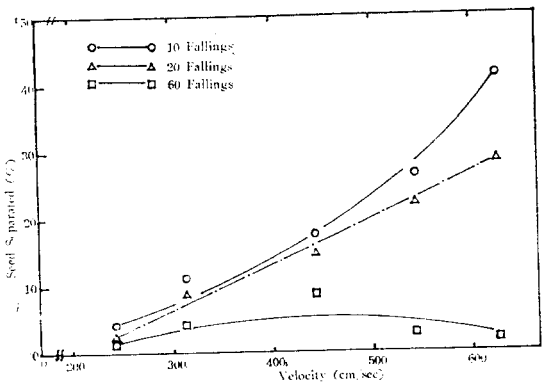

Fig. 4-a Velocity effects on seed separation with the no. of falling as parameters

And reciprocal shaking method shown in Fig. 4-b, shows the similar results with the free falling method. This fact means that it requires a minimum velocity

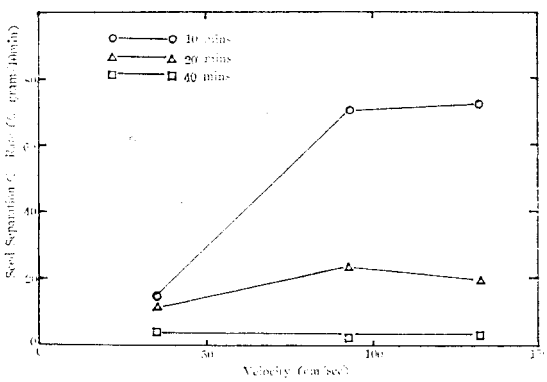

Fig. 4-b Velocity effects on seed separation

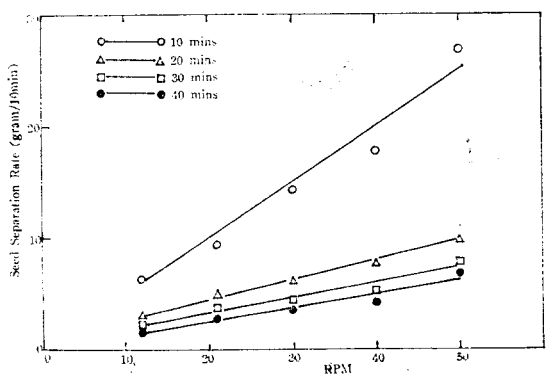

Fig. 4-c Rotation effects on seed separation with the operation time as parameters

to cause seed separation. The pod velocity calculated from the Eqn. (4) in a rotating drum affects the separation rates more uniformly as shown in Fig. 4-c. The results obtained for this analysis ensures the different velocity effects hold in various separating methods.

3. Momentum Effectiveness of Seeds Separation

Table 2. Analytical data

a) Time-course Seed Separations at 200 cm Falling Distance

N	ΣN	M^*	Ms	Mv x N x 10^3	Emv x10^{-7}**
10	10	100.00	3.84	626.1	61.3
10	20	96.16	2.62	602.1	43.5
10	30	93.54	1.47	585.7	25.1
10	40	92.07	0.64	576.5	11.1
10	50	91.43	0.34	572.4	6.0
10	60	91.09	0.17	570.3	3.0
		ΣMs	9.64	Ave. Emv 2.50×10^{-6}	

Note: Seed unseparated, 0.28
* refer to Eqn. 5, **Eqn. 6

b) Time-course Seed Separations at 18cm Reciprocal Distance

t	Σt	M^*	Ms	$2\times Mv\times 60t \times10^{6}$**	$Emv\times10^{-8}$***
10	10	300.00	21.01	23.8	88.5
10	20	278.99	5.28	22.1	23.8
10	30	273.71	1.73	21.7	8.0
10	40	271.98	0.70	21.5	3.2
10	50	271.28	0.40	21.5	1.8
10	60	270.88	0.10	21.5	0.2
		ΣMs 29.22		Ave. Emv 2.09×10^{-7}	

Note: Seed unseparated, 0.28
* refer to Eqn. 5, *** Eqn. 6
** since 2 impacts occur per reciprocal motion

c) Time-course Seed Separations at 51 Revolutional Speed

t	Σt	M^*	Ms	** $1/40\times Mv$ $1/40\times M\times60t\times10^5$	$Emv\times10^{-9}$***
10	10	1000.00	27.17	25.00	47.6	57.2
10	20	972.84	9.62	24.32	46.2	20.8
10	30	963.21	7.86	24.08	45.8	17.2
10	40	955.35	5.20	23.88	45.4	11.6
10	50	950.15	2.75	23.75	45.2	6.0
10	60	974.40	2.31	23.69	45.0	5.2
				Ave. Emv 1.97×10^{-8}		

Note: * refer to Eqn. 5, ***Eqn.6
** since 1/40 mass exist at the highest point

Since mementum, or impact, has been clearly understood to be involved in separation mechanism, momentum effecitiveness of seed separation will prepare some idea of a practical application.

A typical case was selected from each separation (on the similar velocity bases from Table 1), and analysed for their momentum effectiveness as shown in Table 2-a, b, c, and Fig. 5-a, b, c.

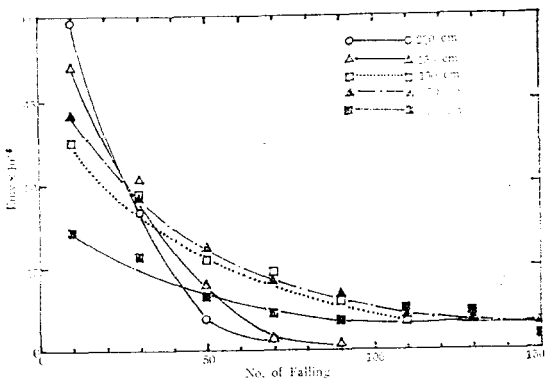

Fig. 5-a Seed separation coefficiency of momentum at various falling distances

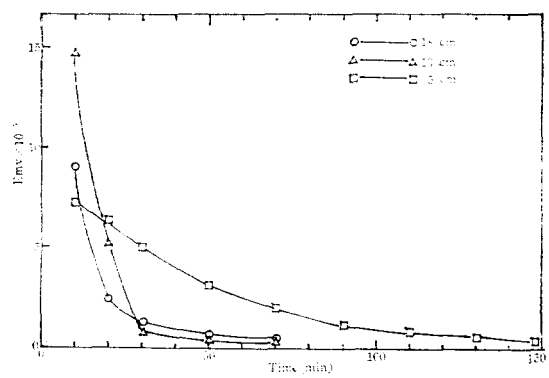

Fig. 5-b Seed separation coefficiency of momentum at various vibration distances

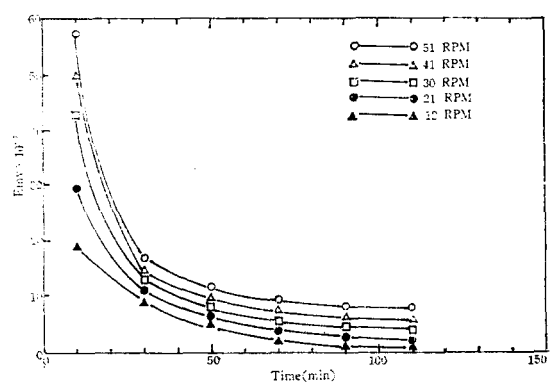

Fig. 5-c Seed separation coefficiency of momentum at various rotational speeds

In the cases of free falling and shaking, the average momentum effectiveness showed very close values, 2.50×10^{-6} and 2.09×10^{-6} respectively. These values together with other previous result of separation rate and velocity effect, strongly indicate that two methods are based on almost same principle.

On the other hand, rotating momentum effectiveness showed a lower value, 3.94×10^{-8}, which represents less momentum effectiveness compared with the above two cases. It may not be adequate to compare the rotating method with the other tow cases, because in rotating system many assumptions were taken for the analysis, for example, where velocity was taken that of highest point instead of average value and mass fraction was taken that of the pepper mass, in upper section as shown in Fig. 2, directly involved in motion, or 1/40, and so on. This discrepency in momentum effectiveness indicate that rotating separation mechanism is quite a distinguised one. However, in view point of application, rotating method was more practical in impact-transfer from shaft force to the botanical structure with the large amount of pepper loaded, and for material handling and seed collection. This means that more over-all momentum effectiveness can be attained with rotating separation, if we consider the momentum effectiveness with shaft force bases applied to the system and the application to drying system.

4. Effect of Cutting Location

Red pepper has a typical botanical structure which put a handicap for seed at inner conrer to escape out of pepper envelope after separation from placenta by impact force.So different locations were cut and seed separated were measured, as shown in Fig. 6, seed separation rates were remarkably different.

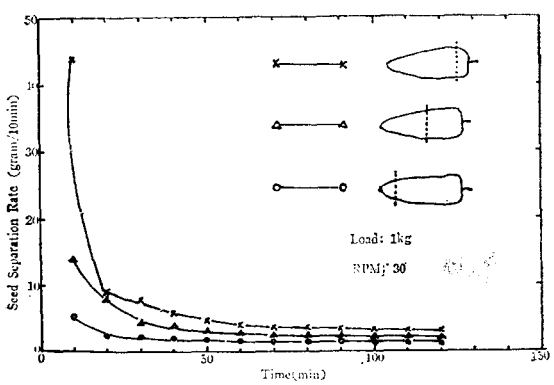

Fig. 6 Cutting orientation effect on seed separation

It is clearly understood that other factor, for instance tumbling factor, may be included to overcome the steric interferance. Better tumbling effects are more easyly obtained in rotating method, than in other two systems. The seed separation is coupled with drying, heat deformation factor will be added, which is now under study to achieve a complete seed separation. While the discussion and analysis, we found the fact that seed separation was effectively achieved mechanically, and rotating method appeared to be a more practical way, in spite of less momentum effectiveness compared to falling and shaking ways. The seed separation rate curve clearly shows the similarity with that of drying. From this fact we confirm the possibility of application to drying of red pepper, and that further reduction of drying period may be achieved and economical utilization of seed will be prepared.

要 約

고추씨를 分離하는 方法으로 自由落下, 上下震盪, 回轉筒를 利用하는 方法과 그 機構에 關하여 硏究한 結果 씨의 分離는 고추에 加해 주는 衝擊量으로 說明할 수있었으며, 이를 運動量의 크기로 分析하였다. 씨의 分離에 寄與하는 運動量의 영향은 速度를 얻은 方法에 따라 相異하였다. 한편 同一速度下에서 運動量의 씨分離效果를 算出하였으며, 自由落下, 上下震盪및 回轉筒方法에서 各各 2.50×10^{-6}, 2.09×10^{-6}과 3.94×10^{-5}의 값을 보였다. 고추씨의 分離速度의 變化率은 고추의 乾燥速度의 變化率과 유사한 經時的 變化樣相을 갖고 있었다.

Aknowledgement

The authors wish to express their gratitute for Mr. E.B. Lee for his financial support for this research.

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