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Effect of seed pelleting with different binder types on the physical characteristics and seed quality of hybrid cucumber (*Cucumis sativus* L.)

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Abstract Concentrations of 0.3 w/v of carboxy methylcellulose (CMC) and 0.3 w/v of hydroxyethyl methylcellulose (MHEC) was found to be easiest formed pellets and appropriated in water solubility period. The pelleted seeds with 0.3 w/v of MHEC had the lowest pore friability, at 4.09%. The pelleted seeds with 0.1 w/v of CMC and 0.1 w/v of MHEC formed fragile pellets with a high percentage of friability. The pelleted seeds with each pelleting method showed significantly higher germination than the unpelleted seeds. The pelleted seeds with 0.3 w/v of MHEC had significantly higher root length than the unpelleted seeds. Therefore, pelleted seeds with 0.3 w/v of MHEC as a binder with 40 g of calcium sulfate per 10 g of seeds showed the most suitable formula for hybrid cucumber variety 'YokKaow' seeds.

Keywords: Seed enhancement, Seed treatments, Adhesive, Binder, Seed quality

Introduction

Cucumber (*Cucumis sativus* Linn) is an economically important vegetable crop in Thailand. It is widely consumed, both fresh and processed, and it is utilized in industries related to cosmetics and medicines. In Thailand, cucumber is a widely cultivated vegetable because it is easy to cultivate, and the harvest is about 35–45 days after planting, enabling farmers to generate income in a short time. However, the seedling process is a crucial step in cultivating cucumber in an industrial system. Cucumber seeds tend to deteriorate easily after planting, which causes uneven germination and unhealthy seeds. Therefore, seedlings tend to be more prone to disease infestation both before and after germination, particularly the infestation of diseases caused by *Fusarium oxysporum* f. sp. *cucumerinum* (FO) (Ye *et al*., 2004).

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In modern cultivation, cucumber seeds are often treated with various active substances, such as plant nutrients or antifungal chemicals. Such methods pose a risk to seed quality, which leads to irregular germination. Today, the most accepted to approache for improving seed conditions are seed coating and seed pelleting, with the latter being vital to the modern crop system (Siri, 2015; Afzal *et al*., 2020). Regardless, there are no companies that can produce cucumber seeds for commercial purposes in Thailand. As a result, producing a homemade cucumber seed pelleting formula in Thailand is necessary to reduce production costs. Seed pelleting helps to scale smaller, flat, or irregularly shaped seeds to make them larger, rounder, and easier to cultivate (Taylor *et al*., 1998). Successful seed pelleting depends on the pelleting material, binder, and active ingredients. In particular, the binder acts as an adhesive between the seed and the pelleting material. The binder is a sticky substance with a viscosity of 7.0–30.0 square millimeters per second, depending on the properties of each type of binder. It is responsible for binding the seeds and the pelleting material together. A good binder must have water-soluble properties that do not impede the water permeability process and air entering the seeds after planting (Kangsopa *et al.*, 2018). Binders are commonly used for seed pelleting include methylcellulose (MC), hydroxyethyl methylcellulose (MHEC), hydroxypropyl methylcellulose (HPMC), and carboxy methylcellulose (CMC).

Currently, there are many types of binders used for seed pelleting, and they have different physical properties when prepared in the form of ready-to-use solutions. Therefore, each binder is specifically suitable for a particular type of pelleting material and type of seed. It is therefore necessary to identify the seeds' physical properties before they are pelleted, and the seed quality after pelleting must be monitored (Siri, 2015). To confirm the complete success of the production of a seed pelleting formula, a report by Buakaew and Siri (2018) found that lettuce seeds pelleted with 0.3% and 0.5% of MHEC (w/v) led to easy pellet formation; the pelleted seeds had low corrosion, and they dissolved well in water.

The objectives were to develop a type and concentration of binder suitable for pelleting cucumber seeds and to monitor changes in the physical characteristics of pellets, germination, and seedling growth to enhance the cultivation of cucumbers for maximum commercial benefits and to add value to cucumber seeds in Thailand.

Materials and methods

This experiment was conducted at the Seed Technology Laboratory and greenhouse of the Agronomy Division, Faculty of Agricultural Production, Maejo University. Hybrid cucumber variety ‘YokKaow’ seeds were used in these experiments which cultivated in 2021. The experiment was conducted between January and May 2022.

Cucumber seed pelleting

Different concentrations of carboxylmethyl cellulose (CMC) and methyl hydroxylethyl cellulose (MHEC) were used as binders. The experiment was planned in a complete randomized design (CRD) with four replicates. The experimental method consisted of pelleting seeds with 0.1, 0.2, and 0.3 w/v of CMC and 0.1, 0.2, and 0.3 w/v of MHEC. Calcium sulfate was used as a pelleting material at a rate of 40 g per 10 g of cucumber seeds. Pelleting was conducted in a Model SKK12 (Seeds Processing Plant, Khon Kaen University, Thailand) rotary drum spinning at 40 rpm. Seeds treated with each pelleting method were then dehumidified with a model SKK05 dehumidifier until the moisture content was 6 ±2%.

Physical tests of pelleted seeds

The experiment was set up in a completely randomized design (CRD) with four replicates. Regarding the formation of cucumber seed pellets during the pelleting process, the level of difficulty for each of the binders to adhere to and cover the seed husks for pellet formation was observed by applying a score of 1–5 to assess pellet formation, where 1 = very difficult, 2 = difficult, 3 = moderate, 4 = easy, and 5 = very easy. The number of seeds per pellet was determined from 100 pellets, which were later randomly assessed for average weight (Kangsopa *et al*., 2018). The water solubility of the pellets was assessed by randomly selecting 10 pellets, which were then soaked individually in 10 ml of water. The time was stopped and immediately recorded when the pellets began to rupture, and water solubility was calculated following the method of Anderson *et al*. (1969). The friability of the pellets was determined in 100 pelleted seeds per experimental method using a 45–2200 Tablet Friability Tester at 25 rpm for 4 minutes. Using 20 seeds/replicate, they were then loaded into the testing machine. The percentage of friability was calculated using the method of Kangsopa *et al*. (2018).

$$\% \text{ Seeds pellet friability (weight loss, grams)} = \left[\frac{\text{weight before friability} - \text{weight after friability}}{\text{weight after friability}} \right] \times 100$$

Seed measurement

Seed quality tests under laboratory conditions

The quality of both pelleted and unpelleted seeds were tested using the between paper (BP) method in a transparent plastic box (110 × 110 × 30 mm, length × width × height) for 4 repeats with 50 seeds each. The seeds were then placed in a germination incubator at 25 ℃ with a relative humidity of 80%, a light intensity of 180 μE, and lighting 24 hours a day.

Radicle emergence was examined in each of the four replications of all experimental methods. Fifty seeds were assessed daily starting on the 3rd day after germination. The initial examination was conducted when the seeds had radicles with a length of 2 mm. The speed of radicle emergence was assessed for each treatment in the same manner as the radicle emergence assessment. The experiment was conducted with 4 replications, each consisting of 50 seeds. Assessments were performed daily from day 1 to day 3. Seed germination was assessed using seeds with normal seedlings. In each of the four replications, the first count of 50 normal seedlings was done on day 4 and the final count was done on day 8 to calculate the germination percentage (ISTA, 2019). The speed of germination was assessed for pelleted and unpelleted cucumber seeds, with 50 seeds in each of the four replications. The evaluation involved daily examination of normal seedling emergence from the 4th to the 8th day based on the method of AOSA (1983). The mean germination time was evaluated daily using the standard germination method for 8 days, in each of the four replications with 50 seeds each. The formula from Ellis and Roberts (1980) was used to calculate the results.

Seedling growth was evaluated in each treatment with four replications, and 10 seedlings were assessed on the 8th day after sowing. The shoot length of the seedlings was measured from the base of the epicotyl to the tip of the leaf, while the root length was measured from the bottom to the tip of the taproot (Klarod *et al*., 2021). Additionally, the seedling length was measured from the tip of the root to the tip of the leaf. Afterwards, the shoot fresh weight and root fresh weight of each treatment were evaluated.

Seed quality tests under greenhouse conditions

The quality of pelleted and unpelleted cucumber seeds was tested for germination in a seeding tray with peat moss as the pelleting material. The emergence percentage of cotyledons was assessed for each experimental method, with 50 seeds in each of the four replications. The evaluation was conducted on the 3rd day after germination and calculated using the method of Jeephet *et al*. (2022). The speed of emergence was evaluated for the cotyledon in each experimental method, with 50 seeds in each of the four replications in all experiment methods, by checking daily from day 1st to day 3rd after sowing. Germination percentage was determined in 50 pelleted and unpelleted cucumber seeds, which were counted for germination in each of the four replications. The first count was carried out 4th days after germination, and the final count was done 8 days after germination (ISTA, 2019). The speed of germination was assessed by examining normal germinating seeds every day starting on day 4th as the first count, until day 8th after germination as the final count. Fifty pelleted and unpelleted cucumber seeds were used for each of the four replications. The speed of germination was assessed using the same method as in laboratory conditions. Shoot length and shoot fresh weight were randomly assessed for both pelleted and unpelleted seeds for each treatment on the 8th day after sowing. The assessment was replicated 4 times with 10 seedlings each. The shoot length was measured from the base of the epicotyl to the tip of the leaf, and the shoot fresh weight was evaluated by weighing 10 seedlings for each treatment (Klarod *et al*., 2021).

Statistical analysis

The percentage of germination was arcsine-transformed to normalize the data before statistical analysis. All data were analyzed by one-way ANOVA in completely randomized design, and the difference between the treatments was tested by Duncan's multiple range test (DMRT).

Results

Physical appearance of pelleted seeds

The use of 0.1 w/v CMC and 0.1 w/v of MHEC 0.1 w/v moderately helped pellets to form, with 0.3 w/v of CMC and 0.2 and 0.3 w/v of MHEC resulting in easy pellet formation. The number of seeds per pellet was not statistically different. The 100-seed weight of 0.3 w/v CMC pellets was higher than that of pellets in the other experimental method groups. However, 0.3 w/v MHEC and 0.3 w/v CMC pellets dissolved more slowly at 2.87 and 2.62 s, respectively, when compared to the other groups. Pellets with 0.1 w/v of CMC and 0.1 w/v of MHEC had a higher percentage of fiability than those in the other pelleting method groups. The binders were unable to completely encapsulate the seeds (Figure 1). The 0.3 w/v MHEC pellets had the least friability at 4.09% and differed from the friability percentage of the other pelleting methods (Table 1).

Table 1. Physical properties of cucumber seeds pelleted with different binders

Treatment	Forming[1]	Seeds/ pellet	Pellet -100seed weight (g)	Pellet dissolution (seconds)	Pellet friability (%)
Unpelleted seeds	-	-	2.50 g[2]	-	-
CMC 0.1 (w/v)	3	1.25	4.98 d	0.79 e	41.59 a[3]
CMC 0.2 (w/v)	4	1.25	7.90 b	2.32 c	8.03 c
CMC 0.3 (w/v)	5	1.00	8.21 a	2.62 b	7.29 d
MHEC 0.1 (w/v)	3	1.00	3.22 f	0.43 f	39.73 b
MHEC 0.2 (w/v)	5	1.25	4.95 e	2.20 d	8.90 c
MHEC 0.3 (w/v)	5	1.00	6.21 c	2.87 a	4.09 e
F-test	-	ns	**	**	**
CV. (%)	-	29.56	0.12	6.73	6.43

**: Significantly different at P≤0.01.[1] The forming scores for the seed pelleting: 1 = very difficult, 2 = difficult, 3 = moderate, 4 = easy and 5 = very easy.[2] Means within a column followed by the same letter are not significantly at P≤0.05 by DMRT.[3] Data are transformed by the arcsine before statistical analysis.

Figure 1. Physical appearance of cucumber seeds pelleted with different binders (10x Magnifications): (T1) CMC 0.1 (w/v); (T2) CMC 0.2 (w/v); (T3) CMC 0.3 (w/v); (T4) MHEC 0.1 (w/v); (T5) MHEC 0.2 (w/v), (T6) MHEC 0.3 (w/v)

Effect of pelleting cucumber seeds on germination and seedling growth

In laboratory conditions, seeds pelleted with each of the pelleting methods had a higher rate of radicle emergence, speed of radicle emergence, germination, and speed of germination than unpelleted seeds, and the differences were statistically significant different. Cucumber seeds pelleted with each treatment had faster germination than unpelleted seeds. In particular, the 0.1, 0.2, and 0.3 w/v CMC and 0.2 and 0.3 w/v MHEC pellets had significantly higher germination rates than the unpelleted seeds (Table 2).

Table 2. Radicle emergence (RE), speed of radicle emergence (SRE), germination percentage (GE), speed of germination (SGE), and mean germination time (MGT) of cucumber seeds after pelleting with different binders tested under laboratory conditions

Treatment	**Laboratory condition**				
	RE (%)	SRE (root/day)	GE (%)	SGE (seedling/day)	MGT (day)
Unpelleted seeds	11 c[1, 2]	7.92 c	15 c	3.08 d	5.76 a
CMC 0.1 (w/v)	72 a	29.00 a	82 ab	17.51 ab	4.82 c
CMC 0.2 (w/v)	70 a	27.83 ab	86 a	18.54 ab	4.79 c
CMC 0.3 (w/v)	63 ab	23.83 ab	78 b	16.84 bc	4.82 c
MHEC 0.1 (w/v)	68 ab	26.08 ab	77 b	15.34 c	5.24 b
MHEC 0.2 (w/v)	63 ab	24.58 ab	85 a	18.99 a	4.59 c
MHEC 0.3 (w/v)	62 ab	23.33 b	85 a	17.87 ab	4.94 c
F-test	*	**	*	**	**
CV. (%)	7.24	13.93	6.05	7.99	4.51

*, **: Significantly different at $P \leq 0.05$ and $P \leq 0.01$ respectively.
[1] Data are transformed by the arcsine before statistical analysis.
[2] Means within a column followed by the same letter are not significantly at $P \leq 0.05$ by DMRT.

Under laboratory conditions, 0.3 w/v of MHEC treatment resulted significantly in higher root lengths than unpelleted seeds. Shoot length, seedling length, and shoot fresh weight of pelleted and unpelleted seeds were not statistically differed. Seeds pelleted with each pelleting method were significantly higher root fresh weights than unpelleted seeds (Table 3). The root length was clearly greater than the unpelleted seeds (Figure 2).

In the greenhouse conditions, the emergence percentage and speed of emergence were not statistically differed when compared to unpelleted seeds. The T3-T7 pelleting methods had higher seed germinated than the pelleted seeds with 0.1 w/v of CMC and unpelleted seeds. Seeds pelleted with each pelleting method showed higher shoot length than unpelleted seeds. Specifically, the T3-T7 treatments had significantly higher shoot fresh weight than the unpelleted seeds (Table 4).

Table 3. Root length, shoot length, seedling length, shoot fresh weight and root fresh weight of cucumber seeds after pelleting with different binders tested under laboratory conditions

Treatment[1]	**Laboratory condition**				
	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Shoot fresh weight (mg)	Root fresh weight (mg)
Unpelleted seeds	10.49 c[1]	6.18	16.67	1.73	0.37 b
CMC 0.1 (w/v)	13.27 ab	5.93	19.20	1.76	0.6 1a
CMC 0.2 (w/v)	12.79 ab	5.12	17.91	1.60	0.56 a
CMC 0.3 (w/v)	12.65 ab	5.75	18.40	1.67	0.53 a
MHEC 0.1 (w/v)	12.83 ab	5.38	18.21	1.75	0.5 2a
MHEC 0.2 (w/v)	11.39 bc	5.47	16.86	1.97	0.58 a
MHEC 0.3 (w/v)	13.61 a	4.97	18.58	1.73	0.6 7a
F-test	*	ns	ns	ns	*
CV. (%)	14.31	9.52	9.11	8.42	5.12

ns, *: non significantly different and significantly different at P≤0.05 respectively.
[1] Means within a column followed by the same letter are not significantly at P≤0.05 by DMRT.

Figure 2. The seedling growth of cucumber was examined under laboratory conditions 8 days after planting: (T1) CMC 0.1 (w/v); (T2) CMC 0.2 (w/v); (T3) CMC 0.3 (w/v); (T4) MHEC 0.1 (w/v); (T5) MHEC 0.2 (w/v), (T6) MHEC 0.3 (w/v)

Table 4. Emergence (EG), speed of emergence (SEG), germination percentage (GE), speed of germination (SGE), Shoot length (SHL) and shoot fresh weight (SFW) of cucumber seeds after pelleting with different binders tested under laboratory conditions

Treatment	**Greenhouse condition**					
	EG (%)	SEG (plant/day)	GE (%)	SGE (plant/day)	SHL (cm)	SFW (g)
Unpelleted seeds	2	0.50	26 c[1, 2]	5.87 b	3.96 d	1.99 c
CMC 0.1 (w/v)	1	0.33	40 b	9.01 b	4.52 c	2.29 bc
CMC 0.2 (w/v)	0	0.00	61 a	14.42 a	5.04 ab	2.70 a
CMC 0.3 (w/v)	0	0.00	61 a	14.44 a	5.16 a	2.78 a
MHEC 0.1 (w/v)	1	0.33	53 a	12.76 a	4.52 c	2.43 ab
MHEC 0.2 (w/v)	0	0.00	56 a	13.48 a	4.82 a-c	2.72 a
MHEC 0.3 (w/v)	0	0.00	63 a	14.19 a	4.78 bc	2.70 a
F-test	ns	ns	*	*	**	*
CV. (%)	21.90	23.81	11.32	18.66	4.67	9.12

ns, *, **: non significantly different, significantly different at P≤0.05 and P≤0.01 respectively.
[1] Data are transformed by the arcsine before statistical analysis.
[2] Means within a column followed by the same letter are not significantly at P≤0.05 by DMRT.

Discussion

Cucumber seeds are of high value and have been in great demand for consumption. However, in cultivating cucumbers, farmers use fertilized seeds, which affects seed quality and storage after harvest. Seed pelleting is one of the long-established methods of improving conditions for simpler yet more efficient cultivation when used in conjunction with agricultural machinery. However, in the seed pelleting process, the water absorption capacity, air, and seed quality after pelleting must be considered (Siri, 2015). The aim of this experiment was selected the two best types and three best concentration levels of binders to produce the best pelleting materials for cucumber seeds. The first step in seed pelleting was formed a pellet using binders. The agglomeration of a pelleting material, binder, and seeds is difficult to initiate during the seed pelleting process (Taylor *et al.,* 1998).

The results of the experiment showed that using both types of binders at three concentration levels leaded to easy pellet formation. Except for seeds pelleted with 0.1 w/v CMC and 0.1 w/v MHEC, pellets can be moderately formed within 10–15 minutes. Pelleting seeds with 0.1 w/v CMC and 0.1 and 0.2 w/v MHEC produced pellets that were easily broken, incompletely shaped, and unhealthy. However, all seed pelleting methods resulted to increase 29–228 times of seed weight compared to the unpelleted seeds.

The water solubility of a pellet is important for the absorption of water and air, which is a vital factor in the seed germination process (Kangsopa *et al.,* 2018). A good binder must be used for water soluble at appropriate intervals. The operations of seedling cultivation may be subjected to moisture from hands or tongs, which affected the pellets, if those producing them are not meticulous (Pedrini *et al*., 2017). Pelleting seeds with 0.3 w/v CMC and 0.3 w/v MHEC was shown to be appropriated concentration level. However, the pelleted seeds with 0.1 w/v CMC and 0.1 w/v MHEC was quickly dissolved.

The friability test was applied using the standard method for the friability testing of tablets in the pharmaceutical industry (Kangsopa *et al.*, 2018). This test demonstrated the packing, transport, and performance capabilities of agricultural machinery (Siri, 2015). Seeds pelleted with 0.3 w/v MHEC were showed little friability in the pellets. Meanwhile, 0.1 w/v CMC and 0.1 w/v MHEC pellets had high fiability, which is associated with more difficult pellet formation compared to the other methods. The pellets were not well shaped and prone to breakage, and the binders did not adhere to the seed hulls. Therefore, both formulas are inappropriated for industrial packing. CMC and MHEC (0.2 w/v) were shown to be unsuitable concentration levels.

It is important that good seed pellets possess good physical characteristics that do not interfere with the germination process (Kangsopa *et al*., 2018). All seeds with each pelleting method had higher germination than pelleted unpelleted seeds when tested in both laboratory and greenhouse conditions. In addition, laboratory testing showed that the seeds pelleted with two types of binders and three concentration levels had better radicle emergence, radicle emergence speed, and germination speed, and the mean germination time was clearly shown better than the unpelleted seeds. The pellets adhered around the seeds and helped them retain moisture well, thereby providing the seeds with consistent moisture (Siri, 2015). In addition, the pellets had a water solubility period that was neither too fast nor too slow, so it did not affect the germination process of the cucumber seeds. The results showed that the pelleted seeds had a higher seed quality than the unpelleted ones. Seeds pelleted with each pelleting method had higher root length than unpelleted seeds, indicating that not all binder types and concentration levels impeded root development. There was no statistically significant difference in shoot length. This is in contrast with Buakaew and Siri (2018), who found that 0.3% and 0.5% MHEC-treated lettuce seeds had shorter shoot lengths than unpelleted seeds.

Germination tests in greenhouse conditions showed that germination had higher than the unpelleted seeds. The pelleting material encapsulated and bonded with a binder of an appropriate thickness provided the cucumber seeds with protection from adverse environmental conditions, as well as increased the moisture content of the seed, thereby promoting a higher rate of seed germination (Siri, 2015). Additionally, the shoots of pelleted seeds showed higher growth than unpelleted seeds. Therefore, the seed pelleting formula affected the physical characteristics of pellet formation and erosion, as well as the water solubility of the pellet, which affected the germination and growth of cucumber seedlings. In addition, the results obtained from this experiment will be used to create a formula for pelleting seeds with plant nutrients to promote germination and increase the shoot and root length of the seedlings (Taylor *et al.*, 1998; Siri, 2015).

Therefore, based on the physical properties and seed quality after laboratory and greenhouse testing, the most appropriate binder type and concentration level for pelleting 'YokKaow' cucumber seeds was 0.3 w/v of MHEC using 40 g of calcium sulfate as a pelleting material.

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