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EJECTION CHARACTERISTICS, TENSILE STRENGTH AND PROTEIN CONTENT OF COMPACTED WINGED BEAN (KACANG BOTOL) SEED CONTAINING LACTOSE

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Abstract— Currently, there is a lack of information in the literature regarding the compaction of winged bean seed into tablet form. Therefore, this research study into the compaction of winged bean seed powder containing lactose monohydrate as an excipient into tablet form. Winged bean, an underutilized legume, holds a great potential for innovative health solutions due to its high protein content. The research was conducted to develop a chewable tablet containing different compositions binary mixture consisting of winged bean seed powder and lactose monohydrate powder

Strength	using uniaxial compaction method. This work focus on determining the winged bean seed chewable tablet ejection characteristics during the compaction process, tablet tensile strength, and its protein content. The tablet ejection characteristics were determined from the force-displacement data obtained during the ejection stage of the compaction process. The tablet tensile strength was measured using the indirect tensile strength test. Meanwhile the protein content was determined using the Kjedahl method.Based on the results obtained, increasing the composition of lactose powder improves the tensile strength of the tablet by increasing the tensile strength up to 0.27 ± 0.05 MPa. Moreover, a higher amount of lactose powder results in higher maximum ejection force during tableting up to $1.06 \times 10^{-5} \pm 6 \times 10^{-6}$ kJ. The maximum protein content was obtained for pure winged bean seed tablet at 29.55 g/100g. The results obtained are useful for developing winged bean seed chewable tablets.

I. Introduction

Winged bean (*Psophocarpus tetragonolobus*), also known in Malaysia as kacang botol, is one of the underutilized legumes. Every component of the plant, including the seeds, immature pods, leaves, flowers, and tuberous roots, is consumable. Winged bean seed possesses a significant protein content ranging from 29% to 37% [1].

Therefore, is is of particular interest to study the potential of formulating the winged bean seeds into tablet form, which is more convenient for consumer consumption on a daily basis. One of the challenges in formulating the winged bean tablet dosage form is the selection of the suitable inert of excipients in the tablet formulation.

Tablets are the most commonly used dosage form due to their accessibility, ease of administration, consistency, and cost-effectiveness. By formulating winged bean seeds into tablet form, it can provide a convenient and reliable form of consumption, ensuring that the nutritional properties of winged beans are delivered effectively and efficiently to consumers.

Excipients play a crucial role in enhancing the stability and performance of tablet formulations. Lactose, which is a commonly used excipient in pharmaceutical industry for tablets [2], has been selected as the excipient for the winged bean seed tablet. Some previous works have studied the use of lactose as an excipient in tableted food materials such as in cocoa tablet and dates tablet. The mechanical strength of the cocoa tablets were found to be dependent upon both the compaction pressure used during tablet formation and the lactose composition [3], and this was also observed in the compaction of dates tablets [4]. This highlights the importance in determine the effects of the lactose composition and the compaction pressure on the winged bean seed tablet characteristics.

Uniaxial compaction method is used in tableting process which high load of compaction involves the transformation of a bulk solid into a new structure that possesses physical properties different from its initial state. In addition, the ejection force and the ejection work, which are the force required to push the tablet out of the die after compaction stage and the work done in pushing the tablet out from the die cavity, must not be too high, to minimise wear and avoid potential manufacturing defects such as tablet capping and lamination. A high ejection force and ejection work values are indicative of high friction between the tablet and die wall interface. Excessive friction can damage the tablet and reduce tooling life by causing wear. Additionally, determining the tablet's mechanical strength and nutritional content is essential. Mechanical strength ensures the tablet can withstand handling and transportation without breaking, while nutritional content, primarily the protein levels, ensures the tablet meets its intended purpose as a protein supplement. These assessments are critical for to provide an effective product for consumers. Besides, based upon the authors knowledge, there is currently no published research that study on the winged bean seed tablet formulation ejection characteristics and mechanical strength.

Hence, this novel study of producing winged bean seed tablet is currently of academically and potentially of commercial interest to discover more about its potential to be manufactured in tablet form.

II. Material and Methods

A. Material

Winged bean seed was obtained from(Crop Powder Sdn Bhd, Malaysia). Tablettose® 80 - lactose monohydrate powder (Meggle Co., Germany) was selected as the excipient in the formulation of the chewable tablet.

B. Preparation of winged bean seed powder

The winged bean seed powder was ground using a dry mill grinder (Panasonic MX-GH1011, Japan) for 3 minutes in order to reduce the size of particle from larger particle into fine powder particles. The seeds were ground for 30 seconds, then rest for 10 seconds. Repeat the process until completed 3 minutes of grinding. Then, the ground materials were dried in universal drying oven (Memmert, Germany) at 60°C for 4 hours to remove excess moisture. After the drying process finished, powder then kept in desiccator for 1 hour to reduce temperature of powder before proceeding with sieving process. After that, the powders were passed through sieve in 250 µm mesh size screen to obtain a fine winged bean seed powder for tablet formation. The powder was then kept in the air-tight container and then placed inside a desiccator.

C. Preparation of powder mixtures

There are three powder samples which are pure winged bean seed powder (WBSP), 80 wt% Winged bean seed powder with 20 wt% lactose powder (WBSPL 1) and 20 wt% Winged bean seed powder with 80 wt% lactose powder (WBSPL 2). The weight of powders is weighted by using electronic weighing balance (Pioneer PX224, OHAUS, Australia). Then, the winged bean seed powder and lactose monohydrate were mixed using a dry powder rotator (Glass-Col, Terre Haute, USA) for 10 minutes. The mixing was done for each individual tablet formulation to ensure each tablet has the required composition of lactose and winged bean seed powder. After mixing, all powder samples were kept in the container and stored in a desiccator with silica gels before being compacted into tablets.

D. Uniaxial die compaction process

Uniaxial compaction method is carried out by using universal testing machine (Model 5566, Instron, Canton MA, USA). 500mg of the powder samples prepared at various winged bean seed compositions was poured and compressed in a 13 mm diameter die (Specac, UK) at a fix compression load of 9.8 kN. The loading rate was adjusted to 0.167 mm/sec in order to compress the material until it reached the desired compaction load. For unloading rate, same rate is used as the loading rate which is 0.167 mm/sec. The force and distance were continuously measured and recorded by the sensor until the tablet fully exited the die, and the highest force observed in the force-displacement plots was identified as the maximum ejection force. The ejection pressure was calculated by dividing the maximum ejection force and cross-sectional area of the tablet. Finally, the tablet was ejected from the die. Afterwards, the tablets were properly labelled and stored in air-tight container, and then placed inside a desiccator. The tablet should be stored for at least of 24 hours to ensure uniform elastic recovery and hardening before conducting mechanical strength tests.

E. Calculation of ejection work

The ejection work represents the energy used during the ejection process which is calculated by integrating the areas under the force and displacement curves obtained during the ejection stage of the compaction process [6].

F. Tablet mechanical strength test

The tensile strength of the tablet was measured by using a universal testing machine (Model 5566, Instron, Canton MA, USA) using the diametrical indirect tensile test [7]. The tensile strength of a flat, round tablet can be calculated using Equation 1 [7]:

$$\sigma = \frac{2F}{\Pi\, dt} \tag{1}$$

where:

F = breaking force recorded when the tablet fractured diametrically

d = tablet diameter

t = tablet thickness

G. Determination of protein content

The crude protein content of the sample was determined using the Kjeldahl method. This method is based on the principle of determining total protein content through the measurement of nitrogen levels, which represents as an indicator of protein content in the analyzed samples. According to [8] with slight alterations, a precise amount of 0.15 g of WBSP was accurately weighed and placed into a micro Kjeldahl test tube. To this, 8 g of a mixed catalyst was added, followed by 2.5 ml of concentrated sulfuric acid. The contents were gently swirled to mix, and the tube wasthen gradually heated in a heating coil under a fume hood. The mixture was boiled until the solution became clear and exhibited a blue-green color. After cooling the flask to 40°C, 10 ml of distilled water was added, and the digested product was transferred into a distillation tube. Subsequently, 10 ml of a 45 % NaOH solution was added slowly to separate the solution into two layers. The distillation tube was then securely attached to the condenser. In a conical flask, 10 ml of 2 % boric acid and a few drops of indicator were prepared. The conical flask was placed on the distillate platform, ensuring the tip of the distillation tube was immersed in the acid solution. The contents of the distillation flask were gently swirled and steam was purged into the flask. The ammonia solution was allowed to distill into the conical flask until approximately 120 ml of distillate was collected. This distillation product was then gently swirled to mix, and the unreacted boric acid was titrated with 0.05N H_2SO_4 until neutral. Then, the same procedure is repeated for the sample of WBSPL 1, WBSPL 2, and a blank sample to ensure accuracy and consistency.

III. Result and Discussion

The ejection force is the pressure experienced by the punch when extruding the tablet out from the die cavity during ejection stage of the uniaxial die compaction process, due to the frictional resistance between the tablet side surface and the die wall. The result obtained indicate the lowest maximum ejection pressure was obtained for WBSP at 0.10 ± 0.04 MPa, followed by tablet WBSPL 1 at 0.12 ± 0.01 MPa and tablet WBSP 2 exerted the highest maximum ejection pressure at 1.01 ± 0.05 MPa. This trend of increasing maximum ejection pressure with the increase in lactose composition was also found for the compaction of lactose-croscarmellose and lactose-sodium starch glycolate binary powder mixtures [9]. The greater tablet ejection pressure indicates higher radial stress on the die wall and an increased friction coefficient at the interface between the compact and the die wall.

In terms of the ejection work, addition of 20wt% lactose monohydrate powder in tablet WBSPL 1, the ejection work decrease compared to tablet WBSP from $2.20 \times 10^{-6} \pm 9 \times 10^{-7}$ kJ to $6.34 \times 10^{-7} \pm 5 \times 10^{-10}$ kJ. However, further addition of lactose monohydrate powder in tablet WBSPL 2 until 80wt% lactose monohydrate content shows an increasing of work during the ejection stage to $1.06 \times 10^{-5} \pm 6 \times 10^{-6}$ kJ compared to WBSPL 1. This situation might occur due to high concentration of lactose powder in the formulation. Therefore, comparatively low addition of lactose monohydrate powder as the excipient helps to decrease the ejection work, meanwhile excessive lactose powder might lead to an increase in the ejection work done to overcome the die wall friction during the ejection of the tablet from the die.

The results also shows that the tensile strength was influenced by the lactose content in the formulation of the winged bean seed tablet as shown in Figure 1.

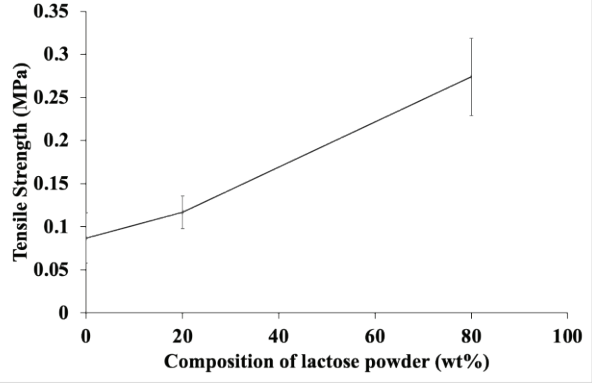

Figure 1: Tensile strength of winged bean seed tablets containing various compositions of lactose monohydrate

A binary mixture of tablet WBSPL 2 which comprises of 20% winged bean seed powder and 80% lactose powder gave the highest tensile strength at 0.27 ± 0.05 MPa compared to the other formulations, while tablet WBSP has the lowest tensile strength 0.09 ± 0.03 MPa. While tablet WBSPL 1 which comprises of 80% winged bean seed powder and 20% lactose powder has tensile strength of 0.12 ± 0.02 MPa. Therefore, the addition of lactose monohydrate improves the tensile strength of the winged bean seed powder. In contrast, the addition of lactose to dates tablets decreases its tensile strength values [4]. However, this was attributed due to the capping of the dates tablets that contained relatively higher lactose composition. Meanwhile, no capping was observed for the winged bean seed tablets in this current study.

According to the results of for the crude protein, WBSP exhibited the highest protein concentration at 29.55 g/100g. This was followed by WBSPL 1, which had a protein content of 25.35 g/100g. WBSPL 2 had the lowest protein content, measuring at 11.43 g/100g. WBSP recorded the highest protein content, attributed to the larger amount of winged bean seed powder in its formulation. The protein content for WBSP considerably high when compared to chickpea seeds (23%) and lentil seeds (26%) [10]. This suggests that winged bean seeds are a viable and rich source of protein. In contrast, the mixture of WBSPL 2, which contains only 20% winged bean seed powder, exhibits the lowest protein content. This lower protein content is attributed to the reduced proportion of winged bean seed, which serves as the primary source of protein in comparison to lactose powder, utilized as an excipient in the powder formulation.

IV. Conclusion

In conclusion, WBSP displays the highest amount of protein content which crucial for the supplementation. Given that the tablet is intended to be consumed as a protein supplement and the protein content should be a priority. Therefore, despite its lower mechanical performance compared to WBSPL 2, WBSPL 1 could be considered as good candidate for the winged bean seed tablet formulation, due to displaying relatively lower ejection pressure and ejection work and containing higher amount of protein in comparison to WBSPL 2 formulation. It is also recommended that further optimization of the compaction compaction process along with the necessary sensorial and toxicology tests must be done prior to human consumption.

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