

KARAKTERISASI MADU BUBUK SPRAY-DRIED: PENGARUH JENIS DAN RASIO BAHAN PEMBAWA TERHADAP SIFAT FUNGSIONAL

CHARACTERIZATION OF SPRAY-DRIED POWDERED HONEY: EFFECT OF CARRIER TYPE AND RATIO ON FUNCTIONAL PROPERTIES

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Abstract. *Honey is a natural food product rich in bioactive compounds; however, it has limitations in the form of high viscosity and a tendency to crystallize, making it necessary to process it into a powdered form to improve stability and ease of use. This study aimed to analyze the effect of adding maltodextrin and gum arabic as fillers at varying ratios on the functional characteristics and rehydration properties of acacia honey-based powdered honey. The study employed an experimental design with three replicates and four treatments: MD1 (1:1.5), MD2 (1:2), GA1 (1:1.5), and GA2 (1:2), with the honey-to-filler ratio determined based on the total solids content of the honey (80% total solids; moisture content $\pm 20\%$). The honey powder was produced using spray drying at an inlet temperature of 160°C, an outlet temperature of 76–81°C, an aspirator setting of 90%, and a pump rate of 30–45. These drying conditions were applied to produce a powder with stable physical characteristics and to enable the evaluation of the filler's effect on functional properties and rehydration capacity. The parameters observed included bulk density, tapped density, particle density, Hausner ratio, Carr index, solubility, and dissolution time. The results showed that the treatment had a highly significant effect ($P \leq 0.01$) on most parameters and a significant effect ($P \leq 0.05$) on particle density. Maltodextrin produced higher density, better flow properties (HR 1.02–1.07; CI 2.18–6.59%), high solubility (93.62–96.24%), and faster dissolution time (4.90–6.60 seconds). In contrast, gum arabic resulted in lower density and a longer dissolution time (18.30–19.50 seconds). This study indicates that the type and ratio of fillers influence particle structure and rehydration performance. The optimal formulation was obtained in the MD2 treatment with a 1:2 ratio of honey to maltodextrin, as it provided the rehydration properties and flow properties.*

Keywords : *Functional properties, Gum arabic, Honey powder, Maltodextrin, Spray dried.*

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INTRODUCTION

Honey is a thick liquid that is generally sweet in taste, produced from flower nectar collected by honeybees, which then undergoes a natural synthesis process within the bees' bodies. According to the latest data from the Central Statistics Agency (BPS) in 2022, national honey production reached 189,780 liters. Honey is commonly used as a natural sweetener in various food products. Honey contains bioactive compounds such as flavonoids, enzymes, amino acids, vitamins, and minerals that are beneficial to health. These compounds act as natural antioxidants and antibacterial agents. The antioxidant activity in honey can persist during storage for up to six months. This activity decreases after that period due to the degradation of bioactive compounds (Zarei *et al.*, 2019). Honey must meet the criteria set forth in the Indonesian National Standard SNI 8664: 2018. Honey has physical characteristics such as relatively high viscosity and a tendency to crystallize. High viscosity can affect honey's flow properties and handling, while crystallization is influenced by its sugar composition, particularly the balance of fructose and glucose. These characteristics are important considerations in processing, especially when converting honey into powder form.

Acacia honey is a type of honey commonly found in tropical and subtropical regions. It is produced by bees from the nectar of acacia flowers, particularly from the *Acacia crassicaarpa* species, which is well-known for its

distinctive color, mild flavor, and superior resistance to crystallization compared to other types of honey. The relatively high fructose content in acacia honey gives it a distinctive sweetness and slows down the crystallization process. Acacia honey is relatively abundant in Indonesia, making this product more commonly found in the community. These characteristics make acacia honey highly promising for development into value-added derivative products. However, its hygroscopic nature and high viscosity remain challenges in the storage and handling of the liquid product.

Processing honey into powder is an approach to improve its stability and ease of application. However, the high content of low-molecular-weight sugars, particularly fructose, presents a major challenge during drying. Fructose has a relatively low glass transition temperature (T_g), which increases the tendency of honey to become sticky during drying and can cause adhesion to the drying chamber and reduce powder recovery. Therefore, the addition of carrier agents is necessary to increase the T_g of the feed matrix and reduce stickiness during drying (Chen *et al.*, 2019). Maltodextrin and gum arabic are commonly used fillers because they can form a protective matrix and improve product stability. Maltodextrin has high solubility and can accelerate the drying process. Gum arabic has emulsifying properties and the ability to form a film that protects sensitive components. Variations in the type and ratio of fillers will affect the

physical characteristics and rehydration properties of powdered honey.

The functional properties of powdered honey are key parameters in determining product quality. Bulk density and tapped density indicate the particles' ability to fill space and their compaction level during storage. The Hausner ratio and Carr index describe flow properties and particle cohesiveness. Solubility and dissolution time indicate the powder's ability to dissolve and disperse in water. These parameters are critical factors in the application of honey-based instant products. Variations in the ratio of honey total soluble solids to filler maltodextrin at 1:2 and 1:1.5, and gum arabic at 1:2 and 1:1.5, are expected to have different effects on all these parameters. Some studies focus only on a single type of filler, drying method, or specific parameter. Studies that simultaneously integrate various physical parameters and rehydration properties remain limited. This study aims to analyze the effect of using maltodextrin and gum arabic at varying ratios on the functional properties of honey powder.

MATERIALS AND METHODS

1. Materials

The research material used consisted of samples of *Apis mellifera* acacia honey from Indonesia obtained from PT Kembang Joyo Sriwijaya, Malang. The honey underwent an evaporation process until it reached a moisture content of approximately 20%, resulting in a material with a dry matter content suitable for formulation. The car-

riers used included DE 18-20 maltodextrin and food-grade gum arabic, while SiO₂ (Merck, China) was added as an anti-caking agent.

2. Preparation of Feed Solution

The honey sample used was acacia honey (*Apis mellifera*) that had been dehydrated to approximately 20% moisture content, making it more suitable for the drying stage. The concentration process was performed prior to drying to reduce moisture content, minimize stickiness, and improve mixing efficiency with the filler material as well as drying characteristics. The reduction in moisture content contributes to lower water activity and an increase in the glass transition temperature (T_g), thereby supporting encapsulation efficiency and producing powder of better quality (Maharani *et al.*, 2023). The formulation process involves mixing acacia honey with fillers maltodextrin and gum Arabic at ratios of 1:2 and 1:1.5 based on weight relative to the honey. The fillers are first dissolved until homogeneous; then, the honey solution is gradually added while stirring using a hot plate stirrer without heating until a homogeneous mixture is obtained. Homogenization was performed to ensure even distribution of ingredients and prevent agglomeration. This mixture was adjusted to have a viscosity of less than 300 cps before entering the spray-drying stage. Viscosity was measured using a Brookfield digital viscometer with spindle No. 2 at a speed of 30 rpm at room temperature. The mixture that met this viscosity limit

was then used in the spray-drying process to ensure optimal atomization.

3. Spray Drying Process

The production process for powdered honey is carried out using a Buchi B-290 spray dryer under controlled operating conditions to produce high-quality powder. The inlet temperature is set to 160°C. The outlet temperature is maintained at 76–81°C to ensure efficient evaporation. The aspirator is set to 90% to maintain the flow of hot air. The pump flow rate starts at 30%. The pump flow rate is increased to 35% – 45% once the flow stabilizes. The nozzle cleaner is set to level 2 to prevent clogging. The process begins by turning on the spray pump and adjusting the temperature until it stabilizes. The pump is run and the pressure is monitored until it stabilizes. The feed hose is placed in water to ensure there are no blockages. The hose is then redirected to the formulated honey solution. The atomization and drying process produces honey powder with uniform physical characteristics. The resulting honey powder is collected, mixed with 1% silica dioxide (SiO₂) by product weight

as an anti-caking agent, and then stored in an airtight container (vacuum sealer) to prevent moisture absorption. Samples of the honey powder were then analyzed to determine physical characteristics and rehydration properties, including bulk density, tapped density, Hausner ratio, Carr index, solubility, and dissolution time. The entire preparation and formulation process was conducted consistently for each treatment to ensure the validity and comparability of the results. The honey powder formulations based on the type of filler and filler ratio are presented in Table 1.

4. Statistical analysis

Data from three repetitions of each test were analyzed using Microsoft Excel. Data analysis was performed using the analysis of variance (ANOVA) method. If the ANOVA results indicated a significant ($P \leq 0.05$) or highly significant ($P \leq 0.01$) difference between treatments, the analysis was continued with Duncan's Multiple Range Test (DMRT).

Table 1. Formulation of honey powder based on the type of filler and the filler ratio.

Treatment Code	Filler Type	Ratio (Honey : Filler)	Ratio/g (Honey : Filler : Water)
MD1	Maltodextrin DE 18-20	1 : 1,5	40,00 : 60,00 : 256,67
MD2	Maltodextrin DE 18-20	1 : 2,5	33,33 : 66,67 : 256,78
GA1	Gum Arabic (food grade)	1 : 1,5	40,00 : 60,00 : 256,67
GA2	Gum Arabic (food grade)	1 : 2,0	33,33 : 66,67 : 256,78

Note : MD = Maltodekstrin, GA = Gum Arabic

5. Statistical analysis

Data from three repetitions of each test were analyzed using Microsoft Excel. Data analysis was performed using the analysis of variance (ANOVA) method. If the ANOVA results indicated a significant ($P \leq 0.05$) or highly significant ($P \leq 0.01$) difference between treatments, the analysis was continued with Duncan's Multiple Range Test (DMRT).

5.1 Bulk density

(Lobubun and Chabib, 2022)

The bulk density of powdered honey was determined by placing 5 g of the sample into a 10 mL measuring cylinder and recording its volume. The sample was then weighed to determine the mass used in the calculation. The bulk density was calculated using the following equation:

$$\text{Bulk density} = \frac{\text{Sample weight}}{\text{Sample volume}}$$

5.2 Tapped density (IDF, 2005b)

The tapped density test for powdered honey is conducted by filling a measuring cylinder with the sample until it reaches a volume of 10 mL, then tapping the measuring cylinder 100 times to compact the sample, and finally recording the volume. Next, the sample is weighed to obtain the mass used in the calculation. The tapped density value is calculated using the formula:

$$\text{Tapped density} = \frac{\text{Sample weight}}{\text{Sample volume}}$$

5.3 Particle density (Bansal et al., 2017)

The particle density test is performed by weighing 1 g of the sample, placing it in a measuring cylinder contain-

ing 5 mL of petroleum ether (PE), shaking until the particles settle, and rinsing with additional PE until the total volume reaches 6 mL. The final volume is recorded. The calculation formula is as below:

$$\rho_{\text{partikel}} (\text{g/mL}) = \frac{m_{\text{bubuk}}}{V_{\text{akhir}} - V_{\text{cairan awal}}}$$

5.4 Hausner Ratio and Carr Index (Mutlu et al., 2020)

The bulk density and tap density values are first determined by measuring each parameter. These two values are used to calculate derived parameters using the equations:

$$\text{Carr index (\%)} = \frac{pt - pb}{pb} \times 100$$

$$\text{Hausner ratio} = \frac{pt}{pb}$$

Description:

Pt : *tapped density*

Pb : *bulk density*

5.5 Solubility (Suhag et al., 2021)

The solubility test for powdered honey was conducted by weighing 2 g of the sample and dissolving it in 20 mL of distilled water, then homogenizing it until a uniform solution was obtained. A weighed and marked filter paper was placed in a funnel, and the solution was filtered to separate the soluble and insoluble fractions. The residue retained on the filter paper represents the insoluble fraction. The filter paper containing the residue is dried in an oven at 105°C for 2 hours, then cooled in a desiccator for 15 minutes before being weighed again. The solubility

value is determined using the following formula:

$$\text{Solubility} = 1 - \left(\frac{(c-b)}{a} \right) \times 100\%$$

Description:

- a : powdered honey sample (2 g)
- b : weight of empty filter paper
- c : weight of filter paper + residue after drying

5.5 Dissolution Time

(Balfas and Nanda, 2019)

The test was conducted by weighing 2 g of the sample, placing it in a beaker, and dissolving it in distilled water to a volume of 50 mL. Next, a magnetic stirrer was placed in the solution, and the beaker was placed on a hotplate stirrer set to 890 rpm and 30°C. Stirring continued until the powdered honey was completely dissolved, and the results were recorded.

RESULT AND DISCUSSION

1. Bulk Density

Based on the research results, the average bulk density (Table 2) ranged

from 0.435 to 0.545 g/mL; this range indicates that all treatments produced bulk densities in the moderate category and remained within the general range characteristic of spray-dried powdered honey. The highest value was obtained in the MD2 treatment (0.545 g/mL), while the lowest value was found in the GA1 treatment (0.435 g/mL). Statistical analysis results indicate that variations in the type and ratio of filler materials have a highly significant effect on bulk density values ($P \leq 0.01$). This difference indicates that the characteristics of the filler play a direct role in determining the bulk density of the resulting honey powder. Maltodextrin produced a higher bulk density value compared to gum arabic because it is capable of forming more compact and uniform particles. The homogeneous particle structure allows for a tighter particle arrangement, thereby increasing the mass per unit volume.

Table 2. The Effect of Carrier Ratio and Composition on Bulk Density, Tapped Density, Particle Density, Hausner Ratio, Carr Index, Solubility, and Dissolution Time.

Parameters	MD1	MD2	GA1	GA2
Bulk density (g/mL)	0.51±0.011 ^c	0.55±0.004 ^d	0.44±0.003 ^a	0.46±0.006 ^b
Tapped density (g/mL)	0.52±0.014 ^{ab}	0.58±0.006 ^c	0.50±0.005 ^a	0.53±0.011 ^b
Particle density (g/mL)	2.42±0.27 ^b	1.76±0.01 ^a	2.44±0.30 ^b	2.29±0.30 ^b
Hausner ratio	1.07±0.010 ^b	1.02±0.006 ^a	1.16±0.010 ^c	1.13±0.015 ^c
Carr Index (%)	6.59±1.07 ^b	2.18±0.44 ^a	13.45±0.12 ^c	11.93±0.94 ^c
Solubility	93.62±0.39 ^b	96.24±0.06 ^c	91.70±0.46 ^a	93.10±0.51 ^b
Dissolution Time (s)	6.60±0.55 ^b	4.90±0.26 ^a	18.30±0.81 ^c	19.50±0.55 ^c

Description : Different lowercase letters in the significance column indicate a significant difference ($P \leq 0.05$) in particle density, as well as a highly significant difference ($P \leq 0.01$) in bulk density, tapped density, Hausner ratio, Carr index, solubility, and dissolution time.

Maltodextrin has relatively low viscosity and good film-forming ability during the drying process. These properties help produce a denser powder, resulting in a higher bulk density. In contrast, the use of gum arabic results in a lower bulk density. This indicates that the resulting powder has a lower compaction level compared to maltodextrin. These results are consistent with the study by Samborska (2019), which reported that the type of carrier affects the density of powdered honey, with maltodextrin yielding a higher density than gum arabic. Jati *et al.* (2023) also reported that the use of gum arabic results in a lower density of powdered honey. These differences indicate that the characteristics of the carrier during the drying process also determine the bulk density of powdered honey.

Increasing the filler ratio from 1:1.5 to 1:2 results in an increase in bulk density. The addition of filler increases the total solids content in the system. A high solids content promotes the formation of larger, denser particles during the drying process. Honey powder with low density tends to have high porosity, making it more prone to absorbing moisture from the environment. This condition can lead to caking and reduce product quality. The use of maltodextrin at a higher ratio has proven to be more effective in improving the density and stability of honey powder. These results align with research stating that the selection of filler type and concentration is a key factor in determi-

ning the physical properties of spray-dried honey powder (Suhag *et al.*, 2021).

2. Tapped Density

Based on the research results, the average tapped density values (Table 2) ranged from 0.50 to 0.58 g/mL. Statistical analysis showed that the type of filler and the formulation ratio had a highly significant effect on the tapped density values ($P \leq 0.01$). The highest tapped density value was obtained in the MD2 treatment at 0.58 g/mL. The lowest value was obtained in the GA1 treatment at 0.50 g/mL. This pattern shows a trend consistent with the bulk density values, where the maltodextrin treatment resulted in a higher density compared to gum arabic. Tapped density is closely related to the ability of particles to compact after being subjected to mechanical force in the form of tapping. Particles with more uniform sizes and more compact shapes will undergo rearrangement more easily, resulting in a significant increase in density.

Maltodextrin treatment resulted in a higher tapped density compared to gum arabic. Maltodextrin is characterized as a polysaccharide with a relatively low molecular weight and moderate solution viscosity. These properties allow for the formation of stable droplets during the spray-drying process, resulting in particles with relatively uniform size and a more compact structure. The compact particle structure reduces internal porosity and improves packing efficiency during the compaction process. The use of maltodextrin as a car-

rier agent can increase tapped density because it produces particles with better packing behavior and lower cohesion (Nurhadi and Roos., 2017). Low cohesion makes it easier for particles to shift position, thereby minimizing the empty space between particles.

The treatment with gum arabic results in a lower tapped density. Gum arabic has a branched molecular structure with a high molecular weight, which causes the solution's viscosity to increase significantly. This condition affects the atomization process, causing the droplets formed to be larger and less uniform. The resulting particles have a porous morphology with an uneven surface and high roughness. This structure increases the interparticle friction and cohesive forces, thereby hindering the rearrangement process during tapping; consequently, the interparticle spaces cannot be optimally filled despite the application of mechanical energy. Gum arabic produces powder with a porous structure and low density due to the limited ability of the particles to undergo compaction (Rosland et al., 2020). A higher solid content accelerates the formation of a solid layer on the droplet surface during drying. This process produces particles with thicker walls and higher internal density. Samborska et al. (2019) state that particles with high internal density have a greater tendency to undergo slight plastic deformation during tapping, thereby enabling them to fill the interparticle gaps more effectively.

3. Particle Density

Based on the research results, the average particle density values (Table 2) ranged from 1.76 to 2.44 g/mL. Statistical analysis revealed significant differences ($P \leq 0.05$) among the treatments. Treatment GA1 yielded the highest value of 2.44 g/mL. Treatment MD1 showed a relatively high value of 2.42 g/mL. Treatment MD2 yielded the lowest value of 1.76 g/mL. These differences indicate that the type and ratio of filler materials influence the intrinsic density of powdered honey particles. Particle density reflects the density of solid material without considering the voids between particles. This value is related to the internal structure of the particles formed during the drying and encapsulation processes (Maharani et al., 2023).

The use of gum arabic results in a higher particle density compared to maltodextrin at a certain ratio. Masyithoh et al. (2025) state that gum arabic has a branched polysaccharide structure and a high molecular weight. This structure forms a more compact matrix during the drying process. The compact matrix reduces the volume of internal voids in the particles, thereby increasing density. Maltodextrin has an amorphous nature with the ability to form a more porous structure. This structure increases the internal volume of the particles, thereby decreasing density. Increasing the maltodextrin ratio enhances void formation due to a less compact solid distribution.

Particle density is closely related to the functional properties of the pow-

der. Particles with high density have low porosity, resulting in slower water penetration. Samborska et al. (2019) reported that porous particles with low density have a larger surface area, thereby accelerating the rehydration process; this condition affects the solubility and dissolution time of powdered honey. Seerangurayar et al. (2017) also explained that a more compact particle structure tends to improve stability during storage by reducing moisture absorption. These results indicate that the selection of filler type and ratio determines the balance between particle density and the functional properties of powdered honey products.

4. Hausner Ratio

Table 3. Hausner Ratio (HR)

Classification	
<i>Flowing properties</i>	<i>Hausner Ratio(HR)</i>
<i>Excellent</i>	1,00 - 1,11
<i>Good</i>	1,12 - 1,18
<i>Fair</i>	1,19 - 1,25
<i>Passable</i>	1,26 - 1,34
<i>Poor</i>	1,35 - 1,45
<i>Very poor</i>	1,46 - 1,59
<i>Very, very poor</i>	> 1,60

Based on the research results, the average Hausner ratio (Table 3) ranged from 1.02 to 1.16. Statistical analysis revealed a highly significant difference ($P \leq 0.01$) among treatments; these values can be interpreted based on the classification of powder flow properties. Based on the classification in Table 3, the range of values 1.00–1.11 falls into the excellent category. The range of values 1.12–1.18 falls into the good category. Treatment MD2, with a value

of 1.02, falls into the excellent category. Treatment MD1, with a value of 1.07, also falls into the excellent category. Treatment GA2, with a value of 1.13, falls into the good category. Treatment GA1 with a value of 1.16 also falls into the “good” category. These results indicate that all treatments remain within the good to very good flowability category. The Hausner ratio is a derived parameter from the ratio of tapped density to bulk density, reflecting the particles’ ability to undergo compaction due to external forces. Mutlu et al., (2020) explain that the difference between bulk density and tapped density determines the extent of particle reorganization during the tapping process. A Hausner ratio value close to one indicates that the particles were already relatively tightly packed from the initial state, so the space between particles is very limited.

The relationship between the Hausner ratio and bulk density and tapped density in this study was clearly evident in each treatment. The MD2 treatment showed relatively small differences in bulk density and tapped density values. This indicates that the particles had a more stable initial arrangement and did not undergo significant volume changes when subjected to mechanical treatment. Farooq et al., (2025) state that powders with a more uniform particle size distribution and a more spherical shape tend to have better flowability and a low Hausner ratio. The 1:1.5 gum arabic treatment showed a larger difference between these two parameters. This condition indicates

the presence of larger interparticle voids in the initial state, allowing for higher compaction during tamping. Jaya et al. (2024) reported that gum arabic forms a film layer that increases the surface roughness of the particles, thereby increasing the friction and cohesion between particles.

The Hausner ratio is also closely related to the microstructural characteristics of the particles, as reflected in the particle density. Particles with high density tend to have a more compact internal structure but can increase contact between particle surfaces. This condition increases adhesion and cohesion forces, thereby increasing resistance to flow. Samborska et al., (2019) explain that powdered honey has a high content of simple sugars, making it hygroscopic and prone to forming liquid bridges on the particle surface. This phenomenon strengthens interparticle interactions and increases the Hausner ratio. Chandrakar et al., (2024) state that the filler material plays a role in reducing this sticky effect by forming a protective matrix around the sugar components. Maltodextrin with a higher ratio is able to reduce cohesiveness because it produces particles with smoother surfaces and a more uniform size distribution.

5. Carr Index

Based on the research results, the average Carr index values (Table 4) ranged from 2.18% to 13.45%. Statistical analysis results indicate a highly significant difference ($P \leq 0.01$) among treatments; these values fall into the

Table 4. Carr Index (CI) Classification

<i><u>Flowing properties Carr Index (CI) %</u></i>	
<i>Excellent</i>	0 - 10
<i>Good</i>	11 - 15
<i>Fair</i>	16 - 20
<i>Passable</i>	21 - 25
<i>Poor</i>	26 - 31
<i>Very poor</i>	32 - 37
<i>Very, very poor</i>	>38

excellent to good categories based on powder compressibility classification. The classification in Table 4 shows that treatments MD2 and MD1 fall into the excellent category because they have values below 10%. Treatments GA2 and GA1 fall into the good category because they are within the 11–15% range. According to Powder Technology, the Carr index describes the ability of particles to undergo volume reduction due to mechanical forces, which is directly related to particle packing efficiency. Samborska et al. (2018) reported that powdered honey with a low Carr index value exhibits a stable initial structure, resulting in no significant volume change during tamping.

The differences in Carr index values in this study are strongly correlated with the bulk density and tapped density results. The MD2 treatment showed a very small difference between the two parameters, resulting in the lowest Carr index. This condition indicates that the particles were compactly arranged from the start and had limited space between them. According to the study by Suhag et al. (2021),

systems with high maltodextrin content produce more uniform particles and have efficient packing capabilities, thereby reducing compressibility. Conversely, the GA1 treatment showed the highest Carr index value, indicating a greater volume change during tapping. This phenomenon suggests that the initial particle structure was looser, allowing for significant rearrangement. Research by Samborska *et al.* (2020) showed that the use of gum arabic in powdered honey increases surface structural complexity, thereby increasing the likelihood of deformation during compression.

The Carr index value is also influenced by the microstructural characteristics and hygroscopic properties of powdered honey. According to Samborska *et al.* (2019), without an adequate carrier, powdered honey will experience increased compressibility due to particle agglomeration. Maltodextrin helps mitigate this effect by reducing direct interactions between sugar components. Gum arabic forms a stronger film layer but can increase interparticle friction, resulting in a greater response to pressure. This explains why the gum arabic treatment in this study yielded a higher Carr index value compared to maltodextrin. The implications of these results indicate that the Carr index not only reflects flow properties but also describes the structural stability of particles against mechanical pressure. A Carr index value in the “excellent” category indicates that the powder has high resistance to volume changes during packaging and transportation.

A value in the “good” category still indicates acceptable performance but has a greater potential for compaction.

6. Solubility

Based on the research results, the average solubility values (Table 2) ranged from 91.70% to 96.24%. Statistical analysis revealed highly significant differences ($P \leq 0.01$) among the treatments. The maltodextrin treatment resulted in higher solubility than the gum arabic treatment. The MD1 and MD2 treatments yielded solubilities of 93.62% and 96.24%, respectively, while the GA1 and GA2 treatments yielded solubilities of 91.70% and 93.10%. The higher solubility in the maltodextrin treatments is related to the characteristics of maltodextrin, which has relatively short glucose chains and hydroxyl groups that can interact with water. These conditions allow most of the maltodextrin to become hydrated and remain in the dissolved phase, resulting in a relatively small remaining insoluble fraction. Maharani *et al.* (2023) reported that using maltodextrin as a filler can increase the solubility of powdered honey.

Increasing the filler ratio from 1:1.5 to 1:2 improved solubility for both types of fillers. For maltodextrin, solubility increased from 93.62% in MD1 to 96.24% in MD2, while for gum arabic, it increased from 91.70% in GA1 to 93.10% in GA2. Increasing the proportion of the filler increases the portion of the matrix that can interact with water, thereby increasing the product's solubility. These results are consistent with the study by Suhag *et al.* (2021),

which showed that increasing the concentration of maltodextrin-based carriers can improve the solubility characteristics of sugar-based powdered products.

Gum arabic exhibited lower solubility values compared to maltodextrin, particularly in the case of GA1. This phenomenon is related to the structural properties of gum arabic as a high-molecular-weight branched polysaccharide capable of forming a viscoelastic film layer on the particle surface during the drying process. This layer increases resistance to water penetration during the initial stage of rehydration, thereby slowing down the dissolution process. Gum arabic tends to rapidly increase the viscosity of the solution upon hydration, which ultimately inhibits the diffusion of water molecules into the particle core. Interactions between honey components and the filler also influence the resulting matrix structure, where maltodextrin yields a more homogeneous distribution, whereas gum arabic forms a denser and more heterogeneous structure. Nevertheless, all treatments exhibited solubility values above 90%, ensuring that the resulting powdered honey retains the characteristics of an instant product with good solubility and no significant residue formation.

7. Dissolution Time

Based on the research results, the average dissolution time values (Table 2) ranged from 4.90 to 19.50 seconds. Statistical analysis revealed highly significant differences ($P \leq 0.01$) among

the treatments. The MD2 formulation produced the fastest dissolution time of 4.90 seconds, while GA1 and GA2 showed the longest dissolution times of 18.30 and 19.50 seconds, respectively. Maltodextrin has an oligosaccharide structure with a relatively low molecular weight and high hydrophilic properties, thereby accelerating the process of water imbibition into the particles. Water rapidly penetrates the matrix, causing particle disintegration and the release of simple sugar components from the honey. This condition increases the diffusion rate of the solute into the medium. An increased maltodextrin ratio enlarges the fraction of easily soluble components, thereby significantly accelerating the dissolution process. These results are consistent with a report by Samborska (2019), which states that maltodextrin can improve rehydration and accelerate dissolution in spray-dried powdered honey products.

Gum arabic formulations exhibit a longer dissolution time due to their complex, branched molecular structure. Gum arabic forms a more compact film layer on the particle surface, thereby inhibiting water penetration and slowing the disintegration process. The relatively high viscosity of the gum arabic solution also reduces the mobility of water molecules around the particles, thereby slowing the diffusion of dissolved components. The resulting matrix tends to be denser and exhibits stronger interparticle cohesion. These conditions enhance resistance to initial hydration and prolong dissolution

time. This phenomenon aligns with the findings of Maharani *et al.* (2023), who reported that filler materials with complex polysaccharide structures produce powders with slower rehydration compared to materials with simpler structures, such as maltodextrin.

The relationship between solubility and dissolution time can be observed from the results in Table 2. The MD2 treatment exhibited the highest solubility 96.24% and the shortest dissolution time 4.90s, whereas the GA treatments showed longer dissolution times of 18.30s for GA1 and 19.50s for GA2, with solubility values of 91.70% and 93.10%, respectively. These results indicate that higher solubility was generally associated with shorter dissolution time in the maltodextrin treatments. However, this relationship was not directly proportional across all treatments, as GA2 showed a slightly higher solubility than GA1 but required a longer dissolution time. The shorter dissolution time of the maltodextrin treatments can be attributed to the high water solubility of maltodextrin, which facilitates hydration and dispersion of the powder in water. In contrast, the higher viscosity developed by gum arabic during hydration may hinder the dispersion of dissolved components and prolong the dissolution process. Therefore, the dissolution performance of the powder was influenced not only by the amount of soluble material but also by the characteristics of the carrier material during hydration.

CONCLUSION

Based on the research results, the type and ratio of fillers affect the functional characteristics and rehydration properties of spray-dried honey powder. In general, the use of maltodextrin produces a powder with higher bulk density, better flow properties, higher solubility, and a shorter dissolution time compared to gum arabic. These characteristics indicate that maltodextrin provides better packaging efficiency and rehydration capacity, whereas gum arabic tends to produce powder piles with lower bulk density and a slower dissolution process due to the characteristics of the matrix formed during drying. The increase in the filler ratio from 1:1.5 to 1:2 consistently reduced powder cohesiveness, as indicated by decreases in the Hausner ratio and Carr index for both types of fillers. However, the response regarding dissolution time depended on the type of filler used. Increasing the maltodextrin ratio accelerates dissolution, whereas increasing the gum arabic ratio does not produce the same trend. These results confirm that formulation optimization is determined not only by the amount of filler but also by the characteristics of each carrier in shaping the physical properties and rehydration of the powder. The best formulation was achieved with the MD2 treatment (honey to maltodextrin ratio of 1:2), as it provided the highest packing efficiency, excellent flowability, and the fastest dissolution time, making it highly suitable for instant food applications.

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