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Physicochemical Characteristics, Amylography Profile and Infrared Spectroscopy of Stored Product Insects (SPI)-Attacked Rice Powder

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Abstract Good post-harvest management is required to minimize rice damage and loss during storage. This loss in the quality and quantity of rice is primarily caused by warehouse pests or insects, categorized as stored-product insects (SPI). The primary causes of SPI's presence in rice are rice quality, storage method, storage conditions, and the presence of larvae during the storing process. The hot and humid climate is a perfect condition for SPI to breed. Therefore, storage conditions with temperature and humidity that are not optimal will result in SPI infestation, especially as the amount of rice accumulates and the storage length increases. Rice grains were attacked by SPIs break, resulting in a powder-like byproduct (rice powder). There is little information on the physicochemical properties, microstructure, rheology, and functional properties of the SPI-attacked rice powder. Therefore, the purpose of this research was to study the physicochemical properties of SPI-attacked rice powder compared to those of SPI-attacked rice, premium quality storage rice, and premium quality commercial rice. This research used a randomized complete block design with four samples and four replications. The samples were SPI-attacked rice powder, SPI-attacked rice, premium quality storage rice, and premium quality commercial rice. The data went through Bartlett and Tukey's tests of homogeneity and additivity. Then, the data were analyzed using analysis of variance (ANOVA) and Least Significant Difference (LSD) at 5%. The results showed that SPI-attacked rice powder had physicochemical properties and amylograph profile as follows: bulk density of 0.42 g/mL, water absorption capacity of 3.87 g/g, oil absorption capacity of 3.50 g/g, degree of whiteness of 77.80, starch content of 46.30 %, protein content of 9.77 %, amylose content of 16.20 %, RVA peak viscosity at 575.67 BU, breakdown at 286.67 BU, final viscosity at 637.67 BU, setback at 353.33 BU, and gelatinization temperature at 75.77°C. The major functional groups identified via FTIR were OH, C-H, C-C and C-O.

Keywords Stored-Product Insects, Rice Powder, Characteristics

1. Introduction

Rice is a staple food for Indonesians, making its supply a priority issue. Meanwhile, the country has a massive population, reaching 275.77 million in 2022. For instance, Indonesia's total rice production in 2021 was 31.36 million tonnes, while the annual rice consumption rate per capita was 81.4 kg [1]. In the supply chain, the rice must be stored when the production rate is high, so there is a supply when the production rate is low. Good post-harvest management is required to minimize rice damage and loss during storage [2]. This loss in the quality and quantity of rice is primarily caused by warehouse pests, categorized as stored-product insects (SPI) [3]. The primary causes of SPI's presence in rice are rice quality, storage method, storage conditions, and the presence of larvae during the storing process. The hot and humid climate is a perfect condition for SPI to breed. So, storage conditions with temperature and humidity that are not optimal will result in SPI infestation, especially as the amount of rice accumulates and the storage length increases [4]. The longer the storage and the more rice there is, the more SPIs there are, thus affecting the quality of rice. The quality and quantity loss of rice due to SPIs depends on the population density of SPIs in the stored rice [5]. Rice grains were attacked by SPIs break, resulting in a powder-like byproduct (rice powder). There is little information on the physicochemical properties, microstructure, rheology, and functional properties of the SPI-attacked rice powder. Therefore, the purpose of this research was to study the physicochemical properties of SPI-attacked rice powder compared to those of SPI-attacked rice, premium quality storage rice, and premium quality commercial rice.

2. Material and Methods

2.1. Time and Place

This research was conducted from March to September 2023 in the Agricultural Products Processing Lab and the Agricultural Products Chemical Analysis Lab at the Department of Agricultural Product Technology, Faculty of Agriculture University of Lampung and Starch Lab, National Innovation Research Agency.

2.2. Tools and Materials

The tools used include grinder, measuring cups, analytical scales and other tools. The instruments used to carry out sample analysis consist of UV- Vis spektrofotometer, sentrifuge, brabender, colorimeter, vortex, oven, Fourier Transform Infra Red (FTIR), desicator, furnaces and other equipment. The materials used are stored-product insects (SPI)-attacked rice powder, SPI-attacked rice, premium quality storage rice and premium quality commercial rice obtained from the Tanjung Karang market in Bandar Lampung.

2.3. Design

This research used a randomized complete block design with four samples and four replications. The samples were SPI-attacked rice powder (sample A), SPI-attacked rice (sample B), premium quality storage rice (sample C), and premium quality commercial rice (sample D). The data went through Bartlett and Tukey's tests of homogeneity and additivity. Then data were subjected to Analysis of Variance (ANOVA) and Least Significant Difference (LSD) at 5%.

2.4. Preparation

Preparation of the SPI-Attacked Rice Powder Sample

As much as 300 grams of SPI-attacked rice powder were taken, then sifted to remove the dirt. The flow chart of the process for preparing SPI-attacked rice powder sample is presented in Figure 1.

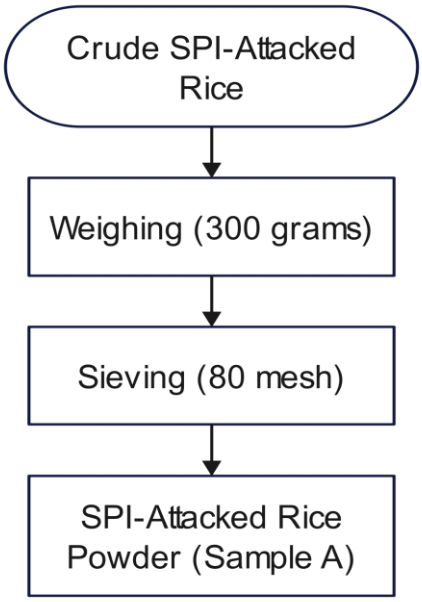


Figure 1. Flow chart preparation of the SPI-attacked rice powder sample

Preparation of the Comparison Rice Samples

The samples for comparison included SPI-attacked rice, premium quality stored rice, and premium quality commercial rice. To obtain the sample, the rice was grounded by using a grinder until fine, then sifted by using the 80 mesh. The flow diagram of the process for preparing comparison rice samples is presented in Figure 2.

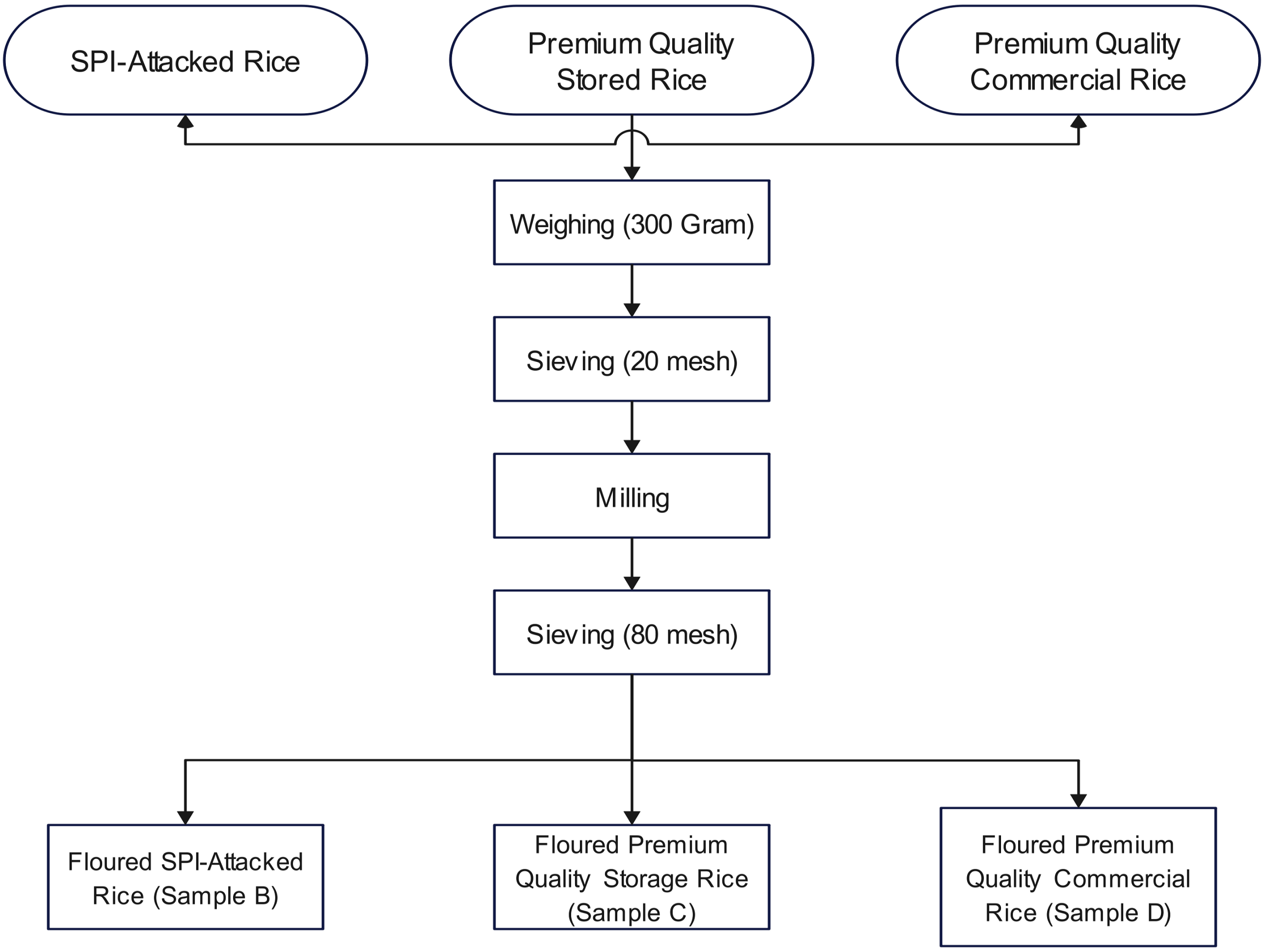


Figure 2. Flow chart preparation of the comparison rice samples

2.5. Observation

Samples before milling were identified for the total damaged rice, total rice powder and total imago. SPI-attacked rice powder sample, floured SPI-attacked rice, floured premium quality storage rice and floured premium quality commercial rice were subjected to physicochemical properties (bulk density, water absorption capacity, oil absorption capacity, whiteness degree, starch content, protein content and amylose content), amylograph profile analysis and infrared spectroscopy (FTIR) analysis.

3. Results and Discussion

3.1. Sample Identification

The appearance of samples used for this experiment was shown in Figure 3a-d. Identification of the samples before milling included total damaged rice (broken or with holes), total rice powder, and total imago in 100 g of each sample.

The results showed that the total damaged rice in 100 g of SPI-attacked rice was 72.71 g. This highest number was followed by the total damaged rice in SPI-attacked rice powder (3.54g/100g), premium quality storage rice (1.09g/100g), and premium quality commercial rice (0.94g/100g). The SPI-attacked rice is categorized as damaged based on the national standards in SNI 6128:2015 that states the maximum amount of total broken or holey rice for medium quality rice 3 is 35g/100g. SPIs cause various damages, such as food contamination with dead or live insects, damage in fragments, and reduced nutritional value of stored products, especially dry stored products [2], [6]. Data samples identification is presented in Table 1.

Figure 3a. SPI-Attacked Rice Powder

Figure 3b. SPI-Attacked Rice

Figure 3c. Premium Quality Stored Rice

Figure 3d. Premium Quality Commercial Rice

Table 1. The Percentage of damage rice, powder and total imago per 100 g of initial samples

Sample	Damaged rice (g/100 g)	Rice powder (g/100g)	Total imago (imago/100 g)
SPI-Attacked Rice Powder	3,54 ±0,67[a]	76,93 ±0,51[a]	19,05 ±0,58[a]
Floured SPI-Attacked Rice	172,71 ±0,45[c]	16,87 ±0,88[c]	5,34 ±0,96[c]
Floured Premium Quality Storage Rice	1,09 ±0,68[b]	1,74 ±0,59[b]	0[b]
Floured Premium Quality Commercial Rice	0,94 ±0,94[b]	1,53 ±0,62[b]	0[b]

Remarks: Numbers followed by the same letter in the same column are not significantly different (α=5%)

Sample identification showed that the total rice powder in the SPI-attacked rice powder was 76.93g/100g. This highest number was followed by the total rice powder in SPI-attacked rice (16.87g/100g), premium quality storage rice (1.74g/100g), and premium quality commercial rice (1.53g/100g). The SPI-attacked rice is categorized as damaged because, based on SNI 6128:2015, the maximum amount of chalky powder for medium-quality rice 3 is 5g/100g. If attacked by SPIs, rice grains will have holes from insect bites and be porous and fragile. In severe cases, only the outer layer of the rice grain remains [7]. Rice damage can also be caused by the metabolic activity of larvae in rice [7]. The next quality component observed was the presence of rice weevil (*Sitophilus oryzae*) imago in the samples. The total imago in SPI-attacked rice powder and SPI-attacked rice were 19.05g/100g and 5.34g/100g, respectively. SNI 6128:2015 states that the maximum amounts of foreign objects (in this case, rice weevil imago) for medium-quality rice 3 is 0.2g/100g. As mentioned before, rice damage due to SPIs depends on the amount of SPIs; so, the higher the population density of SPIs has, the worse the damage will appear [3].

3.2. Physicochemical Properties

The results of physical analysis (bulk density, water absorption capacity, oil absorption capacity and whiteness degree) are presented in Table 2 and the results of chemical analysis (starch content, protein content and amylose content) are presented in Table 3.

Bulk density is one of the most important physical properties of rice because it is a factor in storage, transport, and market. Bulk density is measured by dividing the net weight of rice by the volume of the container. From an economic perspective, low bulk density is preferred for rice. Low bulk density means less product is needed to fill a container [8].

Water absorption capacity refers to the ability of a material to absorb water and associate with water molecules [9], [10]. The results revealed that SPIs had a significant impact on the water absorption capacity of rice. Based on the LSD test, it was found that the water absorption capacity of SPI-attacked rice powder was higher than other samples and significantly different from other rice samples. This significant difference might have been caused by the difference in the protein content of the samples. Another factor was the difference in particle structures and other chemical components that affect water absorption.

An ability to absorb water indicates the presence of many hydrophilic groups in the starch molecules. The water absorption capacity of a food product will impact its tenderness, softness, and viscosity [11], [12]. SPI-attacked rice powder had the highest water absorption capacity with 3.87 g/g. This result might be caused by the high protein content in SPI-attacked rice powder. High protein content tends to result in strong hydrogen bonds due to a polarized or charged side chain in the chemical structure, causing high water absorption capacity [13]. Hydration is reached when the starch molecules and the protein make a hydrophobic interaction, as well as the hydrogen bonds with the water molecules.

Oil absorption capacity was measured to determine a sample's capacity to absorb oil at room temperature. The results of this research showed that SPI-attacked rice powder had the highest oil absorption capacity at 3.50 g/g. Meanwhile, the lowest number belonged to premium quality storage rice at 2.12 g/g. This difference might be caused by the protein content. Like water absorption capacity, oil absorption capacity depends on the protein structure of the sample. The protein structure that supports oil absorption is lipophilic or with non-polar amino acids [14]. Low protein content will result in low oil absorption capacity and vice versa. Oil and water absorption capacities are also similar in that the ability of the starch granule structures to break affects the amount of oil absorbed. Therefore, the breaking of starch granules will break open the existing hydrophobic structures and allow the starch to bind oil [15].

Table 2. Results of physical analysis

Sample	Bulk density (g/mL)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Whiteness degree
SPI-Attacked Rice Powder	0,422 ±0,01^{a}	3,87 ±0,63^{b}	3,50 ±0,41^{b}	77,80 ±0,52^{a}
Floured SPI-Attacked Rice	0,835 ±0,01^{bc}	3,12 ±0,48^{ab}	2,50 ±0,41^{a}	88,88 ±0,33^{b}
Floured Premium Quality Storage Rice	0,830 ±0,02^{b}	2,50 ±0,75^{a}	2,12 ±0,25^{a}	92,49 ±0,56^{c}
Floured Premium Quality Commercial Rice	0,858 ±0,01^{c}	2,88 ±0,41^{ab}	2,38 ±0,25^{a}	95,41 ±0,24^{d}

Table 3. Results of chemical analysis

Sample	Starch contents (%)	Protein contents (%)	Amylose contents (%)
SPI-Attacked Rice Powder	46.30 ±4,15^{a}	9.77 ±0,52^{b}	16.20 ±0,14^{a}
Floured SPI-Attacked Rice	75.80 ±0,49^{b}	5.06 ±0,21^{a}	27.61 ±0,42^{d}
Floured Premium Quality Storage Rice	69.93 ±7,21^{b}	5.33 ±0,15^{a}	22.13 ±0,13^{b}
Floured Premium Quality Commercial Rice	76.77 ±2,94^{b}	5.09 ±0,09^{a}	23.69 ±0,33^{c}

Color analysis was done by using the chromameter tool. Based on the brightness value table (L*), the results varied. The highest score belonged to premium quality commercial rice (95.41), and the lowest score belonged to SPI-attacked rice powder (77.80). This means that the premium quality commercial rice sample had a color that was close to white. The low degree of whiteness of SPI-attacked rice powder indicates that the damage done to rice impacts its color. Mold had grown on SPI-attacked rice powder. Mold growth is caused by storage conditions, namely an increase in water content and humidity [16]. The signs of moldy rice are that it has clumpy and yellowing appearance. Its clumpy and yellowing appearance. Rice contains glucose and protein, so storing it at high humidity causes the glucose-reactive carbonic groups to react with the nucleophilic amino acid groups in the Maillard reaction. The Maillard reaction results in a product that is yellowish to brownish [17]. The low degree of whiteness of SPI-attacked rice powder might also be caused by the insect activity that destroyed the outer layer of rice (aleurone) [18].

The results showed that rice damage due to SPIs had a significant effect on the starch content of rice. The starch contents of the samples ranged from 46.30 – 76.77%, with the highest found in premium quality commercial rice and the lowest in SPI-attacked rice powder. The starch content was measured to determine the effects of SPIs on the carbohydrate content of rice. The degradation might be due to the SPIs eating the starch as a food source to survive. Each hole in the rice grain will have eggs inside, and the female insect will cover the hole with gluey starch leftover. The glue is the saliva of the insect, containing an amylase enzyme that might lower the starch content of rice. It is the enzyme insects that help them break carbohydrates into simpler compounds when they use rice as a source of nutrition [19]. The main carbohydrate in rice is starch, comprised of amylose and amylopectin, which have different characteristics. Amylose lends to the hard characteristic of rice, while sticky amylopectin lends to the gel formation.

The analysis results on amylose content showed significant differences between the four samples. The sample with the highest amylose content was the SPI-attacked rice, with 27.61%, while the lowest was the SPI-attacked rice powder, with 16.20%. Rice with high amylose content tends to be harder due to its water absorption characteristics during cooking. The difference in results might be due to the hydrolysis of amylose by the α-amylose enzyme. The α-amylose enzyme stays active during storage even though its activity tends to decrease over time. The conditions that support the amylolytic enzyme are temperature and humidity because the enzyme is also hydrolytic [20]. If the amylose content is high, then the amylopectin content is low. Amylopectin is a starch component with a double bond in its structure. The α-amylose enzyme works in two phases. The first phase is the breaking of amylose into maltose and maltotriose in a random manner. This degradation happens very quickly and is followed by the rapid decline of viscosity. The second phase is the last formation of glucose and maltose, which does not happen randomly. Both phases are the actions of the α-amylose enzyme on amylose molecules. In the amylopectin molecules, α-amylase produces glucose, maltose, and α-dextrin in a limited amount, as well as oligosaccharide that consists of four or more glucose with α-1.6-glycosidic bonds.

3.3. Amylography Profile

The amylograph profile revealed the characteristics of starch during the heating and cooling process as reflected in the changes in its viscosity. Table 4 and Figure 4 show the amylograph profiles of the samples in this research. Based on the results, premium quality commercial rice had the highest peak viscosity value. Peak viscosity refers to the highest viscosity achieved during heating and is related to the expansion of the starch granules. Meanwhile, pasting temperature refers to the temperature reaching when they start expanding. The pasting temperature reveals that an easy water absorption process leads to the low pasting temperature of starch. The stronger the bonds of starch molecules, the hotter they need to get to break them, raising the pasting temperature [21]. The low pasting temperature of premium quality commercial rice showed that the starch in that sample was easier to gelatinize than others. On the other hand, setback viscosity reflects the starch's resilience against retrogradation [22]. When the starch paste is cold, the maximum viscosity rises due to the gel formation caused by the inter-molecule interaction involving amylose and amylopectin [23]. The breakdown value depends not only on the amylose and amylopectin contents but also on the fat, protein, ash, and fiber contents. The low breakdown value of SPI-attacked rice powder showed that the starches in the sample were more resilient against retrogradation than others.

Table 4. Results of amylography profile analysis

Sample	PT (°C)	PV (BU)	FV (BU)	HF (BU)	BD (BU)	SB (BU)
SPI-Attacked Rice Powder	75,77 ±1,30[c]	575,67 ±81,40[a]	637,67 ±207,32[a]	289,00 ±98,42[a]	286,67 ±23,01[a]	353,33 ±111,51[a]
Floured SPI-Attacked Rice	79,57 ±0,50[c]	5580,33 ±85,59[b]	7345,00 ±125,19[c]	3695,00 ±225,08[c]	1885,33 ±177,65[b]	3741,67 ±109,60[c]
Floured Premium Quality Storage Rice	75,31 ±0,62[b]	5493,33 ±352,16[b]	3838,33 ±135,51[b]	1890,33 ±59,72[b]	3621,67 ±323,63[c]	1949,67 ±83,76[b]
Floured Premium Quality Commercial Rice	71,56 ±0,71[a]	6699,33 ±258,25[c]	3899,00 ±27,50[b]	1982,33 ±123,87[b]	4717,00 ±188,75[d]	1915,33 ±94,07[b]

Description:

PT = *pasting temperature*

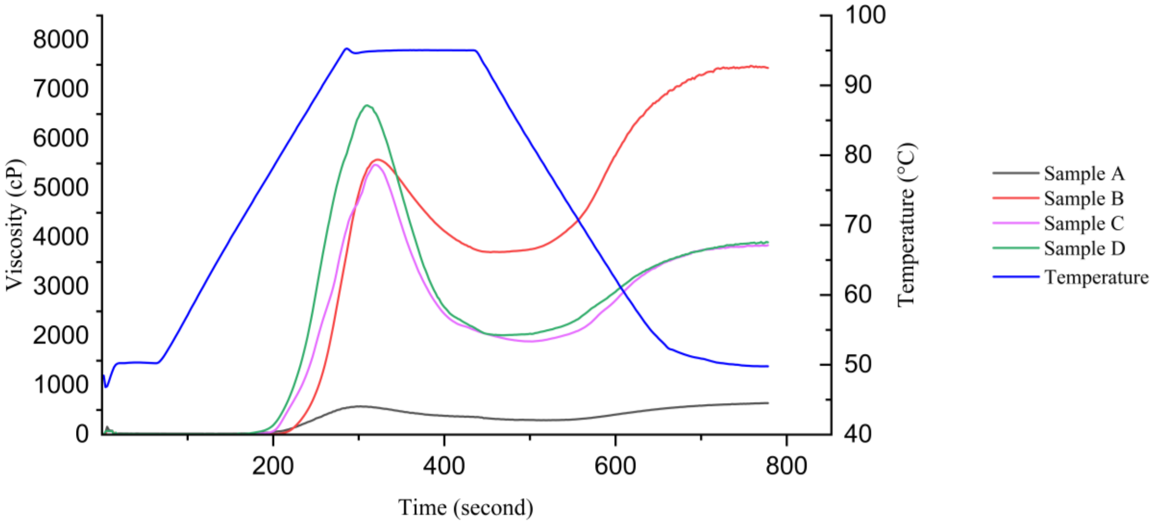
PV = *peak viscocity*

FV = *final viscosity*

HF = *hold viscosity*

BD = *breakdown*

SB = *setback*



Information:

Sample A: SPI-Attacked Rice Powder

Sample B: Floured SPI-Attacked Rice

Sample C: Floured Premium Quality Storage Rice

Sample D: Floured Premium Quality Commercial Rice

Figure 4. Amylograph profiles of various samples

All samples had different pasting characteristics (peak, time and temperature). The pasting and swelling properties of each starch are controlled by the amylopectin structure, the starch composition, and the granule structure. When a starch is heated with water hotter than the pasting temperature, the starch granules with high amylopectin content will swell more than the ones with low amylopectin content. Particle size plays an important factor in dough hydration and water absorption [24]. During heating in the RVA test, the pasting temperature of amylopectin is reached, and the viscosity rises to peak viscosity. In that process, the granules are hydrated and swelling, releasing amylose and amylopectin. If the peak viscosity declines, it signifies the decreased capacity of the starch granules to hold water. Rice with high amylose content has a lower breakdown value, signifying the higher stability of the starch granules.

The results showed that premium quality storage rice and SPI-attacked rice had similar peak viscosity values of 5493.33 BU and 5580.33 BU, respectively. Starch content of SPIs attacked rice powder is also much lower if compared to those of other samples. The higher the protein content is, the lower the viscosity is.

The higher the protein content of rice is, the more protein bonds there are in the starch (amylose), inhibiting the release of amylose and requiring more energy for the release to happen [25]. After peak viscosity is reached, the viscosity of starch declines drastically due to the disintegration of the granules and the release of the polymer of the dissolved starch from the swollen granules to the solution. How much viscosity affects the swelling power and the breakdown value depends on the type and amount of starch, the temperature gradient, the friction property, and the mixture composition [26]. Breakdown viscosity is the difference between peak viscosity and trough viscosity to determine the pasting properties. Premium quality commercial rice had the highest value of breakdown viscosity (4717.00 BU), while the SPI-attacked rice powder had the lowest (286.67 BU). A high breakdown viscosity indicates that the paste tends to harden at the end of the cooking process, preventing the products from easily disintegrating.

The final viscosity is a parameter measured to determine starch's pasting properties at a cool temperature (50^{o}C). In this research, the final viscosity value belonged to SPI-attacked rice with 7345.00 BU. The increase in viscosity during the cooling period shows a tendency for the amylose in the hot paste to reassociate when the temperature decreases [27]. Meanwhile, setback viscosity refers to the difference between final viscosity and trough viscosity. The highest increase of viscosity due to the cooling process (setback viscosity) in this research happened to SPI-attacked rice with a value of 3741.67 BU. On the other hand, the lowest value belonged to SPI-attacked rice powder with 353.33 BU. A high setback indicated that the starch molecules did not form a compact conformational isomerism. This structure caused an increase in retrogradation tendency due to the increase of soluble amylose needed in the retrogradation process. During this process, the amylopectin and amylose chains were aligned to form a stronger crystallization [28].

Conversely, a low setback viscosity value shows low retrogradation activity. Starch retrogradation can change the pasting properties of a starch. It can also strengthen the paste, cause the starch paste to lose water absorption capacity, and reform large crystalline [29]. These changes are usually unwanted in starch-or-flour-based food products because they can change the structure and sensory properties of the products, such as breakfast cereals or parboiled rice. Starch retrogradation can make the product tough or not sticky enough. Samples with high starch retrogradation are unsuitable for application on products requiring low breakdown and high viscosity, like instant soup powder that must be rehydrated before consumption [30]. Samples with low peak viscosity and high breakdown can be used for products that require sufficient viscosity when cold. In this research, SPI-attacked rice powder had the lowest viscosity among other samples. Therefore, this sample would not be suitable for viscous products. Starch gelatinization occurred at varying temperatures. Premium quality commercial rice had the lowest gelatinization temperature at 71.56^{o}C while SPI-attacked rice powder had the highest (79.57^{o}C). Starch gelatinization temperature refers to the temperature when the starch's viscosity starts to increase during heating at the beginning of the gelatinization process. The variation occurs due to the variation in size, shape, and amount of energy needed for the starch to swell. Gelatinization temperatures can be noted once the starch granules start breaking. The lower the gelatinization temperature is, the shorter the gelatinization process is. Viscosity is an important parameter that impacts the quality of many food products. It shows a fluid's resistance to flow because it requires energy to destroy strong molecular structures between solids and fluids [31].

3.4. Infrared Spectroscopy

The spectrums from the Fourier Transform Infra-Red (Figure 5) showed similar patterns across all samples. This indicated that no samples underwent any significant changes in their functional groups/chemical structures.

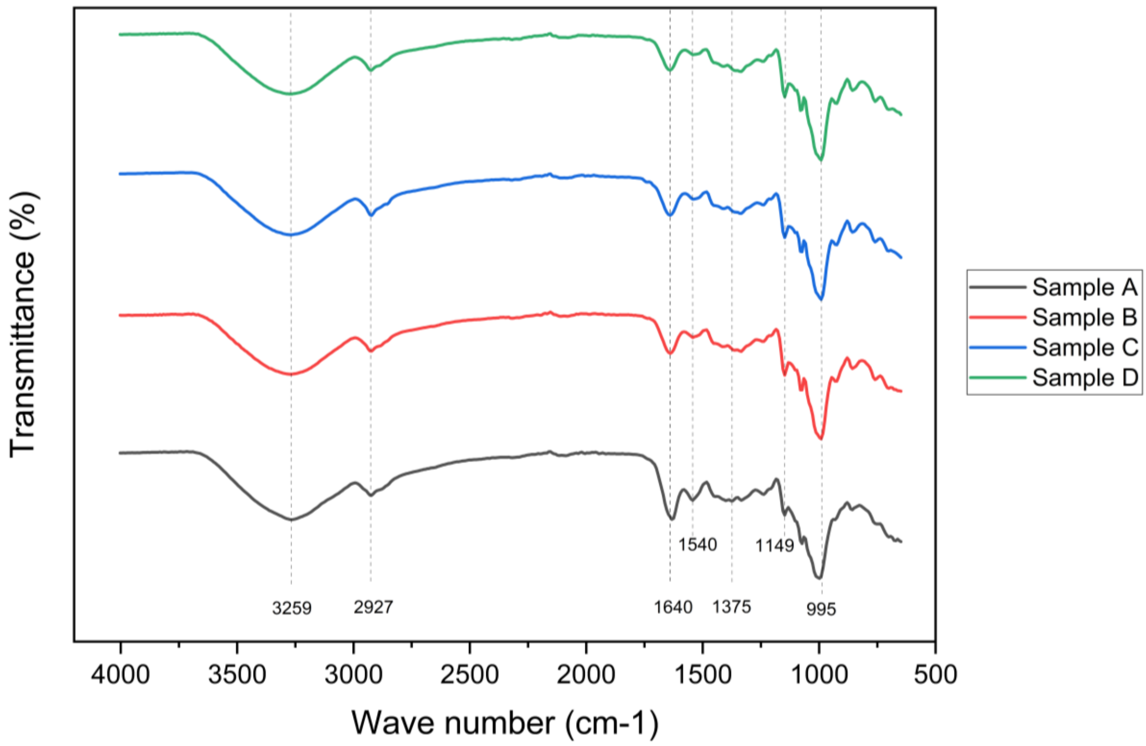


Figure 5. Fourier transform infra red (FTIR) spectra of various samples

Information:
Sample A: SPI-Attacked Rice Powder
Sample B: Floured SPI-Attacked Rice
Sample C: Floured Premium Quality Storage Rice
Sample D: Floured Premium Quality Commercial Rice

Despite displaying similar patterns, SPI-attacked rice powder had a lower absorbance intensity than others. The decrease in intensity indicated conformational changes [32]. FTIR analysis on starch could inform us of the structure regularity of starch closest to the grain surface due to FTIR's limited ability to penetrate the starch grain, 2μm deep maximum [33]. The data could then inform us of what changes happened to the samples. Then, graphics were made from the data obtained, and peak analysis was done by using the OriginPro 2023 software.

The chemical functional groups of the rice samples could be seen based on the absorbance peaks. All rice samples reached peak absorbance at the wavelength of about 3259 cm^{-1}, signifying the presence of the –OH group. The stretching vibration of the C—H group was also seen on all rice samples, marked by the peak occurring at 2927 cm^{-1}. According to [34], the absorption peak at 3000 – 2900 cm^{-1} indicated the presence of the C—H functional group. In this research, a sharp peak at 1640 cm^{-1} and a peak at 1540 cm^{-1} could be seen on all samples. These peaks signified the presence of amide I and amide II groups that came from non-starch components like fat and protein. These peaks also indicated that the samples had low starch purity. This might happen because the samples were rice powder instead of rice starch, containing other non-starch components, as read on the FTIR. Absorbance at 1100 – 800 cm^{-1} with a strong peak at 995 cm^{-1} could also be seen in this research. Absorbance at those wavelengths indicated the presence of the C—C, C—O, and C—H functional groups. Meanwhile, the small peak at 930 cm^{-1} signified the presence of α glycosidic bond (1→4).

The analysis results showed that there was no peak difference between samples A, B, C, and D. This explained that even though the rice was attacked by SPIs and turned into rice powder, the conformation of the functional groups in the starch did not experience change as indicated by the absence of new peaks or the loss of existing peaks on sample A and B. These results were in line with the research [35]. that stated that the physical modification of *indica* rice did not cause any changes in the conformation of functional groups of rice starch because it only affected the crystallinity. The same thing might also happen to rice damaged by SPIs.

The FTIR can also measure the crystallinity of the starch granule surface by calculating the difference between the absorption bands at 1047 cm^{-1} and 1022 cm^{-1}. According to [36], the infrared absorption at 1047 cm^{-1} is related to the regularity and crystallinity of the starch granules because infrared absorption increases along with crystallinity. On the other hand, the absorption band at 1022 cm^{-1} is caused by the amorphous region of starch granules because the absorption at that wavelength decreases while the starch crystallinity increases.

4. Conclusions

The attack of stored product insects on rice that resulted in SPI-attacked rice powder impacted physicochemical properties and amylograph profile, bulk density, water absorption capacity, oil absorption capacity, degree of whiteness, starch content, protein content and amylose content. The results showed that SPI-attacked rice powder had physicochemical properties and amylograph profile as follows: bulk density of 0.42 g/mL, water absorption capacity of 3.87 g/g, oil absorption capacity of 3.50 g/g, degree of whiteness of 77.80, starch content of 46.30 %, amylose content of 16.20 %, RVA peak viscosity at 575.67 BU, breakdown at 286.67 BU, final viscosity at 637.67 BU, setback at 353.33 BU, and gelatinization temperature at 75.77^{o}C. The major functional groups identified via FTIR were OH, C-H, C-C and C-O.

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