Gelatinization and Rheological Properties of Blend of Defatted Rice Bran and Broken Rice

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Abstract. Defatted rice bran (DRB) and broken rice (BR) are by-products with large output in rice processing, but without being utilized properly. In order to strengthen the utilization of rice bran and broken rice, the pasting and rheological properties of the binary mixture of defatted rice bran-broken rice flour closely related to the adjustment of equipment and process parameters were studied. The results show that the peak viscosity, valley viscosity and final viscosity reduced during gelatinization, and the decrease increased first and then decreased with the rise of the proportion of defatted rice bran in the mixed system. Moreover, the addition of defatted rice bran may reduce the gelatinization temperature, attenuation value and setback value, reduce the difficulty of gelatinization and improve the stability of the mixed system. The conclusion revealed the binary mixture of defatted rice bran and broken rice flour belongs to pseudoplastic fluid, and the rheological properties are in accordance with the power law equation. The apparent viscosity of the binary mixture of defatted rice bran and broken rice flour is significantly affected by different mixing ratio, particle size and gelatinization temperature (P < 0.05).

1. Introduction
Rice is one of the main food crops in my country, with an annual output of more than 200 million tons [¹]. As a staple food, rice produces about 20% of rice husk, 15% of broken rice and 10% of rice bran and other by-products in the process of processing rice, such as abundant fraction of medium-sized broken rice from the rice milling process [²]. The rice bran enriches 80% of the nutrients, in which the composition of the broken rice is basically similar to that of whole rice, containing high-quality plant protein, starch, and a large number of B vitamins and minerals [³-⁵]. The content of oryzanol in rice bran is very rich. Oryzanol has anti-aging, anti-lipid oxidation, hypolipidemic, endocrine regulation, growth promotion and other physiological effects [⁶]. The utilization rate of rice bran nowadays is less than 10%, and the utilization rate of broken rice is less than 16%, and most of them are used as feed, which causes a great waste of food [⁷, ⁸]. At present, the utilization of rice bran and broken rice is gradually expanding at home and abroad, but there is little research on the aspects related to processing characteristics. The experimental team performed degreasing treatment on rice bran in the early stage. The results of the previous study showed that defatted rice bran has a longer storage period, which is convenient for its subsequent processing and utilization [⁹]. In the paper, the defatted rice bran was used to mix with broken rice flour (regarding as binary mixture, namely DRB-BR mixture), and combine the process of heating, mixing, and cooling in the food production process to form a gel food. Meanwhile, the rheological
characteristics were studied in order to provide a theoretical basis for the processing and production process parameters.

2. Materials and methods

2.1. Materials
Defatted rice bran (Defatted Rice Bran, DRB, obtained through the laboratory, passed through 80 meshes sieve); incomplete broken rice (BR) and raw rice bran were provided by Longding Agriculture Co., Ltd. (Zhalai town, Inner Mongolia). Defatted rice bran-broken rice flour mixing system consists of different proportions of defatted rice bran (DRB) and broken rice (BR) constitute (after referred to as DRB-BR mixed system or binary mixture).

2.2. Methods

2.2.1. Gelatinization parameters measurement. Gelatinization properties were determined using starch gelatinization viscosity tester (FDV-E, Shanghai Nirun Intelligent Technology Co., Ltd. China) with Standard test (GB/T 14490-19931 method). The temperature program of the gelatinization test was set as follows: the start is at 50°C, after holding for 2 minutes, the temperature is increased to 95°C at a rate of 7.5°C/min, and then maintained at 95°C for 6 minutes, and then the temperature is reduced to 50°C at the same speed. The temperature program was conducted to use water bath (HH-2, dual-hole digital display, Shanghai Fuma Experimental Equipment Co., Ltd., China). All the experiments were performed in triplicate samples parallelly.

2.2.1.1 Gelatinization characteristics of different broken rice granule size Prepare the DRB-BR mixed system according to the method in 2.2.1, fix the mass fraction of defatted rice bran and rice granule to DRB25-BR75, and change the rice granule size in the range from 80 mesh, 120 mesh, 160 mesh, to 200 mesh. The granule size was obtained by standard sieves (Zhejiang Shangyu Daoxu Zhangxing Screen Factory, China). The rest of the steps are the same as above.

2.2.1.2 Gelatinization characteristics of different mixing ratios DRB and BR (100 meshes sieve) were added into deionized water and stirred evenly to prepare the suspension with wet base water content \( w = \frac{W_{DB}(DRB-BR)}{W_{total}} = 14\% \), where \( W_{DB} \) (DRB-BR) was the mass of the mixed DRB-BR powder, and \( W_{total} \) was the total mass of suspension. The mass ratio of DRB and BR were (0:100%, namely pure broken rice flour), (25%:75%), (50%:50%), (75%:25%) and (100%:0, namely pure rice bran), which were denoted as DRB0-BR100, DRB25-BR75, DRB50-BR50, DRB75-BR25 and DRB100-BR0, respectively. Directly after the gelatinization test the resulting mixture paste was subjected to further rheological study.

2.2.2. Rheological measurement. The rheological properties of the binary mixture of DRB-BR was performed using a rheometer (Mars II, Thermo-Haake, Germany) with cone-plate measuring geometry (diameter 35mm, angle 2°, gap size 0.105mm). A sweep frequency test was performed in the linear viscoelastic range and in the angular frequency range of 1~100 rad/s.

2.2.2.1 Rheological properties of different mixing ratios. According to the method of 2.2.1.2, the DRB-BR mixing system with different mixing ratios was prepared, and then placed in a 90°C water bath to gelatinize for 40 minutes. After taking it out and cooling to room temperature, start to measure the rheological properties of the cold paste.

2.2.2.2 Rheological properties of different rice granular size. According to the method 2.2.1.2, the DRB-BR mixed system of different size of rice granular by use of different meshes sieve was prepared, and then placed in a 90°C water bath to gelatinize for 40 minutes. After taking it out and cooling it to room temperature, the rheological properties were tested.
2.2.2.3 Rheological properties under different heating temperatures. Prepare DRB-BR mixed powder with different mixing ratios according to the method of 2.2.1.1, and then heat them in a water bath at 20°C, 40°C, 60°C, 80°C, and 100°C for 40 minutes, and take them out and cool down to room temperature. Testing of rheological properties.

2.2.2.4 Steady state shear measurement. Choose the CC26Ti cylindrical probe and the matching sample cup, take a proper amount of sample and place it in the sample cup, test temperature at 25°C, measure the change in the apparent viscosity ($\eta$) of the sample within the range of 0~20s$^{-1}$ for the shear rate ($\gamma$), and measure in triplicate samples parallelly. Take the mean value and use the power law equation to regression fit the data points of apparent viscosity and shear rate $^{[10, 11]}$. The power law is formula $\eta = K\gamma^{n-1}$ as shown. The consistency coefficient is denoted as K in the formula, which represents the measurement of the viscosity of the sample, and flow index is denoted as n, which represents the degree of deviation from Newtonian fluid. The fluid is classified as an ideal Newtonian fluid with the value of $n=1$. On the other hand, pseudo-plastic fluid with a value of $0<n<1$, as which its apparent viscosity decreases with the increase of the shear rate. Moreover, the fluid is attributed to swelling plastic with $n>1$, which means the apparent viscosity increases with the rise of the shear rate $^{[12-15]}$.

2.3. Statistical analysis. All the experiments were performed in triplicate and the results are presented as the mean ± standard deviation. Data and diagram followed by the experiments analysis were established with Excel and Spss19.0 software, the least significant difference as well as regression fitting on the data were performed using Origin8.0 software (Stat Soft Inc., USA). Significance level was set at 0.05, and statistical differences were considered as significant for $p < 0.05$.

3. Results and discussion

3.1. Gelatinization characteristics

Gelatinization temperature (Temp$_G$) refers to the temperature corresponding to the onset of viscosity, indicating the difficulty of gelatinization$^{[16]}$. Peak viscosity (VP) reflects the degree of expansion of starch granules during gelatinization, which is related to the content of amylopectin and the size of starch granules. The greater the degree of expansion, the higher the corresponding peak viscosity (VP)$^{[17-19]}$. Valley viscosity (VV) reflects the shear resistance of the tested sample under high temperature gelatinization conditions. Final viscosity (VF) indicates the ability of the tested sample to form paste or gel after cooling. Breakdown is the difference between peak viscosity and valley viscosity (VV). The smaller the breakdown value is, the better the thermal stability of the sample is. Setback (S) refers to the difference between the final viscosity (VF) and the lowest viscosity. The smaller the setback value is, the better the cold paste stability of the tested sample is and the sample is not easy to aging$^{[10, 20, 21]}$.

3.1.1. Gelatinization characteristics with different mixing powder ratio. The data in table 1 showed that the gelatinization temperature of the mixed system was lower than that of the mixed system after adding DRB, indicating that it entered the gelatinization state earlier, and the gelatinization temperature was the lowest, indicating that pure rice flour was easy to gelatinize, but the peak viscosity of pure rice flour was too large, which was beyond measurable range of the instrument, and indicating that it was difficult to grasp the ability of pure rice flour to form sticky or gel after ripening and cooling. After adding DRB, the pasting time and temperature of the mixed system were relatively higher than those of the pure BR component, but they decreased with the rise of DRB addition ($P<0.05$). The viscosity of DRB-BR reduced as an overall downward shift, that is, the peak viscosity, valley viscosity, final viscosity, attenuation value and setback value were all significantly decreased compared with those of BR single component ($P<0.05$), indicating that appropriate addition of DRB could avoid the problem of excessive viscosity caused by BR pure component, which was beneficial to the stability of hot paste and cold paste. However, when DRB was added too much, the shear resistance and the ability to form sticky or gel of the mixed system were poor. Therefore, the use of DRB or BR alone was not conducive
to the control of food production conditions, and the mixed use of DRB and BR was more conducive to the improvement of food processing and quality.

### Table 1 Gelatinization characteristic parameters of Binary DRB-BR Blend with different blending percentage

| Mixing ratio     | T<sub>gel</sub>(min) | T<sub>peak</sub>(℃) | V<sub>F</sub>(mPa·s) | V<sub>V</sub>(mPa·s) | A(mPa·s) | V<sub>F</sub>(mPa·s) | S(mPa·s) |
|------------------|-----------------------|----------------------|----------------------|----------------------|---------|----------------------|---------|
| DRB0-BR100       | 6.71<sup>a</sup>       | 71.1<sup>a</sup>     | —                    | —                    | —       | —                    | —       |
| DRB25-BR75       | 7.95<sup>e</sup>       | 85.0<sup>e</sup>     | 11.0<sup>a</sup>     | 849.3<sup>d</sup>    | 418.5<sup>d</sup>| 430.8<sup>d</sup>| 1068.3<sup>d</sup>|
| DRB50-BR50       | 7.89<sup>d</sup>       | 82.6<sup>d</sup>     | 12.2<sup>c</sup>     | 600.1<sup>c</sup>    | 324.3<sup>c</sup>| 275.6<sup>c</sup>| 748.4<sup>c</sup>|
| DRB75-BR25       | 7.23<sup>c</sup>       | 79.3<sup>c</sup>     | 12.4<sup>d</sup>     | 338.0<sup>b</sup>    | 214.5<sup>b</sup>| 123.6<sup>b</sup>| 390.8<sup>b</sup>|
| DRB100-BR0       | 6.12<sup>a</sup>       | 69.1<sup>a</sup>     | 12.6<sup>b</sup>     | 193.8<sup>a</sup>    | 147.6<sup>a</sup>| 46.2<sup>a</sup>  | 261.1<sup>a</sup>|

Note: The superscript letters in the same column indicate that the differences are significantly different ($P<0.05$).

#### 3.1.2. Gelatinization characteristics with different rice granule size.

It can be seen from the data in table 2 that when the BR particle size was 80 meshes sieve, the required gelatinization temperature of the mixed system was the highest and the time to reach the gelatinization temperature was the longest. With the decrease of the BR particle size, the gelatinization temperature of the mixed system was significantly reduced and the time to reach the gelatinization temperature was also significantly shortened. It can be seen that the smaller the BR particle size was, the more easily the mixed system was gelatinized. Studies have shown that this may be related to the particle size of starch granules. The closer the accumulation of starch granules is, the more difficult the gelatinization is and the higher the gelatinization temperature is<sup>[20]</sup>. The smaller the BR particle size, the shorter the time to reach the peak viscosity, the greater the degree of expansion of BR starch, the smaller the peak viscosity, valley viscosity, final viscosity, attenuation value and setback value, that is, the shear resistance of the mixed system and the ability to form viscosity or gel after cooling are better, and the stability of hot paste and cold paste are improved. Some conclusion<sup>[18]</sup> in which many physicochemical properties of starch, such as swelling capacity, gelatinization and gelation ability, are related to the average particle size of starch were consistent with the experimental results.

However, when the BR particle size is 200 mesh, the gelatinization temperature required by the mixed system is the lowest and the time required to reach the gelatinization temperature is the shortest. The mixed system is the most easy to gelatinize, but the viscosity after gelatinization is too large, which is beyond the measurement range of the instrument. It shows that in actual production, too fine grinding of rice flour will make the viscosity too large to affect the ability of the mixed powder material to form sticky paste and gel after ripening and cooling, thus further affecting the taste of the mixed powder food after being cooked.

### Table 2 Gelatinization Characteristics with different granules size of BR

| Granule size (meshes sieve) | T<sub>gel</sub>(min) | Temp<sub>G</sub>(℃) | T<sub>peak</sub>(min) | V<sub>F</sub>(mPa·s) | V<sub>V</sub>(mPa·s) | A(mPa·s) | V<sub>F</sub>(mPa·s) | S(mPa·s) |
|-----------------------------|----------------------|---------------------|----------------------|----------------------|----------------------|---------|----------------------|---------|
| 80                          | 10.9<sup>c</sup>     | 96.1<sup>c</sup>   | 12.1                 | 138.7<sup>a</sup>   | 50.0<sup>a</sup>   | 88.7<sup>a</sup>| 120.8<sup>a</sup>| 70.8<sup>a</sup>|
| 120                         | 7.2<sup>b</sup>      | 77.8<sup>b</sup>   | 11.5                 | 1183.7<sup>b</sup>| 591.2<sup>b</sup>| 592.5<sup>b</sup>| 1328.7<sup>b</sup>|
| 160                         | 7.39<sup>b</sup>     | 79.6<sup>b</sup>   | 11.3                 | 2871<sup>c</sup>   | 2028.5<sup>c</sup>| 842.5<sup>c</sup>| 2853.9<sup>c</sup>|
| 200                         | 5.9<sup>a</sup>      | 68.1<sup>a</sup>   |                      |                      |                      |         |                      |         |

Note: The superscript letters in the same column indicate that the differences are significantly different ($P<0.05$).

#### 3.1.3. Prediction of gelatinization characteristics.

Taking into account that other powder mixing ratios and BR particle sizes may be applied in actual production and processing, this experiment is based on the pasting properties of the mixed system of several powder mixing ratios and BR particle sizes that have been determined to the remaining conditions. A prediction was made to provide a theoretical basis for the production and processing of DRB-BR mixed system food.
It can be seen in Fig. 1 that the changes of peak viscosity, valley viscosity and final viscosity of DRB-BR mixed system were linear with the mixing ratio of DRB-BR and the size of BR particle size, and the correlation coefficient $R^2 > 0.93$. The prediction equation is shown in Table 3. The change of attenuation value and setback value of DRB-BR mixed system was linear with the proportion of mixed powder, and was in line with the trend of logarithmic equation with the particle size of BR, and the correlation coefficient $R^2 > 0.90$. The quadratic equation can be used to predict the changes of gelatinization temperature, gelatinization time and peak time of DRB-BR mixtures with different blending ratios. The trend of gelatinization characteristics of DRB-BR mixed system with different BR particle size is shown in Figure 2. The gelatinization temperature, gelatinization time and peak time had a linear relationship with the trend of power law equation, and the correlation is significant. The prediction equations and correlation coefficient were shown in Table 3.
Trend line of gelatinization characteristics of Binary DRB-BR Blend with different granules of BR

Table 3 Prediction equations (PE) of gel parameters

| Gel parameters       | PE at different mixing ratio     | $R^2$ | PE at different BR granule size | $R^2$ |
|----------------------|---------------------------------|-------|---------------------------------|-------|
| Gel temperature      | $y = -0.0056x^2 + 0.5226x + 72.332$ | 0.923 | $y = 408.87e^{-0.11x}$          | 0.879 |
| Peak viscosity       | $y = -8.9137x + 1052.4$         | 0.986 | $y = 34.154x - 2700.7$          | 0.9819|
| Valley viscosity     | $y = -3.6899x + 506.83$         | 0.992 | $y = 24.731x - 2077.9$          | 0.936 |
| Final viscosity      | $y = -11.116x + 1311.9$         | 0.969 | $y = 34.364x - 2665.2$          | 0.9955|
| Gelatinization time  | $y = -0.0006x^2 + 0.053x + 6.8029$ | 0.969 | $y = 159.1x^{0.625}$           | 0.8831|
| Peak time            | $y = -0.0004x^2 + 0.0696x + 9.52$ | 0.984 | $y = 18.979x^{-0.794}$         | 0.9679|
| Attenuation value    | $y = -281.6lnx + 1349.3$        | 0.988 | $y = 1097.7lnx - 4704.1$       | 0.9912|
| Setback value        | $y = -395.1lnx + 1931$          | 0.975 | $y = 1125.1lnx - 4797.8$       | 0.9016|

3.2. Rheological properties of DRB-BR mixture

3.2.1. The effect of mixing powder ratio on the rheological properties. As shown in Fig.3, the initial viscosity of the rheological curve was high, as which the viscosity was generally high after the gelling and cooling of the mixed system due to the effect of the three cross-linked structure in the paste. The increase of shear rate caused a significant decrease in apparent viscosity of the cold paste with different granules.
mixing ratios, indicating the nature of pseudoplastic fluid shear thinning. Corresponding to the value with $0<n<1$ in table 4, the viscosity of the mixed system with different mixing ratios lowered slightly, which may be caused by the difference in amyllose content in the mixed powder\cite{19, 22}. When the shear rate continues to increase, the viscosity dropped slowly, which may lead to Newton-type flow characteristics. Along with the increase of DRB content and shear rate, the network crosslinking in the mixed system was loose, so the shear thinning increases and the apparent viscosity decreased gradually. During the shear movement, the intermolecular rearranged and the n value tended to be stable\cite{23}. With the effect of DRB adding amount, the apparent viscosity of the binary mixture declined gradually. When the mixing ratio was DRB\textsubscript{75}-BR\textsubscript{25}, the apparent viscosity no longer decreased, but increased with the rise of DRB content. Based on the results presented in Fig.3, it seems to be evident that the shear flow curve generally reflects that the addition of DRB has no effect on the flow type of the binary mixture, but it can overall reduce the apparent viscosity of the cold paste of the mixture to varying degrees, revealing that the addition of DRB in BR may weaken the flow resistance and benefit for product processing.

![Rheological curves with different blending percentage](image)

The fitting results of power law equation in table 4 showed that with the increase of the added amount of DRB, the value of consistency coefficient $K$ dropped first and then increased. When the mixing ratio was DRB\textsubscript{50}-BR\textsubscript{50}, the $K$ value was the smallest, and the rheological index $n$ was relatively small, which was consistent with the change of apparent viscosity, indicating that it was the most difficult to form in the cold paste gel process, and the shear thinning characteristics were strong. The consistency coefficient $K$ and rheological index $n$ of the mixture with too large proportion of DRB (such as DRB\textsubscript{100}-BR\textsubscript{0}) or too small proportion of DRB (such as DRB\textsubscript{0}-BR\textsubscript{100}) were relatively large, which showed that the DRB-BR mixture was easy to form in the cold gel process, and the shear thinning was weakened. In addition, there was no significant correlation between rheological properties and pasting properties of DRB-BR blends with different blending ratios.

| The mixing ratio | $K$ | $n$ | $R^2$ |
|------------------|-----|-----|-------|
| DRB\textsubscript{0}-BR\textsubscript{100} | 11.41$\pm$0.32$^a$ | 0.735$\pm$0.010 | 0.921 |
| DRB\textsubscript{50}-BR\textsubscript{50} | 8.518$\pm$0.288$^d$ | 0.699$\pm$0.012 | 0.924 |
| DRB\textsubscript{25}-BR\textsubscript{75} | 5.214$\pm$0.213$^a$ | 0.645$\pm$0.014 | 0.935 |
| DRB\textsubscript{75}-BR\textsubscript{25} | 7.148$\pm$0.334$^b$ | 0.639$\pm$0.016 | 0.922 |
| DRB\textsubscript{100}-BR\textsubscript{0} | 8.180$\pm$0.269$^c$ | 0.675$\pm$0.012 | 0.942 |

Note: The superscript letters in the same column indicate that the differences are significant with $P<0.05$

3.2.2. The effect of rice granule size on the rheological properties. It can be seen from Fig. 4 that the apparent viscosity of the DRB-BR mixture gradually increased with BR granular fining size in the range of 80–160 meshes sieve. This is because when the BR particle size became smaller, the overall specific
surface area of the BR increased, the water absorption rate of the BR starch increased, both the coagulation effect and the apparent viscosity increased respectively. When the granular size was 200 meshes sieve, the apparent viscosity slightly but significantly lowered, which almost similar to that of granular size of 80 meshes sieve. The putative reason was that the overall collosol properties of the mixed system were weakened just because of the particle size of DRB and BR too small. As a result, the adhesion and adhesiveness between DRB and BR were reduced, indicating that the apparent viscosity of shear flow decreased. Regarding the fitting results of the power-law equation in Table 5, it was found that the K value and n value increase with the decrease of BR particle size in the range of 80~160 meshes sieve. The consistency coefficient K value of the DRB-BR mixture from 80 meshes sieve to 160 meshes sieve, were positively correlated with the some parameters of the gelatinization properties, for peak viscosity, valley viscosity, final viscosity, attenuation value and setback value, and in the contrast to that of which negatively correlated with the other parameter, for peak time. The K value and n value decreased at a finer 200 meshes sieve, and both the consistency coefficient and rheological index of the mixture was the largest at 160 mesh of the granular size, which indicating not only the cold paste stability of the mixture better but also the shear thinning characteristics weaker. It can be seen that the change of BR particle size has a significant effect on the rheological properties of DRB-BR mixture (P<0.05). The experimental results presented that the BR particle size of neither too thick nor too thin makes the mixture easily form but deform in the food processing cold paste gelatinization.

### Table 5: Equation fitting parameters of rheological parameters with different granules of BR

| Particle size | K      | n        | R²   |
|---------------|--------|----------|------|
| BR80          | 2.112±0.064a | 0.653±0.010 | 0.960 |
| BR120         | 4.339±0.137c | 0.716±0.012 | 0.921 |
| BR160         | 5.755±0.133d | 0.750±0.009 | 0.938 |
| BR200         | 2.389±0.059b | 0.570±0.008 | 0.988 |

Note: The superscript letters in the same column indicate that the differences are significant with $P<0.05$

#### 3.2.3. Rheological properties under different heating temperature

The results of the apparent viscosity of DRB-BR mixture varied with the heating temperature at gelatinization were expressed in Fig. 5 and table 6. Regarding the heat process from temperature 40°C to 60°C, they were obviously lower than the gelatinization temperature of the DRB-BR mixture presented in Fig.1a and Fig.2a under different mixing conditions, meanwhile, the apparent viscosity of the mixture was at a low level at different shear rates. When the heating temperature reaches 80 ~ 100 °C, which is close to or higher than the gelatinization temperature of the mixture, the apparent viscosity of the mixed system increases sharply at different shear rates. It can be observed the K value increased significantly ($P<0.05$) from the fitting results of
the power law equation in table 6, and the rheological index n increased respectively, indicating the DRB-BR mixture confirmed a large consistency of the hot paste and a gradual weakening of the shear thinning characteristics.

4. Conclusion
The change of both blending ratio and BR particle size had a significant effect on the gelatinization characteristics of DRB-BR mixed system with $P < 0.05$. The peak viscosity, valley viscosity, final viscosity, attenuation value of the mixed powder formed by adding appropriate amount of DRB in BR was reduced respectively comparing with single DRB or BR components. Overall, a limit up to 50 % DRB adding is appropriate for the taste and stability of food processing in the aspects of gelatinization, as well as the limit up to 200 meshes sieve granule size of BR due to too small the BR granule size highly possible resulting in excessive viscosity after gelatinization. The changes of peak viscosity, valley viscosity and final viscosity of DRB-BR mixture were linear with the blending ratio and BR particle size, with correlation coefficient $R^2>0.93$. The attenuation value and setback value of DRB-BR mixture are linear with the adding proportion but in line with the trend of logarithmic equation with the particle size at $R^2>0.90$. On the other hand, the change of gelatinization temperature, gelatinization time and peak time of the mixture with adding ratio can be predicted by quadratic equation, while with the BR particle size to conform the trend of power law equation, respectively. In addition, the rheological curve of DRB-BR mixture manifested that the mixture fluid is pseudoplastic with shear thinning characteristics, in which the consistency coefficient $K$ value and the apparent viscosity change trend are the same with fitting correlation coefficient $R^2>0.921$. The changes of mixing ratio, BR particle size and heating temperature have obvious effect on the rheological properties of the DRB-BR mixture ($P<0.05$). With the rice in the proportion of DRB, the apparent viscosity of the mixed system first reduced and then increased. When the mixing ratio is at DRB$_{50}$-BR$_{50}$, as well as 200 meshes sieve of granule size of BR in mixture, the apparent viscosity is the smallest and the most difficult for forming process.

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