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Improving the quality of bean dregs by physical methods during its use in bakery technology

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АНОТАЦІЯ

Фанг Ванг. Підвищення якості бобових відходів фізичними методами при їх використанні у технології печива. – Дисертаційна наукова робота на правах рукопису.

Дисертація на здобуття наукового ступеня доктора філософії за спеціальністю 181 «Харчові технології», галузь знань 18 «Виробництво та технології». Сумський національний аграрний університет, Суми, 2022.

Дисертація присвячена науковому обґрунтуванню та розробці технологій підвищення якості бобових відходів фізичними методами при їх використанні в технологіях печива.

Встановлено, що створення нових технологій продуктів харчування дозволяє вирішити проблему нестачі розчинних харчових волокон (SDF), покращити якісні та функціональні характеристики бобових залишків (відходів). Крім того, це забезпечує кращу якість при виробництві печива з додаванням борошна з бобових залишків. Поєднання ультратонкого помелу з високим тиском, мікрохвильовою та високотемпературною обробкою є перспективним напрямком у створенні технологій переробки бобових залишків за рахунок взаємного впливу фізичних факторів, завдяки чому поживні речовини в бобових залишках трансформуються.

Мета дисертації - наукове обґрунтування та розробка технологій підвищення якості бобових відходів фізичними методами при їх використанні в технологіях печива. Об'єктом дослідження є якість бобових відходів, оброблених фізичними методами. Предметом дослідження є фізико-хімічні властивості борошна з бобових відходів, оброблених фізичними методами; фізико-хімічні властивості тіста та печива, виготовленого з використанням бобових відходів; їх технологічні, реологічні та органолептичні властивості; параметри процесів обробки бобових залишків фізичними методами.

Доведено актуальність і доцільність використання ультратонкого помелу в поєднанні з обробкою високим тиском, обробкою у мікрохвильовій печі та високотемпературною обробкою як ефективного джерела розчинної

харчової клітковини для функціональних композицій і покращення харчових властивостей бобових залишків.

Досліджено склад, характеристики та фізико-хімічні властивості борошна, виробленого з використанням окремих технологій фізичного впливу та комбінованих технологій обробки бобових відходів.

При дослідженні як різних (ультратонкий помел, високий тиск, мікрохвильова, високотемпературна обробка), так і комбінованих технологій, вивчені залежності змін властивостей SDF, вмісту білка, мінералів, розміру частинок (скануюча електронна мікроскопія, SEM, електрофорез натрію додецилсульфат-поліакриламідним гелем, SDS-PAGE), інгібітору трипсину, від параметрів фізичних методів обробки. Визначено розчинність у воді, адсорбційну здатність жиру, катіонну адсорбційну здатність, кольоровість і білизну бобових залишків, а також водно-релаксаційні властивості, в'язкість, стабільність, динамічні реологічні властивості суспензії бобових залишків. Отримано опис процесів зміни досліджуваних параметрів. Отриманий результат використаний для вибору оптимальних параметрів комбінованої технології та для підвищення вмісту SDF у функціональному печиві при використанні борошна з бобових залишків.

У роботі було застосовано декілька фізичних методів для підвищення вмісту SDF в бобових залишках; оптимальні умови для покращення якості SDF бобових залишків були визначені методом однофакторного експерименту. Було виявлено, що вміст SDF в бобових залишках, оброблених за допомогою ультратонкого помелу (U), високого тиску (HP), мікрохвильової печі (M), високотемпературного приготування (HTC) та їх комбінуванні (UHP, U-M та U-HTC), становив 15,15 ± 0,12 %, 10,40 ± 0,19 %, 13,84 ± 0,13 %, 13,87 ± 0,13 %, 18,86 ± 0,11 %, 19,23 ± 0,19 % та 16,89 ± 0,13 %, що було значно вищим, ніж у контрольному зразку на 6 % ± 0,2% відповідно. Доведено, що бобові залишки після їх обробки фізичними методами є джерелом розчинної харчової клітковини, а застосування комбінованих методів є перспективною тенденцією розвитку.

Розроблено технології підвищення вмісту SDF бобових залишків. Визначено раціональні значення окремих параметрів і режими технологічних схем цих технологій.

Вміст білка в бобових залишках аналізували методом AOAC. Встановлено, що при обробці різними фізичними методами вміст білка в бобових залишках після обробки U, HP, M і HTC знижувався з 23,46 % до 11,96 %, 16,30 %, 12,85 % і 13,09 % відповідно. При комбінованій обробці, особливо U-HP, вміст білка в бобових залишках зменшився ще більше. Було доведено, що вміст білка в бобових залишках значно знижувався після використання як різних фізичних методів обробки окремо, так і з використанням комбінованих методів.

Як і очікувалося, деякі параметри були суттєво знижені ($p < 0,05$) за різних фізичних технологій порівняно з контролем; комбінована обробка мала найбільший вплив на розмір частинок бобових залишків. Розмір частинок бобових залишків був найменшим (69,52 мкм) після обробки U серед усіх досліджуваних методів оброблення. Однак серед усіх комбінованих технологічних методів найменший розмір частинок було отримано при U-HP (27,43 мкм). Було доведено, що комбіновані методи обробки ще більше покращили шорсткість часточок бобових залишків.

Мінеральний вміст бобових залишків визначали методом індуктивно-зв'язаної плазмово-атомно-емісійної спектрометрії. Комбінація U-HP методів збільшила вміст Ca, Na, Fe, Ti та Sr., а комбінація методів U-M та U-HTC значно збільшила вміст K та Ca. Найвищий вміст Se та Sn було виявлено у зразках при обробці U, проте методи M та HTC зменшили вміст елементів K, Ca, Mg та Zn. Комбінування методів обробки сприяло підвищенню вмісту мінеральних елементів у дослідних зразках.

Після обробки різними фізичними методами мікроструктура бобових відходів відповідала результатам розподілу частинок за розміром. Поверхня оброблених мікрочастинок бобових відходів була шорсткою, неправильною та повною отворів, порівняно з контрольними зразками (поверхня мала пухку структуру листа з багатьма складками, а пучок волокон мав упорядковану структуру). Обробка бобових залишків U та комбінованою обробкою показали сотову структуру та дрібний розподіл частинок, що покращило показники оброблених бобових залишків.

Використання SDS-PAGE для визначення молекулярно-масового розподілу білків довело, що обробка U не впливає на вміст білкових субодиниць в бобових залишках. Обробка HP та U-HP мала певний вплив на молекулярну масу білка. Після обробки M та U-M білкові смуги з молекулярною масою понад 90 кД стали світлішими. Після обробки HTC та U-HTC білкові смуги повністю зникли. Було доведено, що обробка одним з методів M і HTC та комбінованими методами U-M і U-HTC мали великий вплив на молекулярну масу білка.

Експериментально встановлено, що вплив нетеплових методів обробки (U, HP та U-HP) на зниження вмісту інгібіторів трипсину значно поступається впливу термічної обробки. HTC та U-HTC мали помітний вплив на інгібування активності інгібіторів трипсину, які були знижені з 7365 TIU/г до 1210 та 96 TIU/г відповідно. Це вказує на те, що термічна обробка ефективно знижує активність інгібітора трипсину.

Були проведені дослідження щодо зміни розчинності у воді, здатності до набухання, здатності до поглинання жиру та катіонної адсорбційної здатності при переробці бобових залишків. Результати показали, що, обробка, як одним окремим методом, так і комбінована обробка значно підвищували розчинність бобових залишків у воді, але розчинність бобових залишків після комбінованої обробки була вищою, ніж після використання окремих методів обробки. Здатність до набухання та адсорбційна здатність бобових залишків була знижена, а результативність обробки одним окремим методом була вищою, ніж при комбінованій обробці. Адсорбційна здатність бобових залишків показала, що зразки, оброблені комбінованою технологією, містили менші частинки, тому вони мали більшу катіонну здатність до поглинання. Підтверджено, що попадання борошна з бобових залишків в кишковий тракт сприяє поглинанню Na^+ і виведенню його з організму, тим самим знижуючи частоту серцево-судинних та інших захворювань, ефективність переробки бобових відходів збагачує їх застосування в харчових продуктах і покращує їх фізіологічну функцію.

Релаксаційні властивості води в бобових залишках, оброблених різними фізичними технологіями, визначали за допомогою ядерного магнітного резонансу (НМР).

Після обробки HTC, U-HP, U-M та U-HTC частка зв'язаної води в бобових відходах зросла, а частка нерухомої води зменшилась після регідратації. Площа піку бобових відходів, оброблених HP і HTC, дещо збільшилася. Крім того, вміст вільної води (A_{24}) позитивно корелює з вмістом води (W %) висушених залишків.

Для визначення в’язкості за допомогою експрес-аналізатора в’язкості готували суспензію бобових відходів. В'язкість суспензії бобових відходів знижувалася після різних методів обробки, особливо після комбінованої обробки. Однак лише M-обробка збільшувала в’язкість суспензії бобових залишків порівняно з контрольними зразками. Це свідчило про те, що в’язкість бобових залишків, оброблених за комбінованою технологією була низькою.

Очевидно, що різні способи обробки можуть впливати на стабільність бобових залишків. Після витримки протягом 48 годин і 72 годин зразків, оброблених M, HTC і U-HTC було зареєстровано зараження мікробами, а об’єм надосадової рідини зменшився або зник. Однак бобові залишки під час обробки HP та U-HP були найбільш стабільними з незначними змінами об’єму супернатанту через 72 години. Через тиждень у кожній пробірці з’явився запах, що вказує на мікробіологічне забруднення. Таким чином, комбінована технологія може бути корисною в харчовій промисловості для збільшення терміну зберігання харчових продуктів.

Динамічні реологічні властивості суспензії бобових залишків визначали за допомогою ротаційного реометра. Для порівняння, G′ і G″ бобових залишків, оброблених U та HP, були нижчими, ніж у M та контрольних зразків, і вищими, ніж у зразків HTC та всіх комбінованих обробок. Однак, крім обробки M, HTC та всі комбіновані методи обробки (U-HP, UM та U-HTC) були на нижчому рівні, а тенденція зміни коефіцієнта втрат (tan δ) і G″ мала ту саму тенденцію. Це вказувало на те, що комбінована обробка може зменшити зернистість волокна бобових залишків, але їх в'язкість і еластичність не збільшуються.

Залишки бобових, оброблених термічними методами (M, HTC, U-M і U-HTC), мали нижчі значення L*. За винятком обробки U-HP, значення a* і b* інших видів обробки були значно вищими, ніж у контрольній групі. Обробка HP, M, HTC та U-HTC призвела до вищих значень ΔE (загальна різниця кольору) зразків. На індекс білизни (WI) також суттєво впливали різні методи фізичного впливу. Ці результати продемонстрували, що різні фізичні методи обробки мали певний вплив на кольоровість бобових залишків.

Встановлено, що впровадження запропонованих комбінованих технологій обробки бобових відходів для виробництва печива є економічно доцільним. У цьому дослідженні комбінована технологія U-M була використана для отримання борошна з бобових залишків для хрусткого та твердого печива.

Сила борошна, що використовується для приготування **хрусткого печива** (борошно з низьким вмістом клейковини) і **твердого печива** (борошно середнім вмістом клейковини), різна, але має постійну тенденцію щодо в'язкості тіста. Експериментально встановлено, що додавання борошна бобових залишків значно знижувало в'язкість тіста, і всі індекси демонстрували тенденцію до їх зниження (пікова в'язкість, мінімальна в'язкість, в'язкість при розриві, кінцева в'язкість, в'язкість зниження). Експериментальні результати показали, що додавання певної кількості борошна з бобових залишків може ефективно покращити желатинізуючу характеристику борошна та підвищити хрусткість печива.

Вимірювання текстури тіста для хрусткого печива в аналізаторі текстури показало, що значення твердості збільшувалося при збільшенні вмісту бобових відходів у складі печива. Твердість становила 5019,95±114,01 г при додаванні 15 %, що на 54,78 % вище, ніж у контролі. Однак, при додаванні більше 20 % борошна бобових відходів твердість тіста знижувалася. Показано, що жувальність печива позитивно корелювала з твердістю та клейкістю.

Зі збільшенням вмісту бобових залишків зменшилося значення L* та збільшилося значення a* хрусткого печива, що вказує на збільшення темного та жовтуватого кольору, значення b* зменшилися на 5-25% при додані борошна з бобових залишків. Що стосується кольору хрусткого печива, то він став темнішим (нижчий L*), більш червонуватим (вищі значення a*) і менш жовтуватим (нижчі значення b*), коли додавали борошно з бобових залишків, на 15-25%. Тенденція визначення була подібна до результатів аналізу хрусткого печива. Було доведено, що колір виробів може бути пов'язаний як із окремими інгредієнтами продукту, так і з кольором, який утворився внаслідок взаємодії інгредієнтів.

Твердість хрусткого печива поступово збільшувалася зі збільшенням вмісту бобових залишків. Коли борошно бобових залишків додавали на 15%, твердість досягла максимуму 2328,49 N. При додаванні 20% борошна бобових залишків, твердість печива мала тенденцію до зниження. Твердість, клейкість і жування позитивно корелюють. Додавання борошна бобових залишків може ефективно покращити желатинізуючу характеристику борошна та підвищити хрусткість печива.

Зі збільшенням частки борошна бобових залишків внутрішня структура печива сильно змінюється, пухирці повітря поступово збільшуються, а поверхня з дрібної стає шорсткою. Коли додавання борошна бобових залишків перевищило 20%, вершкове масло в тісті не може покривати частинки крохмалю, білки клейковини та волокна, присутні в борошні, що впливає на якість хрусткого печива.

За характеристиками тіста та сенсорною оцінкою хрусткого печива максимальна кількість бороша бобових залишків становила 20%, що надавало печиву кращого смаку.

Завдяки результатам однофакторних та ортогональних експериментів з тістом була отримана оптимальна формула хрусткого печива з бобовими відходами: 80 г борошна з низьким вмістом клейковини, 20 г борошна бобових залишків (після обробки U-M), 50 г вершкового масла, 20 г цукрової пудри, 5 г кукурудзяного крохмалю, 20 г жовтків, 1 г солі, 0,75 г розпушувача; випікання при 175 °C 11 хв. Хрустке печиво, приготоване за цією технологією, мало хрусткий смак, золотистий колір і приємний бобовий аромат. Сенсорна оцінка хрусткого печива з бобовими залишками склала 94 бали, а значення твердості – 1597,41 Н.

Зі збільшенням додавання борошна з бобових відходів характеристики клейстеризації демонстрували значне зниження ($p < 0,05$). Пікова в’язкість зменшилась на 22,37%, мінімальна на 20,82%, а кінцева – на 20,22% порівняно з контрольною групою. Причина може полягати в тому, що бобові залишки мають сильну здатність поглинати воду і конкурують з крохмалем за поглинання води, в результаті чого крохмаль не може бути повністю клейстеризований. При реологічному аналізі бобові залишки підвищили в’язкість і еластичність твердого тіста.

Зі збільшенням вмісту борошна бобових залишків твердість була вищою за контрольну. Найвища твердість становила 7464,53±219,99 Н, коли рівень додавання борошна з бобових залишків склав 12,5%, що на 86,27% вище за контроль. Ймовірно, це було пов’язано з тим, що клітковина і білок бобових залишків конкурують з борошном за вологу, таким чином, це сприяє утворенню глютену та спричиняє збільшення твердості тіста. Твердість, клейкість і жування позитивно корелюють. Тенденція визначення була подібна до результатів твердого тіста.

Зі збільшенням вмісту борошна з бобових залишків зменшувалося значення L* (колір став темнішим) і збільшувалося значення a* (колір більш червонуватий) твердого печива, яке змінювалося від золотисто-коричневого до карамельного кольору. Під час випікання температура зовнішніх шарів продукту перевищувала 150 °C, і відбувалася реакції Майяра та цукрової карамелізації, які відповідають за кінцевий колір скоринки.

Параметри досліджуваних зразків продемонстрували збільшення твердості, когезії, клейкість, жувальної здатності печива порівняно з контролем. Твердість становила 4698,98±97,71 Н при рівні додавання борошна 12,5%, що на 53,75% вище, ніж у контролі. Показники клейкості печива з бобовими залишками були достовірно вищими за контрольні та становили (P < 0,05). Однак значення показників розжовування печива з додаванням 2,5 % борошна з бобових залишків істотно не відрізнялися від аналогічних показників з 5 % доданого борошна (P > 0,05). Розжовувальна здатність становила 473,57±131,04 при рівні додавання борошна з бобових залишків 12,5%, що на 93,14% вище, ніж у контролі.

Результати дослідження SEM також підтвердили, що борошно бобових залишків має певний вплив на твердість печива, що узгоджувалося з результатами TPA текстури печива.

За характеристиками тіста та сенсорною оцінкою твердого печива оптимальна кількість бобових відходів становила 10 %, що надавало печиву кращого смаку.

Завдяки результатам однофакторних і ортогональних експериментів з дослідження тіста була отримана оптимальна формула твердого печива з бобовими відходами: 90 г пшеничного борошна, 10 г борошна з бобових залишків (після обробки U-M), 30 мл води, 25 г цукрової пудри, 5 г крохмалю, 1 грозпушувача та 0,5 г солі, 20 г яєчного жовтка, 5 г соєвої олії; температуру випікання 195 °C тривалість випікання 8 хв. Сенсорна оцінка твердого печива з бобовими відходами склала 88 балів, а значення твердості – 4344,95 Н.

Розроблено комплекс заходів для впровадження результатів дослідження на практиці. Встановлено, що впровадження запропонованого рецептурного складу та технології виробництва печива з бобовими відходами є економічно доцільним. Нові технології будуть застосовуватися в харчовій промисловості.

Ключові слова: бобові залишки, розчинні харчові волокна, підвищення якості, борошняні кондитерські вироби, сенсорна оцінка, борошно пшеничне, технологія, параметри, реологічні властивості, рецептура, сполуки кальцію, концентрація, фізико-хімічні показники, технологічні показники, висушування.

ANNOTATION

Fang Wang. Improving the quality of bean dregs by physical methods during its use in bakery technology. – Qualifying scientific work on the rights of the manuscript.

Thesis for a PhD Degree specializing in181 «Food Technology», subject area 18 «Production and technology». Sumy National Agrarian University, Sumy, 2022.

The dissertation is devoted to the scientific substantiation and development of technologies for improving the quality of bean dregs by physical methods during its use in bakery technology.

It is established that the creation of new technologies of combined food can solve the problem of the lack of SDF, and improve the quality and functional characteristics of bean dregs. In addition, it provides better quality for the production of bean dregs biscuit. Combination of ultrafine grinding with high pressure, microwave and high-temperature cooking is a promising direction in the creation of processing the bean dregs due to mutual influence between physical technology is combined with each other, so that the nutrients in bean dregs are transformed.

The purpose of the dissertation is scientific substantiation and development of technologies for improving the quality of leguminous waste when using physical methods in baking technologies. The object of the study is the quality of leguminous waste processed by physical methods. The subject of the study is the physicochemical properties of leguminous waste processed by physical methods; physico-chemical properties of dough and cookies made using bean waste; their technological, rheological and organoleptic properties; parameters of the processing of leguminous residues by physical methods.

The relevance and feasibility of using ultrafine grinding combined with high pressure, microwave and high-temperature cooking for a good source of soluble dietary fiber for functional compositions and nutritional quality of bean dregs has been proved.

The compositions, characteristics and physicochemical property of Physical single technology and combination technology for the treatment of bean dregs are investigated.

In physical single technology and combination technology, the dependences of changes in the parameters of the SDF, protein, mineral content, particle size, scanning electron microscopy (SEM), sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE), trypsin inhibitors, water solubility, fat adsorption capacity, cationic adsorption capacity, chrominance and whiteness of bean dregs, and water relaxation properties, viscosity, stability, dynamic rheological properties of bean dreg slurry are determined. We obtained describing the processes of changing parameters. The resulting can be used for selecting optimum combination technology and for rich SDF in functional biscuit in the production of bean dregs.

Several physical techniques were applied to increase the SDF content of bean dregs in this work, the optimum conditions for improving SDF of soybean dregs were determined by single factor test. It was found that the SDF contents in bean dregs treated with ultrafine grinding (U), high pressure (HP), microwave (M), high temperature cooking (HTC) and their combination techniques (UHP, U-M and U-HTC) were 15.15 ± 0.12%, 10.40 ± 0.19%, 13.84 ± 0.13%, 13.87 ± 0.13%, 18.86 ± 0.11%, 19.23 ± 0.19%, and 16.89 ± 0.13%, respectively, much higher than that of the control sample, which was only 1.63 ± 0.2%. It has been proved that the bean dregs under physical technology treatment is a good source of soluble dietary fiber, and the application of combined methods is the development trend.

Technologies of increase the content of SDF of bean dregs have been developed. The rational values of individual parameters and modes of technological schemes of these technologies are determined.

The protein content of bean dregs was analyzed as described in the AOAC reference method. It was found that the single technical treatments, the protein content in bean dregs after U, HP, M and HTC treatments decreased from 23.46% to 11.96%, 16.30%, 12.85% and 13.09%, respectively. The protein contents in bean dregs were further reduced after combination treatments, especially U-HP treatment. It was proved – protein content in bean dregs decreased greatly after physical technology treatment with either single techniques or with combined techniques.

As expected, some parameters were decreased significantly ($p < 0.05$) by different physical technologies as compared with those of the control, the combined treatment had the greatest effect on the particles of bean dregs. The particle size of bean dregs was smallest (69.52 μm) after U treatment, among all single technology treatments. However, among all combined technology treatments was smallest by U-HP (27.43 μm) treatment. It has been proved that combination treatments were further improved roughness of bean dregs.

The mineral content of bean dregs was determined by inductively coupled plasma-atomic emission spectrometry. U-HP combination increased the contents of Ca, Na, Fe, Ti and Sr. and the combination of U-M and U-HTC treatments greatly increased the K and Ca contents. In single treatment, the highest contents Se and Sn were found in the samples by U treatment, however, M and HTC techniques reduced the contents of K, Ca, Mg and Zn element in single treatment. The combination treatments help the exposure of mineral elements in the samples were confirmed.

After various physical treatments, the microstructure of bean dregs SEM were consistent with the results of particle size distribution. The surfaces of treated bean dregs were rough, irregular and full of holes compared with control samples (had a loose sheet structure with many folds, and the fiber bundle exhibited an ordered structure). The bean dregs by U and combined treatments showed honeycomb structure and small particle distribution. It was proved – processing performances improved of bean dregs.

SDS-PAGE was used to detect the molecular weight distribution of proteins. U treatment had no effect on the content of protein subunits in bean dregs. HP and U-HP treatments had some effect on the molecular weights of the protein. After the M and U-M treatments, the protein bands for molecular weights above 90 kD became lighter in color. After HTC and U-HTC treatment, the protein bands had disappeared completely. It has been proved that the single treatments M and HTC and the combined treatments U-M and U-HTC had great influence on the molecular weights of protein.

It was experimentally established that the effects of non-heating treatments (U, HP and U-HP) on the reduction of trypsin inhibitor content were much inferior to those involving heat treatment. HTC and U-HTC had prominent effects on inhibiting trypsin inhibitor activity, which were decreased from 7365 TIU/g to 1210 and 96 TIU/g, respectively. This indicated that heat treatment effectively reduced trypsin inhibitor activity.

Research was carried out on changes in the water solubility, swelling capacity, fat absorption capacity and cationic adsorption capacity of processing performance of bean dregs. The results showed that both single treatments and combination treatments significantly increased the water solubility of bean dregs, and the solubility of bean dregs from the combined treatment were higher than those from the single treatment. However, the swelling capacity and fat adsorption capacities of bean dregs were decreased, and the single treatment were higher than those from the combined. The adsorption capacity of bean dregs showed that the bean dregs treated by the combination technology contained smaller particles, so they had stronger cationic absorption capacity. It has been confirmed that the introduction of the bean dreg powder into the intestinal tract is beneficial to absorb Na^+ and discharge it from the body, thereby reducing the incidence of cardiovascular and other diseases, processing performance of bean dregs enriches their application in foods and improves their physiological function.

Water relaxation properties in bean dregs treated by different physical technologies were determined by low field nuclear magnetic resonance (LF-NMR) After the HTC, U-HP, U-M and U-HTC treatments, the proportion of bound water of bean dregs increased and the proportion of immobile water decreased after rehydration. And the peak area of the bean dregs treated with HP and HTC increased slightly. In addition, the free water content (A_{24}) is positively correlated with the water content (W %) of dried bean dregs. This technique can effectively and nondestructively determine the change of water relaxation in samples.

Bean dreg slurry was prepared for determination of viscosity with a rapid viscosity analyzer. The viscosity of bean dregs slurry was decreased after different treatment, especially the combined treatment. However, only M treatment increased the viscosity of bean dregs slurry, compared to the control samples. This indicated that the viscosity of bean dregs under the combination technology was low.

Different treatments could obviously effect of different treatments on the stability of bean dreg slurry. After standing for 48 h and 72 h, microbial infection occurred in tubes M, HTC and U-HTC treatment, and the supernatant volume decreased or disappeared. However, the bean dregs under HP and U-HP treatment were the most stable, with little change in supernatant volume after 72 h. After standing for a week, there was an odor in every tube, indicating that each tube was corrupted. This indicated that combination technology that could be useful in the food industry to prolong the shelf life of foods.

The dynamic rheological properties of the bean dregs slurry were determined by a rotary rheometer. In comparison, the G′ and G″ of the bean dregs treated with U and HP were lower than those of M and control samples, and higher than those of the samples by HTC and all combined treatments. However, except the M treatment, HTC and all the combined treatments (U-HP, UM and U-HTC) were at a lower level, and the change trend of the loss factor (tan δ) and G″ have the same trend. This indicated that the combined treatment could reduce the granularity of bean dreg fiber, but its viscosity and elasticity did not increase.

The bean dregs treated by thermal treatments (M, HTC, U-M, and U-HTC) had lower values of L^*. Except for the U-HP treatment, the a^* and b^* values of the other treatments were significantly greater than those of the control group. The HP, M, HTC and U-HTC treatments resulted in higher values in the ΔE (total color difference) of the samples. The whiteness index (WI) was also significantly affected by different physical treatments. These results demonstrated that different physical treatments had definite effects on the chrominance of bean dregs.

It is established that the introduction of the proposed combined technologies to treat bean dregs for the production of biscuits is economically feasible. In this study, U-M combined technology was used to prepare bean dreg powder for crisp biscuits and hard biscuits.

The strength of flour used in making **crisp biscuits** (low gluten flour) and **hard biscuits** (medium gluten flour) is different, but has a consistent trend on the viscosity of paste. It was experimentally established that the addition of bean dregs greatly reduced the viscosity of paste, and all the indexes showed a downward trend (peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity). The experimental results show, that the add a certain amount of bean dregs powder can effectively improve the gelatinizing characteristics of flour and increase the crispness of biscuits.

Measurement of crisp biscuits dough texture in the texture analyzer showed that the hardness value increased when bean dregs content in the biscuit formulation was increased. The hardness was 5019.95±114.01 N when the bean dregs addition level of 15%, which was 54.78% higher than the control. However, above 20% of the bean dregs the dough hardness decreases. It can be explained that the chewiness of biscuits was positively correlated with hardness and gumminess.

With the increase of the amount of bean dregs powder decreased $L*$ and increased $a*$ crisp biscuits values, indicating more dark and yellowish, $b*$ values decreased added bean dregs at 5-25%. Concerning the crisp biscuits color, it became darker (lower $L*$), more reddish (higher $a*$ values), and less yellowish (lower $b*$ values) when bean dregs was added at 15-25%. The determination trend was similar to the crisp dough results. It was proved – the color of a baked good can be attributed to both the individual ingredients of the item and the color developed from ingredient interactions.

The hardness of crisp biscuits increased gradually with the increase of bean dregs. When the bean dregs powder was added at 15%, the hardness reached the maximum of 2328.49 N. When the bean dregs powder was added at 20%, the hardness of biscuit showed a downward trend. The hardness, gumminess and chewiness are positively correlated. The determination trend was similar to the crisp dough results. The addition of bean dregs powder can effectively improve the gelatinizing characteristics of flour and increase the crispness of biscuits.

With the increase of the proportion of soybean residue powder, the internal structure of the biscuit changes greatly, the gap gradually becomes larger, and the surface becomes rough from fine. When the addition of soy powder exceeds 20%, the butter in the dough is unable to coat the starch particles, gluten proteins and fibers present in the flour, affecting the quality of the crisp biscuits.

According to the characteristics of dough and the sensory evaluation of crisp biscuits, the maximum amount of bean dregs was 20%, which gave the biscuits a better taste.

Through single factor and orthogonal test results the optimal formula of bean dregs crisp biscuits was obtained: 80 g low-gluten flour, 20 g bean dreg powder (after U-M treatment), 50 g butter, 20 g powdered sugar, 5 g corn starch, 20 g egg yolks, 1 g salt, 0.75 g baking powder, and baked at 175 °C for 11 min. The bean dregs crisp biscuits prepared by this processing technology got the crispy taste, golden color, and good bean fragrance. Sensory score of bean dregs crisp biscuits was 94 points, and hardness value was 1597.41 H.

With the increase of bean dregs addition, gelatinization characteristics showed a significant downward ($p < 0.05$). The peak viscosity decreased by 22.37%, the trough viscosity decreased by 20.82%, and the final viscosity decreased by 20.22% compared with the control group. The reason may be that bean dregs have strong water absorption capacity and compete with starch for more water, resulting in starch can’t be fully gelatinized. In rheological analysis the bean dregs increased could viscosity and elasticity of hard dough.

With the increase of bean dregs, the hardness was higher than that of the control. The highest hardness was 7464.53±219.99 N, when the bean dregs addition level of 12.5%, which was 86.27% higher than the control. This was probably due to fiber and protein of bean dregs compete with the flour for moisture, in a way that promotes gluten production until it suppresses the behavior causing an increase in the hardness of the dough. The hardness, gumminess and chewiness are positively correlated. The determination trend was similar to the hard dough results.

With the increase of the amount of bean dregs, the reduced *L** (became darker) and increased *a** (more reddish) of hard biscuits values, which changes from golden brown to caramel color. The cake crust temperature exceeded 150 ºC during baking, and thus Maillard and sugar caramelization reactions take place and are responsible for the final crust color.

The parameters showed increases in the hardness, cohesiveness, gumminess, chewiness of the biscuits compared with control. The hardness was 4698.98±97.71 N when the bean dregs addition level of 12.5%, which was 53.75% higher than the control. The gumminess values of the biscuit with bean dregs were significantly higher than that of the control and significantly ($P < 0.05$). However, the gumminess values of the biscuit with bean dregs additions of 2.5 % were not significantly different from additions of 5% ($P > 0.05$). The chewiness was 473.57±131.04 when the bean dregs addition level of 12.5%, which was 93.14% higher than the control.

The SEM results further confirmed that bean dregs powder had a certain effect on the biscuit hardness, which was consistent with the TPA results of biscuit texture.

According to the characteristics of dough and the sensory evaluation of hard biscuits, the maximum amount of bean dregs was 10%, which gave the biscuits a better taste.

Through single factor and orthogonal test results the optimal formula of bean dregs hard biscuits was obtained: 90 g wheat flour, 10 g bean dreg powder (after U-M treatment), 30 mL water, 25 g sugar powder, 5 g starch, 1 g baking powder and 0.5 g salt, then add 20 g egg yolk, 5 g soybean oil, surface fire temperature at 195 °C for 8 min. Sensory score of bean dregs hard biscuits was 88 points, and hardness value was 4344.95 H.

A set of measures has been carried out to put the results of the study into practice. It is established that the introduction of the formulation process for the production of biscuits products is economically feasible. The new technology will be applied to the food industry.

Keywords: bean dregs, soluble dietary fiber (SDF), quality improvement, flour confectionery, sensory evaluation, wheat flour, technology, parameters, rheological properties, recipe, calcium compounds, concentration, physicochemical parameters, technological characteristics, drying.

LIST papers published on the topics of thesis

Scientific works in which the main scientific results of the dissertation are published:

Articles in scientific professional journals Ukraine

1. Wang, F., Sukmanov, V., & Zeng, J. (2019). Effect of ultrafine grinding on functional properties of soybean by-products. *Ukrainian Food Journal*, *8*(4), 687-903. (**Web of Science Core Collection)**,
Personal contribution: Conceptualization, Methodology, Formal analysis, Data Curation, Investigation, Writing - original draft, Writing-Review & Editing.

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Personal contribution: Methodology, Formal analysis, Writing – original draft.

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CONTENT

LIST OF CONDITIONAL NOTATIONS

List of abbreviations

U: Ultrafine grinding

HP: High Pressure

M: Microwave

HTC: High temperature cooking

U-HP: Ultrafine grinding -High Pressure

U-M: Ultrafine grinding -Microwave

U-HTC: Ultrafine grinding -High temperature cooking

SDF: Soluble dietary fiber

SEM: Scanning electron microscopy

TIA: Trypsin inhibitor activity

INTRODUCTION

Relevance of the topic

SDF has a potential “prebiotic” label, it has attracted increasing interest in recent years, as many studies have revealed. SDF might be involved in disease prevention and health promotive activities, including antagonistic glucagon, improving blood sugar and insulin sensitivity in nondiabetic and diabetic individuals, inhibiting the absorption of glucose in the small intestine, and reducing postprandial blood sugar. Bean dregs are by-products from the processing of tofu or soy milk and consist of 50–60% total dietary fiber (TDF) and 20–30% protein. In addition, bean dregs are rich in minerals and are a good source of isoflavones.

Research results the bean dregs are characterized by poor taste, perishability, and low soluble fiber, and contain certain anti-nutrient factors-trypsin inhibitors, and most of them are used as feed or discarded as waste disposal. At present, there are some chemical, physical and physical-chemical methods for improving the quality of the bean dregs. But, as far as we know, ultrafine grinding technology combination with other physical techniques has not been treated in bean dregs, and its application in baked food.

For the improvement of bean dregs caused by poor taste, perishability, and low soluble fiber, perspective is to application of combined methods may be the development trend, increase its SDF content in food products as application of combined methods, and explore novel combinations to modify the functional characteristics of bean dregs and its application in biscuits.

Research of the problem of SDF deficiency in bean dregs and the development of directions of its improvement, in particular by creating new technologies with high SDF content, and the physicochemical properties were improved, thereby making it more suitable for use in functional foods, devoted to numerous works of domestic and foreign scientists: Y. Chen, Y. Jing, B. Li, I. Mateos-Aparicio, S. Tsubaki, G. Fayaz, M. Wennberg, E. Pérez-López, N.N. Rosa, K.X. Zhu and others. However, the problem of SDF deficiency in nutrition requires further study and improvement by individual technologies or combinations of technologies, which makes it expedient to carry out further research aimed at improving the nutrition of modern man.

Creation of bakery product with adequate to physiological needs consumers with a set of essental macro-food and micro-food substances and specified functional and technological properties is one of the ways to improve the nutrition of the types of food. The types of such products containing in raw materials of soybean by-product and wheat flour.

Selectivity of joint use of physical technology in the treated of bean dregs is determined by the improvement of SDF content, as well as protein content, mineral content, trypsin inhibitor content, processing performance and physicochemical property in order to assess the effects of changes of bean dregs realized with different physical treatments.

Physical methods have the advantages of short processing times, ease in processing, low cost and high safety, and they do not require the use of solvents, so they have good prospects for development and application. A combined method may have greater effects than any single approach in improving the quality of bean dregs. Currently, the application of combined methods may be the development trend.

Thus, a promising direction is the development of multiple physical technology combined used in bean dregs to physiological needs consumers and specified functional and technological properties, on the based on the combination of bean dregs after processing, and wheat flour make two types of baked goods with different textures: crisp biscuits and hard biscuits therefore Theme: "Improving the quality of bean dregs by physical methods during its use in bakery technology " is relevant.

Connection of work with scientific programs, plans, topics.

Work carried out in accordance with the main directions of scientific research the food departments of Sumy National Agrarian University, Henan Institute of Science and Technology and scientific research of the Poltava State Agrarian University on the state budget topic "Innovative and resource-saving technologies of food production" (No. SR 0115U006745).

The purpose and objectives of the study

The purpose of the dissertation work is scientific substantiation and development of the bean dregs using physical technology. The obtained results contribute to enhance SDF content, reduce anti-nutrition factors, and expand development and utilization of bean dregs, which constitute the basis for its application in baked food and the food industry. To achieve the main goal, it was necessary to solve a number of interrelated tasks:

– analyze literary sources in accordance more methods for increasing SDF content and improving the physical-chemical of bean dregs have been reported, including chemical, fermentation, enzymatic and physical methods;

– to analyze the advantages and disadvantages of different methods, it shows that the physical methods have the advantages of short processing times, ease in processing, low cost and high safety, and they do not require the use of solvents, so they have good prospects for development and application;

– to project a series of physical processing technologies were designed to modification the bean dregs, including single technology ultrafine grinding (U), high pressure (HP), microwave irradiation (M), high temperature cooking (HTC) and combination technologies (U-HP, U-M, U-HTC) with various parameters were used to treat bean dregs to characterize the nutritional and functional characteristics of bean dregs more systematically;

– evaluation of the nutritional and functional characteristics of bean dregs based on various physical techniques, select an efficient and reliable combination technology for the development of biscuit products.

– determine the content of SDF in bean dregs, single factor tests were carried out under different technical conditions to determine the optimal technical parameters;

– determine the technical parameters with the highest SDF content under single technology (U, HP, M, HTC) and combined technology (U-HP, U-M, U-HTC);

– To evaluate the changes of nutrient composition and physicochemical properties of bean dregs under certain technical parameters;

– To determine a better processing technology, processing bean dregs for the preparation of crisp biscuits and hard biscuits;

– to optimum amount of bean dregs in different biscuits was evaluated by measuring indexes of dough and biscuits, and the technology was optimized;

– to determine the socio-economic effectiveness of scientific and technical developments and implement the results of work in practical production.

Object research – Bean dregs: Wet bean dregs were obtained at local market (Fresh okra has high moisture content, bad taste and mouth feel, and is difficult to store). Bean dregs with high SDF are produced for the production of biscuits by combination technology.

Subject of research – is the effects of different physical technology on compositions and characteristics of bean dregs; effect of ultrafine grinding technology combined with high-pressure, microwave and high-temperature cooking technology on the physicochemical properties of bean dregs; effect of bean dregs powder treated by U-M on dough properties and quality of crisp biscuits; effect of bean dregs powder treated by U-M on dough properties and quality of hard biscuits.

Research methods – standard physicochemical, reological, organoleptic, experiment planning methods and mathematical processing of experimental data computer programs.

Scientific novelty of the obtained results

Bean dregs under physical technology treatment is a good source of soluble dietary fiber;

Nutritional and functional compositions in bean dregs under different physical technology were detailly analyzed;

Combined treatments are the appropriate methods for improving bean dregs.

Scientific rationale for new technologies of the biscuit functional purpose with addition of flour from waste of soy processing processed by U-M treatment.

First:

– the content of SDF in bean dregs was determined by single factor test under different techniques;

– the influence of physical technology on the change of indicators of nutritional and functional compositions, determined to assess the effects of changes of bean dregs realized with different physical treatments;

– U treatment combined with HP, M, HTC technologies enhanced nutritional quality;

– scientifically based and optimized parameters determine efficient and reliable combination technology;

– the obtained results contribute to enhance SDF content, reduce anti-nutrition factors, and expand development and utilization of bean dregs, which constitute the basis for its application in baked food;

– scientifically based technologies of crisp biscuits and crisp biscuits with using the bean dregs by U-M treatment.

Practical significance of the results.

Based on the results of theoretical and experimental studies developed by the U-M treatment technology of bean dregs for making biscuits.

Writing and approval of various technological documents for developed products.

Use in the educational process in preparing students, lecturing, writing teaching materials and textbooks.

This work was financed by Central government guiding local scientific and technological development projects (No. 2021), the Program of Xinxiang Major Scientific and Technological Project (No. ZD2020003); and Science and Technology Projects in Henan Province (grant number 19A550007). The work was carried out for the period from 2018 to 2019 at the food departments of Sumy National Agrarian University, and the period from 2019 to 2021 at the food department of Henan Institute of Science and Technology.

The applicant's personal contribution is in planning an experiment, organization and conduct of analytical and experimental research in laboratory and production conditions, analysis, processing and generalization results, formulating conclusions and recommendations, preparing materials for publication, development and approval of normative documentation, introduction of new technologies into production.

Publication. Based on the results of the dissertation, 6 articles were published in scientific journals. 2 articles - in scientific publications included in the List of scientific professional publications **Scopus Q1**, which, taking into account the Procedure for awarding the degree of Doctor of Philosophy are counted as 4 articles; 4 articles in scientific publications included in the List of scientific professional publications **Web of Science Core Collection** - Ukrainian scientific journal of category A.

Structure and scope of the dissertation. The dissertation is set out on 172 pages of computer text. The dissertation consists of an annotation, introduction, 5 sections, conclusions, the list of references includes the name of 201 sources. The main body of the dissertation is 147 pages of printed text. The work is illustrated with 19 tables, 27 figures.

SECTION 1
REVIEW OF STUDIES ON INCREASING THE QUALITY OF BEAN DREGS BY PHYSICAL METHODS WHEN USING THEM IN COOKIES TECHNOLOGIES

This review compiles the research carried out on functional characteristics and utilization of bean dregs in baked goods (bread, cake and biscuit). The effects of physical techniques on quality improvement of bean dregs were reviewed. In this review, we aim to highlight physical methods impact on bean dregs and baked goods are emphasized, as well as the effects of physical techniques on anti-nutrition factors. Further research should focus on technological innovations to develop high quality raw materials from soybean by-products to improve the quality of baked foods.

1.1 Dietary fiber

Physiological functions of dietary fiber

Dietary fiber is the general term of the carbohydrates that are not easy or cannot be decomposed and digested by digestive enzymes and absorbed of human intestinal tracts after being ingested by human, including cellulose, hemicellulose, lignin, pectin, mucus, gum, β-glucan, arabinoxylan and so on. It was resistant to digestion and adsorption in the human small intestine and can be fully or partially fermented in the large intestine (Al-Sheraji et al., 2011; Sangnark & Noomhorm, 2003). With the development of society and the continuous improvement of human living standards, people had less intake of dietary fiber, and food nutrition has not been properly matched. In the long run, it will cause diseases such as diabetes and obesity. Dietary fiber intake requirements (25 g for women and 38g men every day) (Weickert & Pfeiffer, 2018). Dietary fiber can affect the ecology of human intestinal microorganisms, promote intestinal peristalsis, increase satiety, lower blood glucose levels, and also has the effect of losing weight (Huang, Qian & Yun, 2016; Psichas et al., 2015). The presence of dietary fiber may change the gelatinization temperature, molecular structure and crystallite structure of the starch, thereby further affect the digestive properties of the food. Daily intake of dietary fiber can reduce hunger, prolong food intake, and control cholesterol intake (Chen, Chen, Wang, Qin, & Bai, 2017). Dietary fiber can effectively inhibit the growth of harmful bacteria, promote the proliferation of beneficial bacteria, regulate the balance function of intestinal flora, and protect colonic health (Holscher, 2017). With the development of nutrition and related disciplines, more and more studies had found that dietary fiber plays a very important role in human health. It was an indispensable nutrient for human healthy diet, especially in the health of the digestive tract. Comprehensively, dietary fiber has physiological functions, such as lower blood fat and blood sugar, improve the intestinal environment, and control body weight (Chutkan, Fahey, Wrigh & McRorie, 2012; Mehta, Ahlawat, Sharma & Dabur, 2015). The bean dregs dietary fiber was mainly composed of cellulose, hemicellulose (dry weight content 40~60 g/100 g) and lignin. Dietary fiber includes soluble and insoluble dietary fiber. Soluble dietary fiber (SDF) has high viscosity and strong water holding capacity. It can be used by intestinal microorganisms and slow down the digestion rate. Soluble dietary fiber consists of naturally formed gels or viscous fibers such as hemicellulose, seaweed polysaccharides, guar gum, pectin, et al (Anson et al., 2012). SDF has attracted increasing interest in recent years, as many studies have revealed. SDF might be involved in disease prevention and health promotive activities, including antagonistic glucagon (Olli et al., 2015), improving blood sugar and insulin sensitivity in nondiabetic and diabetic individuals (Anderson et al., 2009), inhibiting the absorption of glucose in the small intestine (Repin et al., 2017) and reducing postprandial blood sugar (Yu, Ke, Li, Zhang, & Fang, 2014). Therefore, SDF has a potential “prebiotic” label. Insoluble dietary fiber cellulose mainly contains cellulose and hemicellulose, which can promote gastrointestinal motility, accelerate food absorption through the gastrointestinal tract, reduce energy absorption, and clean the digestive wall, dilute carcinogens in food, and accelerate the migration of toxic metabolites (Elleuch et al., 2011; Gajula, Alavi, Adhikari, & Herald, 2008). In addition, it is good for intestinal health and prevention of colon cancer.

There are a lot of foods containing dietary fiber, such as grains, vegetables, fruits, tea and other processed of scraps, and many wastes from food factory also containing large amount of dietary fiber, such as wheat bran, rice bran, yam skin, dragon skin, navel orange peel, tea stems and so on. Add dietary fiber to cereal products, not only can increase nutrition, prevents disease, but also improve the viscosity, texture, sensory properties of the product, and extend the shelf life of the food. Therefore, recycling and reusing waste resources not only enriches food types, but also increases the added value of products, which is of great practical significance.

Application of different types of fibers in bakery products

Different types of fibers were used in baked products to effectively improve the viscosity, texture, and sensory properties of the product, while reduced the heat of the product (Brownlee, Chater, Pearson & Wilcox, 2017; Vitali, Dragojevi, & Šebečić, 20009). It increases the nutrition and flavor of the product and better meets the consumer's demand for high dietary fiber food. Microwave reaction technology is combined with ultrafine grinding was used to separate the dietary fiber from the cardamom, and used in the production and development of biscuits. The results showed that the hardness of the biscuit product improved with the increase of cardamom dietary fiber content. Addition of 10% cardamom dietary fiber was used instead of wheat flour. The biscuit has anti-free radical properties, and was 6 times higher than that of the control group. Above 7.5% cardamom dietary fiber addition, the nutritional and quality properties of the biscuit improved (Aboshora et al., 2019). Used jet mill to treat barley and rye flour for biscuit production, the composite flour was softer than the commercial flour, the color was darker, and the total phenolic content and antioxidant activity were higher, and barley flour was increased in hardness compared to biscuits made from whole wheat flour. Rye flour was darker in color, so the biscuits were darker in color (Drakos, Andrioti-Petropoulou, Evageliou & Mandala, 2019). Used bean powder and soy protein powder to make biscuits. Soybean protein powder has a higher protein content of 9.42% compared with that of wheat flour. The addition of soybean powder improved the nutritional quality of biscuits, and further increases the sensory score of biscuits (Dreher & Patek, 1984).

By optimizing the formulation of the biscuits, the resistant starch 14%, sodium caseinate 14.51%, raftilose 25%, and simplesse 25.02%, a low-sugar, lowfat "functional" biscuit was developed. Add to sodium caseinate can increase the hardness of the biscuit dough, and the thickness of the biscuit was positively correlated with the texture (Gallagher, O'Brien, Scannell, & Arendt, 2003).

When making biscuits, by adding different types of dietary fiber, the sensory properties of the product can be improved, and the calories of the biscuits can be reduced, thereby becomes a functional food that is beneficial to the human body. For the addition of fiber, although the nutritional value of the product is improved, whether the taste and texture of the biscuits meet the needs of consumers, and whether the cost is accepted by the producer, we need to do further research. There are many foods contained fiber. The bean dregs were wastes in soybean processed. The bean dregs were mostly used in feed mills or discarded, which caused waste of resources. In order to further increase the added value of products, a large number of studies have proved that bean dregs highly utilized in food, and mostly used for the development of flour products. In recent years, many varieties of bean dregs have been developed, such as taro, bread, biscuits, cakes, noodles, etc. The addition of bean dregs complements the nutritional value of the products, and increased the overall acceptability of the product. And bean dregs Not only develops new varieties, but also a new market has been developed.

1.2 Application of bean dregs in bakery products

With the development of the food industry, the availability of bean dregs has been gradually developed, and commonly used in baked goods (cakes, bread, biscuits). Addition the bean dregs in the flour and adds the correspond ingredients to make the bean dregs biscuits, it not only improved the flavor of the traditional biscuits, but also provided a new type of healthy food for consumers. A large number of literature studied has shown that the addition of bean dregs to flour. It can improve the nutrition and flavor of biscuits, and provided a new method for the utilization of soybean food (Yang, Nie & Lin, 2013; Chen, 2013).

Application of bean dregs in bread and cakes

Bean dregs can be used in a variety of Wester-styles baked goods, it not only to provide natural fiber and protein, but also to provide a unique fragile texture for bread, muffins, donuts, brownies, marshmallows, etc (Shurtleff & Aoyagi, 1978). The bean dregs bread was made from the bean dregs and the flour, assess the sensory, texture, and flavor of bread products. With the increased of the amount of bean dregs, the bean flavor of the bread was more intense. The hardness was gradually increased, and the internal texture was superior to ordinary bread. Above 10% level bean dregs powder, the bread was soft, with aroma, and the highest quality score. However, hardness, cohesiveness and occlusion of the bean dregs bread were higher, and the elasticity was lower, which provided a reference for the improvement of the bean dregs bread (Yang & Chen, 2016). The used of bean dregs and grain rice to mix and make puffed biscuits, the rice cake made by mixing the ratio of bean dregs, and rice flour to 7:3 was most popular among the public. The addition of bean dregs was related to moisture and hardness, and the heating temperature and time were affected specific area of rice cake. The higher the content of bean dregs, the greater the hardness, the smaller the specific volume area and the lower the integrity. The bean dregs fiber was combined with rice flour, increased the adhesion strength between the particles and the toughness of the biscuit. With the increased of the amount of bean dregs, the $L*$ value and the $a*$ value of the product gradually decreased, and the $b*$ values increased significantly (Xie, Huff, Hsieh & Mustapha, 2008). Make a new type of cake product, used eggs, flour, sugar, bean dregs and peanut dregs as raw materials. Among them, flour: peanut residue: bean dregs were (1:1:3), The finished cake was complete in shape, attractive in color and aroma, and the finished product is soft and elastic. The pores were evenly distributed and the flavor was outstanding. The total dietary fiber content was 3.1%, and better than traditional cake. Nevertheless, there is a fishy smell in bean dregs or peanut dregs, how to use a certain technology to effectively remove, and still need to be further research (Wang & Liu, 2015). The mixture of bean dregs and rice flour is used to make glute-free layered cakes. The addition of bean dregs has a great impact on the cake batter and the product. When the substitution percentage of rice four by bean dregs increased the decrease in cake volume is observed, giving rise to harder and less cohesive cakes. When addition 10% of the bean dregs flour can improve the quality and nutrition of the cake (Ostermann-Porcel, Rinaldoni, Campderrós & Gómez, 2020). When making bean dregs bread, based on wet bean dregs, sugar, yeast, butter, the dough was analyzed and the bread was sensory evaluated. In the test of dough, the decisive indicators were hardness, elasticity and chew ability. The sensory evaluation of bread was related to the dough, and chew ability does not have much effect on dough quality (Zhao et al., 2016). When making bean dregs bread, added 8% bean dregs can increase the water absorption properties of bread flour, and improve the stretching properties of the dough. Addition of bean dregs increased the hardness and chew ability of bread, and delays the aging rate of bread (Meng, Liu, Li, Zhang & Xie, 2017). The soybean cake was fermented in stages, which shorten the fermentation process. As the increased of fermentation time, the hardness of the bean dregs cakes increased significantly, and the elasticity, cohesiveness and resilience decreased significantly. The surface of bean dregs cake had obvious changes, the inside of the product occurred uniform air holes, and organization more uniform (Yao, Pan, Wang & Xu, 2010).

A large number of literature have shown that bean dregs were added to bread can increase the nutritional value of the product, improve the flavor and volume of the product, and also have the effect of delaying aging. However, due to the strong water absorption of the bean dregs, a large amount of the addition will increase the hardness of the product, and the elasticity, cohesiveness and recovery were reduced, thereby affecting the taste of the product. These studies can provide more reference for the improvement of the bean dregs bread. Soybeans have a certain taste of soybean meal, and directly affect the taste quality of the product. The reason was that the oxidization of fat oxidase in soybean causes the oil to oxidize, thereby produce the taste of soybean meal. Bean curd in the bean dregs also exists, and whether it will affect the flavor of the product and other series of problems, and it should be paid close attention.

Application of bean dregs in biscuits

Biscuits as a widely consumed product in the world, it has rich nutritional value and become an indispensable snack food (Akubor, 2003; Hooda & Jood, 2005). Biscuits are baked goods with lower water activity than bread. Biscuits usually made from wheat flour, eggs, sugar, salt, oil and water (Manley, 1998). Biscuits play an important role in the baked industry, the main factors affected the quality of biscuits was the texture, taste and appearance of biscuits. Improve the nutritional content of cookies and being accepted by consumers is the most important aspect (Škrbić & Cvejanov, 2011; Torbica, Hadnadev & Hadnađev, 2012). The word "biscuit" comes from France, it means r-baked bread, the earliest biscuits were baked from bread. The biscuits were mainly divided into tough biscuits, crisp biscuits and fermented biscuits on the market in China. The crispy biscuits were made of lo-gluten wheat flour as the main raw material, with more oil and sugar, and the taste was crisp. The dough of the plastic biscuit lacks elongation and elasticity, it has good plasticity, the biscuit is crispy and sweet, it is a highly acceptable biscuit variety. The tough biscuits are a kind of biscuit with less sugar and fat, it is composed of wheat flour, sugar (or suga-free) and oil as the main raw materials, and added leavening agent, modifier, and other auxiliary materials. After the process of powdering, rolling, forming, baking. The surface of the biscuit had many patterns, the appearance was smooth and flat, there was even pores, the section was layered, and the taste was crisp. Biscuits have become a kind of snack food instead of people's lives, because of different tastes and textures, it was suitable for all the people. With the improvement of living standards, a new generation of mea-making biscuits on the market, which can control calories, it is the main ingredient for obese patients to lose weight. Bean dregs have rich in dietary fiber, among them, insoluble dietary fiber content is high. However, the taste of the bean dregs is not easy to be accepted by the public. Therefore, the development of functional food has been done by researchers.

Mix fresh bean dregs with starch, soy flour, and hydroxypropyl methylcellulose to make biscuits. Among them, the highest water retention of the dough with hydroxypropyl methylcellulose was 147.8%. Bean dregs dough has the lowest elasticity, followed by soya flour dough. Soy flour crackers and hydroxypropyl methylcellulose crackers were harder during storage. Bean biscuits were crispy and chewy. However, fresh bean dregs may produce a fishy smell and may affect the shelf life of the finished product (Park, Choi & Kim, 2015). The amount of bean dregs added directly affects the performance of the biscuit dough, and the taste of the finished product, on the basis of adjusting the amount of oil, sugar and water added, the maximum amount of the bean dregs powder was 40%. The greater the amount of bean dregs added, will affect the formation of biscuits, but it may require the addition of more grease (Wu, Shang, Li & He, 2006). The bean dregs were rich in dietary fiber, and the bean dregs were retreated with ultrafine grinding used to make cookies. With butter, bean dregs powder, sugar powder and baking process as a single factor, through orthogonal experiments, determine the best process recipe for making bean dregs biscuits: flour 864 g, bean dregs powder 180 g, 300g sugar powder, 750 g butter, baking temperature was 180 °C, bottom fire 160 °C, baked time 12 min. Under this formula, the biscuit has golden color and the shape to keep good, crispy taste and rich bean flavor. There were more bean dregs added, which was a kind of high-fiber snack food, it suitable for most consumers, and included special people, it can improve human health to a certain extent (Huang, Yang & University, 2015). The use of ultrafine powdered bean dregs to produce sugar-free bean dregs biscuits, and the quality of the products from the shape, texture, taste, aroma and color of the biscuits to determine the best process conditions for making biscuits: baked temperature 160 °C, baked time 10 min, the bean dregs addition amount was 30%, the oil: sugar mass ratio was 1.0:1.5, the oil and sugar: the optimal ratio of the bean dregs flour was 1.0: 2.0, and the ratio of baking soda to ammonium bicarbonate was 2:1. It is shown that the addition of bean dregs can increase the content of wet gluten in the flour. When the amount of bean dregs added was less than 7.5%. The rheological properties of the dough were good, which was beneficial to the formation of biscuits (Chen, 2013). Untreated bean dregs were directly added to wheat flour for the development of crisp biscuits, the best optimized formula was obtained: bean dregs: Wheat flour were 3:7, butter was added in 30% of powder, and sugar was added in 20% of powder, baked temperature: 200 °C on fire and 180 °C under fire, the biscuit has a complete structure, uniform color and crispy taste, it has rich aroma of bean dregs and good quality (Qiu & Yuan, 2018). But whether biscuits produced with wet bean dregs will reduce the shelf life of the biscuits, and whether the taste was better than the biscuits made from dried bean dregs. The addition of wet bean dregs will cause ant-nutritional factors in the biscuits, which were not conducive to the health of the human body. In addition to this, added to the bean dregs were not pulverized, which may affect the taste. The use of black bean dregs to make biscuits have a significant effect on the water holding capacity, texture, and senses of ordinary bean dregs. When the added amount is 40%, the hardness of the biscuit is the largest. It may be that the dietary fiber in the black bean dregs and the gluten contents in the dough are diluted, which affects the formation of the gluten network, which causes the biscuits to dry out and increase their hardness. Using headspace soli-phase microextraction gas chromatograph-mass spectrometry, the flavor content of 30% black bean dregs cookies is richer, dietary fiber (58.8±0.481) g/100 g, protein content is (23.8±0.175) g/100 g, fat content It was (8.08±0.121) g/100 g, the amino acid nitrogen content was (0.132±0.012) g/100 g, and the ash content was (3.56±0.078) g/100 g (Li et al., 2017).

Bean dregs biscuits were made with bean dregs powder, fat, white sugar, and skimmed milk powder as single factors. Through orthogonal tests, sensory evaluation and hardness were the main evaluation indicators. The results showed that the hardness of the biscuit gradually decreased with the increased of the amount of bean dregs, and the hardness was the highest when the additional amount was 20%. The final formula was: flour 88%, bean dregs powder 12%, skim milk powder 20%, fat was 45%, white sugar 40%, egg liquid 35%, baking soda 0.6%, salt 0.6%, the biscuits were golden in color, it has crisp, sweet and milky aroma, it has a certain health effect on the human body (Guo, Mu, Jie & Guo, 2015). Bean dregs and cassava flour are mixed to produce glute-free biscuits, and inulin is used instead of sugar. Studies have shown that with the increase of bean dregs, the hardness of biscuits increases, color $L*$ value decreases, and the color becomes darker. Using sensory evaluation as the main index, and adding 30% of bean dregs. The quality of the produced biscuits is good. Research under a light microscope revealed no abnormalities in the cookies.

The protein and fiber contented of the biscuits has been increased and is welcomed by customers (Ostermann-Porcel, Quiroga-Panelo, Rinaldoni & Campderrós, 2017). The addition of the bean dregs, rice bran and broken rice in glute-free sweet biscuits is conducive to improving the stability of biscuits. The experimental sweet biscuits had characteristics of color, weight, volume and diameters (internal and external) very similar to the commercial, whereas texture, lipids and energy value decreased, and water activity, moisture and protein increased during storage. The sweet biscuits showed the same stability when compared to the standard. Thus, the bean dregs, rice bran and broken rice were considered viable alternatives for the development of new products (Tavares et al., 2016). Bean dregs flour have great potential for application in confectionery products. The formulation of the molded sweet biscuit in which 30 % of the wheat flour was substituted by bean dregs flour was considered adequate. The color, flavor and overall quality of the molded sweet biscuit did not differ significantly from those of the standard biscuits (Grizotto, Rufi, Yamada, & Vicente, 2010).

Researchers have studied the recipe of biscuits, the combination of bean dregs and other powders to make biscuits, it can effectively improve the taste of the product and attractive color. The amount of bean dregs added varies depending on the powder used to carry out the biscuits. For biscuits, the proportion of dietary fiber added to the bean dregs can be increased, because the biscuits have lower requirements for gluten content. However, the sensory evaluation of biscuits has a considerable subjectivity, and different scholars have different opinions on the amount of bean dregs added in biscuits. After the bean dregs were mixed with the flour, the hardness of the product was much increased, and the amount of the bean dregs added was only 10% or less. The combination of bean dregs and starch, bean dregs can be added up to 30%, and will produce a certain degree of brittleness, if it exceeds a certain amount, it may affect the edible taste of the biscuit. There were a wide variety of biscuits, but the above researchers have studied more in bean dregs biscuits, while the research on tough biscuits was relatively rare, especially making recipes for biscuits, most recipes contain more fats and sugars. Although the bean dregs biscuits increased the nutritional needs of human beings to a certain extent, but for special people, whether it can be eaten normally, such a problem deserves our continued discussion. For example, using a certain processing method to treat the bean dregs for the addition of baked goods, so as to develop a functional biscuit suitable for all people to eat, low sugar, low fat, it is a huge challenge currently facing. At the same time, we must control the production process or use some new and improved technologies. In this way, functional food with high quality and nutrition can be obtained. Despite the fact that there are more and more researches on bean dregs, but in the face of existing defects, food workers need to continue to explore, and still require a lot of research work.

Application of bean dregs in other food

Bean dregs are not only used in baked goods, but also in steamed bread, noodles, dumpling skins and beverages.

Addition bean dregs the water absorption, silty index, formation time and stability time of dough increased and prolong the shelf life of steamed bread (Song, Hou, Zhang & Zhao, 2014). Added to wheat flour at the bean dregs powder of 0, 5, 10, 15 and 20 g/100 g used to make Chinese steamed bread. The results of the present study suggested that increased amount of bean dregs powder led to a significant increase in hardness, gumminess, chewiness and adhesiveness in dough and Chinese steamed bread (Cui, Cui, Ma, Zhang & Zhang, 2014). The ultrafine grinding technology was used to treated bean dregs, and mix flour to make traditional Chinese steamed bread. The quality of steamed bun was the best when the added amount of bean dregs was 13% (Zhang, Cui & Qi, 2009). Replacing part wheat flour with bean dregs powder to make noodle and steamed bread. Addition to 25% and 15% of bean dregs powder mix with flour to make noodles and steamed bread respectively. Researches show that the noodle and steamed bread had almost similar qualities to those made from 100% wheat flour (Lu, Cui, Liu, & Li, 2013). Bean dregs may improve rheological properties of silty clay and stretch in certain scope. Addition 16% of bean dregs can improve the rheological characteristics of the flour, and bean dregs noodles reaching the optimum conditions (Song, Li, & Geng, 2011). In addition to, taking bean dregs as raw material, different fungal fermented was used to make bean dregs sauce (Zhao et al., 2015) and white soy sauce (Yoshida, Takeuchi & Yoshii, 2010).

At present, the bean dregs have been widely used in food, and made a great contribution to the food industry. Domestic and foreign scholars on the research of the bean dregs has not only is still in the primary stage, many researchers use special technology to improve the quality of the bean dregs, applied to food to improve product quality.

1.3 Application of physical technology in food

High pressure

High pressure technology refers to the sealing of food materials in an elastic container or pressure-resistant device system. The pressure conditions are generally (100–700 MPa), it often used water or other fluid medium as a medium to achieve sterilization, and change materials, the purpose of physical and chemical properties. High pressure as a good no thermal processed technology, it can ensure the safety of food, reduce the process degree of food, and maintain the original flavor of food (Norton & Sun, 2008). High pressure can modify or denature macromolecules (such as starch, protein, etc.) by destroying secondary bonds in macromolecular substances, and small molecules composed of covalent bonds of vitamins, minerals, aroma components and pigments of substance has no significant effect. High pressure technology is commonly used in food processing, and the most mature application is fruit and vegetable processing. For example, used in high pressure technology for the production, sterilization and preservation of fruit and vegetables, jams and juices. High pressure technology also applies to the processing of meat products and aquatic products. For instance, pressure processing shellfish food can not only increase the safety and shelf life of raw meat, but also maintain the fresh taste of shellfish. At the same time, th1e removal of shellfish after high pressure treatment is more convenient. However, high pressure is increasingly used in the processing of food products, such as cereal crops, potato crops and legume crops. At present, the application of high pressure technology in the processing of food products is mainly the modification of starch and protein, such as changing the viscosity and transparency of food, and also relates to the physical and chemical properties relates to food flavor and nutritional value.

As early as 1990, Japan used high pressure treatment products for the first time. Ten years ago in Europe, high pressure processing food were already in the stage of research or trial production, and the label of "new food" was spread throughout Europe (Fonberg-Broczek et al., 2005). High pressure processing has become a technology with potential use for these purposes. Its main advantages are short processing time, uniform effect, good instantaneity (Mújica-Paz, Valdez-Fragoso, Samson, Welti-Chanes & Torres, 2011). The compare with other technologies, such as heat treatment and pasteurization, these techniques fail to maintain the original color, taste and nutrition of the raw materials. While high pressure processing maintains the sensory attributes and nutritional value of the product (Barba, Esteve & Frigola, 2013; Viljanen, Lille, Heiniö & Buchert, 2011; Chaikham & Apichartsrangkoon, 2012). High pressure processing has become a commercially viable food manufacturing tool. In food processing and preservation applications, the importance of in-situ engineering and thermodynamic properties of food and packaging materials in process design was emphasized (Balasubramaniam, Martínez-Monteagudo & Gupta, 2015). In recent years, high pressure has become a new tool for improving gluten-free food, which has changed the properties of food, such as protein and starch (Barba, Terefe, Buckow, Knorr & Orlien, 2015).

Using high pressure technology to process sugar cookies, research shows that high pressure technology reduces the number of mesophilic bacteria, yeast, and mold microorganisms in the product. After high pressure treatment, the shelf life of biscuit dough is expanded, with a higher density. In the baking process, the maturation time of the biscuit is shortened, compared with untreated dough. Dough processed under high pressure technology corresponds to the biscuit produced, with a darker color, and the dough surface is smooth and uniform. There are even cracks on the surface of the biscuit, but it will not significantly influence the quality characteristics of the biscuit (Aguirre, Karwe & Borneo, 2018). The cake batter is treated with high pressure technology. When the high pressure condition is 300–600 MPa, the duration is 3–6 min. Cake paste was measured for microbial flora, density, microstructure and rheology, and the cake was analyzed for specific volume, weight loss, color and texture. The results showed that compared with the untreated ones, the number of molds and yeast decreased with increasing pressure. The density of the batter increases, the cake volume decreases, the surface color deepens, and the hardness increases (Barcenilla, Román, Martínez, Martínez & Gómez, 2016). Corn starch and rice flour are respectively subjected to high pressure treatment for bread production. Set the high pressure condition to 600 MPa, 40 °C, 5 min. The results demonstrate that high pressure treatment can effectively slow down the aging speed of bread, extend the shelf life, and improve bread quality. Therefore, corn starch and rice flour under pressure treatment can increase the shelf life and quality of gluten-free bread (Cappa, Barbosa-Cánovas, Lucisano & Mariotti, 2016). Sorghum flour is treated under high pressure for the production and processing of bread. When the pressure conditions at 200–600 MPa, 20 °C, and observe the rheological properties of the batter. When the pressure at 300 MPa, the batter structure weakens. When the pressure is higher than 300 MPa, the batter consistency increases. At 600 MPa, processing 2% sorghum flour can delay the aging of bread. Adding 10% sorghum flour, the exact volume of the bread is small, and the product quality is poor. Therefore, under appropriate pressure conditions, the amount of sorghum flour should be controlled (Vallons, Ryan, Koehler & Arendt, 2010).

High pressure technology has made a great contribution to grain products, changing the performance of grain and improving product quality. Cereals undergo high pressure treatment, which can effectively reduce the amount of microorganisms in food and extend the shelf life of food. After the batter is treated with high pressure, it can effectively improve the rheological properties, the structure of the batter is enhanced, and the color of the product can be increased. But as the pressure increases, the hardness of the dough will gradually increase. On the basis of improving the product, the quality of the product is not covered, so the pressure conditions corresponding to different products are different. Studies have revealed that the high hydrostatic pressure treatment in the heat rheology of batter, with the increased of pressure level, induced gelation of starch content. High pressure treatment at 450 MPa and 600 MPa, 25 °C for 15 min, the concentration of gouache paste was (1:5), gelation was completed, the higher concentration of slurry requires higher pressure 、temperature or longer holding time (Alvarez, Fuentes, Olivares & Canet, 2014). High pressure treatment significantly increases dough hardness and adhesion and reduces stickiness. When making bread, use a scanning electron microscope to observe the cut surface of the bread. Under pressure at 0-200 MPa, as the pressure increases, the pores become larger and larger, the protein is affected when the pressure level is higher than 50 MPa, and the starch modification requires a higher pressure level. High pressure treatment has little change in the color of the dough, but during the baking process, the color of the breadcrumbs changes dramatically. Studies have shown that high hydrostatic pressure treatment can obtain grain products of the new type in the range of 50-200 MPa (Bárcenas, Altamirano-Fortoul & Rosell, 2010). Wheat starch slurry (10% w/v) was subjected to high hydrostatic pressure treatment at 300, 400, 500, 600 MPa, 20 °C for 30 min. The gelation temperature was lowered, the surface and internal structure particles of the starch were destroyed, and waxy wheat starch was effectively modified (Hu, Zhang, Jin, Xu & Chen, 2017). High pressure can change the secondary structure of SPI, 7S, 11S proteins in nanoemulsion. Enhance their stability, and can be used as an effective emulsifier (Xu, Mukherjee & Chang, 2018). The gelatinization characteristics of pea starch under high pressure were investigated. At 0–600 MPa, the initial viscosity increased from 8 cP to 34 cP. High pressure treatment can promote "cold gelation" of pea starch aqueous dispersion, and strengthen gelatinization of starch particles. In addition, the shape, size, and particle size distribution of starch particles is changed (Leite et al., 2017). Antioxidant activity of buckwheat treated with high pressure was improved. It can also effectively inhibit the formation of fat. After comparison, this study shows that high pressure treatment at room temperature has better nutritional value than no-high pressure treatment (Waliszewski, Pardio & Carreon, 2002). Effects of high pressure and thermal processing on photochemical, color and microbiological quality of herbal-plant infusion. When the high pressure treatment conditions are at 400 or 500 MPa and 25 °C for 15 or 30 min, the natural color of the product can be better retained. The comparison with pasteurization (90 °C, 1–3 min). These two treatments can effectively eliminate yeast and E. coli (Chaikham, Worametrachanon & Apichartsrangkoon, 2014). High pressure technology was used to process potato starch, and it for cycles of 6, at 400 MPa, showing higher peak viscosity and attenuation value. For cycles of 3, the peak time and final viscosity was higher than those of the natural control sample. This shows that the treatment under high pressure has a significant effect on the sample. This study can be used to prepare food for slow digestion and hypoglycemia (Colussi et al., 2018). High pressure treatment can enhance the mixing properties of lo-grade wheat flour in food applications.

When the high pressure conditions are at 500 and 600 MPa, the flour moisture is controlled at 56%, and the starch particles are combined with protein aggregation, which causes the protein network in the dough to break. When the moisture content is 33%, the structure of the dough is promoted, the formation of a protein network and the strength of the dough are increased. At 500 or 600 MPa for 5 min, the protein structure is modified and the starch granules remain intact (Mccann, Leder, Buckow & Day, 2013). Taro, carrot and sweet potato are processed under high pressure at 600 MPa for 5–30 min. The results showed that high pressure treatment caused certain physical damage to the three vegetable structures. It can result in cell wall of vegetables to rupture, increase the drying speed, and shorten the processing time. Reduce gelatinization temperature for sweet potato starch. Increased softening and pre-gelatinization of carrot and sweet potato starch, making it more convenient for consumers to process (Oliveira et al., 2015). The high pressure was used to modify the sweet potato residue, and the microstructure of the insoluble dietary fiber of the sweet potato residue was observed as a loose, smooth, honeycom-shaped porous network structure. The modified insoluble dietary fiber of sweet potato residues has a significant effect on the ability to regulate blood sugar, blood lipids, and eliminate foreign harmful substances. When the modified conditions are at 600 MPa, 15 min, and 60 °C, it is helpful to adjust the ability of blood glucose and blood lipid; The modified conditions can remove external harmful substances at 100 MPa, 10 min, and 42 °C. And this method should also be used to study the modification of cereals such as bean dregs (Li et al., 2012). After the soybean in the grain is subjected to high pressure treatment, it can prevent the migration of water in the soybean, make the moisture distribution in the soybean uniform, and shorten the soaking time for the production of soybean products. Scanning electron microscopy analysis showed that the microstructure of soybeans could be changed after high pressure treatment, and it could help soybeans absorb water. Found by DSC and SDS-PAGE, some proteins of soybean were denatured during high pressure treatment (Zhang, Ishida & Isobe, 2004).

Most of the above researchers were enriched in the studied of cereal starch, which has a modification effect on starch slurry, and can destroy the surface and internal structure particles of starch. The high pressure on the dough can increase the hardness and reduce the presence of microorganisms. The treatment of buckwheat can increase the antioxidant activity. High pressure treated grain pressure is controlled at 400–600 MPa for 10–15 min. Treated starch by high pressure can be used to make hypoglycemic food, high pressure treatment can destroy the structure of the product, loosen the surface of the raw material, and form a porous structure, thereby shortening the pretreatment time. However, for high pressure processing of cereals, there is no specific research areas have been provided. And it currently enriches in basic research. Therefore, the grain after high pressure treatment needs further excavation in food, which provides more new ideas for applied research.

Ultrafine grinding

Ultrafine grinding is a mechanical or hydrodynamic method that overcomes the internal cohesive force of the solid to break it, thereby pulverizing the material particles of 3 mm or more to 10–25 μm. In the process of ultrafine pulverization, the bean dregs are modified by friction, extrusion, collision and other forces (Xiang & Ning, 2006). Based on the principle of micron technology, ultrafine grinding can make the product fine in size, larger in specific surface area and specific surface activity; the ultrafine grinding product has excellent physical and chemical properties, and the utilization rate is improved (Liu & Wang, 2007). Ultrafine grinding can significantly change the structure, and specific surface area of raw materials. it compared with traditional mechanical processed methods, ultrafine powders can improve the physicochemical properties of raw materials, for example, it has better hydration properties and fluidity, stronger free radical scavenging activity, flavor and mouthfeel. This new technology of superfine grinding has been proven, and used to prepare ultrafine powders with good properties (O'Toole, 1999). At present, most countries use ultrafine grinding technology to treat pollen, tea, wheat bran, rice bran, peel, rice, soybean, beet pulp, animal bone, seaweed, edible fungi and other raw materials to preserve nutrients and improve taste (Zhang, Zhang & Shrestha, 2005). At the same time, this technology has contributed greatly to the development of baked goods and other products.

Used the three different grain sizes of ordinary bean dregs, high-grade ultra-micro bean dregs powder and low-grade ultra-micro bean dregs powder and prepare mooncakes with flour, the sensory evaluation, color and texture were used as the evaluation criteria, the results showed that the ultrafine powdered bean dregs were better than the moon cake made of ordinary bean dregs powder and formed well, the texture showed a trend of rise and then decreased. When the bean dregs powder was added to 20%, it reached the maximum value 13561.81g, as the amount of additional increased, the finished product darkens and was not easily formed. When the high-speed ultrafine grinding bean dregs was added at 16%, the finished moon cake was the best, but if it was necessary to further increased the replacement amount of ultra-micro bean residue. It can be considered from the point of view of bean dregs dislocation and edible rubber assisted molding. Thus preparing a wide moon cake of high dietary fiber (Tao et al., 2017). Ultrafine grinding technology processes wheat flour and corn flour for bread production. At 9,000, 10,000, and 11,000 rpm, as the speed increases, the water retention capacity, swelling, water solubility, and gelatinization of cereal flour are improved. The quality of the product is enhanced, the volume of bread produced is increased, and the hardness is reduced (Chung, Han, Lee & Rhee, 2010). The finer wheat bran granules help develop cereal bread with nutritional value. Studies have found that the amount of bioaccessible phenolic acids in whole wheat bread and brown bread is higher than white bread, and the finer bran particles in bran bread, the higher the biological acceptability of phenolic acid (Hemery et al, 2010). Both the mixing characteristics of the dough and the quality of the bread product are affected by the thickness of the bran. When the bran particle size is small, the brain cells cause rupture, which reduces the quality of the bread (Noort, Haaster, Hemery, Schols & Hamer, 2010). Micronisation has the potential to increase antioxidant activity and soluble fiber of proso bran it can be used for enrichment of gluten-free bread with fiber and phenolics (Mustač et al., 2020). The use of ultrafine grinding technology in the production of more baked goods in the grain, it can increase the aging rate of the product, and reduce the hardness of the product, it's suitable for special populations.

The application range of ultrafine pulverization was relatively wide. The use of ultrafine pulverization in tea leaves enables the tea to dissolve into the water more quickly, and the scent was more prominent and effective to save the immersion time. For example, instant tea sold on the markets. The use of ultrafine grind of Chinese medicinal materials not only enables greater medicinal properties, but also reduces the loss of scraps and facilitates taking them. It can also introduce traditional Chinese medicine into everyday diets and develop a variety of health care products. This technology can be used on micron and submicron scales, and used in cereals such as whole wheat flour modification and related technologies (Rosa, Barron, Gaiani, Dufour & Micard, 2013).

Crushing whole grains with ultrafine grinding technology can improve the water absorption and stability of the flour. The exact volume area of the steamed bread was increased, and the steamed bread color was improved. The bran is ground and recombined with red wheat, and the steamed bread has a high sensory score. Therefore, ultrafine pulverization can improve the characteristics of power and improve the quality of products (Liu et al., 2015). After the whole grain flour and starch are subjected to ultrafine grinding, reduction in starch crystallinity was resulted. Along with these structural changes, decreased viscosities and higher pasting stability (Niu, Zhang, Jia & Zhao, 2017). Ultrafine grinding technology for preparing wheat bran dietary fiber. The results show that ultrafine pulverization can effectively pulverize fiber particles to the submicron level. As the particle size decreases, the hydration characteristics of wheat bran dietary fiber are significantly reduced, insoluble dietary fiber is converted to soluble dietary fiber, the antioxidant activity is improved, but the DPPH free radical scavenging activity is reduced (Zhu, Huang, Peng, Qian & Zhou, 2010). Wheat bran has three kinds of ultrafine crushing treatments with different particle sizes, and is applied to the production of steamed bread. Among them, the bran with the smallest particle diameter causes the strength of the dough to decrease, and the CO_2 produced is reduced. The exact volume area of the steamed bread becomes smaller and the hardness increases, which adversely affects the quality of the steamed bread. It can be seen that ultrafine grinding particles help improve the quality of steamed bread in a certain range, but it is not as fine as possible (Xu, Xu, Wang & Zhou, 2018). Ultrafine powder treats bean dregs and applies to noodles. The study concluded that compared with ordinary bean dregs, the bean dregs had a smaller particle size and increased soluble dietary fiber content. Adding bean dregs can make the dough form a stable structure, and the noodles are hard to break. Adding 7.5% ultrafine bean dregs powder reduces the cooking loss rate, almost no bean smell, and a high sensory score. Therefore, the ultrafine grinding bean dregs can significantly increase the nutritional value of the product when coupled with the noodles (Tian, Xie, Ma & Yang, 2014).

The above research scholars have shown that ultrafine grinding can reduce the particle size of raw materials, and improved the solubility and antioxidant activity. Superfine grinding has a wide range of applications, such as chocolate, which can increase the taste, smooth effect, and used in shells, it is a great source of calcium. Applied in the production of healthy food, if the particles are slightly larger, it will affect the taste and will not function as a health care. This requires ultrafine grinding technology, which is pulverized to a sufficiently fine particle size, and an effective mixed operation is provided to ensure uniform distribution of the food, and to facilitate absorption by the human body. Therefore, ultrafine grinding has become one of the important technologies for modern food processed, especially for health food processing. The used of this technology is currently seen in Chinese research scholars. So this technology should be respected.

Microwave

Microwave heating is now attracted much attention as an alternative heating source. Microwaves enable rapid and uniform heating of polar substances by direct and internal heating generated by friction of dipole rotations (Mizrahi, 2012). Microwave baking are easy and fast. However, for products that need to be baked for a long time, the microwave technology cannot be faced with the traditional technology. The main factor is the protein and starch in the flour, so the formula has to be adjusted and the lo-gluten flour with protein content of 8.7% needs to be selected. The bread baked by microwave is softer and has a better shell and texture (Ozmutlu, Sumnu & Sahin, 2001). When making the bread without gluten, the addition of whey protein concentrate increases the volume and moisture content of the bread. After microwave baking, the hardness of the bread increases, the glycemic index decreases and the shelf life is prolonged, which is good for people who suffer from obesity, diabetes and celiac disease (Therdthai, Tanvarakom, Ritthiruangdej & Zhou, 2016). The presence of endogenous β-glucanaseg in rice flour, can cause a substantial reduction β-glucanase molecular weight, affecting detrimentally their efficacy for bioactivity. Heat treated with microwave power (900 W) applied in cycles of 20 s intervals combined with downtimes of 1 min, it was applied to the rice flours before bread making at flour water contents (25%) and treatment time (4 min) to reduce β-glucanase activity. Bread volume is better than untreated. Microwaving rice flour helps improve glute-free bread, as well as of any-glucan-containing yeast-leavened bakery product without altering its sensorial attributes (Pérez-Quirce, Ronda, Lazaridou & Biliaderis, 2017).

Other physical techniques

Twi-screw extrusion process to produce bean dreg-maize snack foods, it showed that the products extruded at the optimized condition had the best appearance, taste, texture and overall acceptability (Shi, Wang, Wu & Adhikari, 2011). Electro hydrodynamic (EHD) technique improves the drying speed of bean dregs. The bean dregs cake after drying kept a whole shape and there was no cranny in the surface, the color of the sample became distinctly browner than that of the untreated (Li, Sun & Tatsumi, 2006). Ultrasonic parameters had predictive capacity for bread making performance for a wide range of dough formulations Lower frequency attenuation coefficients correlated well with conventional quality indices of both the dough and the bread (Peressini et al., 2017). Bran hydration, autoclaving and freezing treatments and their combinations are promising approaches to reduce the dehydration of whole grain wheat flour dough and to improve wholegrain wheat flour bread loaf volume (Cai, Choi, Park & Baik, 2015). There is no doubt that these technology has made a great contribution to food and agricultural by-products, provides important help for the production of baked goods.

1.4 Improve quality of bean dregs by physical technology

Improve soluble dietary fiber of bean dregs

SDF of bean dregs is a carbohydrate-based polymer with significant health benefits that is enriched in whole grains, nuts, fruits, and vegetables. In recent years, in order to increase the soluble dietary fiber fraction of fiber-rich plant food bean dregs have different approaches were investigated.

At present, more and more methods for increasing SDF content and improving the physical-chemical of bean dregs have been reported, including chemical, fermentation, Biological and physical methods (Feng, Dou, Alaxi, Niu & Yu, 2017; Sun et al., 2020; Vong, Hua, & Liu, 2018). However, the application of chemical methods is complicated, causes serious pollution, and makes it difficult to control the degree of hydrolysis in polysaccharides. Although the fermentation method features low cost and high safety, it has the disadvantages of complex operation and a long fermentation cycle. Biological, the biological process is complex, the period is long and the condition is difficult to control. Physical methods have the advantages of short processing times, ease in processing, low cost and high safety, and they do not require the use of solvents, so they have good prospects for development and application. It refers to change the chemical composition and physical structure of bean dregs dietary fiber through physical and mechanical effects such as high temperature, high pressure and high shear force, thereby improving the physical and chemical characteristics and functional quality of bean dregs.

Common physical methods, such as blast extrusion processing (BEP), are a new type of food processing technology. Numerous researchers have used it to improve the functional properties of cereals such as oats, glute-free flour cereals (Stojceska, Ainsworth, Plunkett & & İbanoğlu, 2010; Zhang, Bai & Zhang, 2011). Blasting extrusion and twin-screw extrusion could increase the content of SDF in bean dregs and improve the physicochemical properties of bean dregs (Chen, Ye, Yin & Zhang, 2014; Jing & Chi, 2013; Li, Long, Peng, Ming, Zhao, 2012).

Steam explosion (SE) could increase the content of SDF of bean dregs from 1.34% to 36.28% under explosion strength 1.5 MPa for 30 s (Li et al., 2019). The blasting extrusion processing (BEP) on the increase in soybean residue SDF content under optimal conditions (170 °C and an extrusion screw speed of 150 r/min). Compared with the control, the content of soluble dietary fiber from soybean residues treated by BEP (SDF) was increased from 2.6±0.3% to 30.1±0.6%. In addition, BEP SDF showed improved water solubility, water retention capacity and swelling capacity (Chen, Ye, Yin & Zhang, 2014). Twin-screw extrusion was applied for soluble dietary fiber extraction from soybean residue. The soluble dietary fiber content of bean dregs reached 12.65%, which was 10.60% higher than that of unextruded and boiled bean dregs (Jing & Chi, 2013). A novel in-situ enhanced extrusion with the aim to improve the solubility of dietary fiber in bean dregs was developed. The SDF fraction of the extrude (21.35 g/100 g) was higher than that of untreated OKP (2.30 g/100 g). The novel extrusion improved the water and oil holding as well as swelling capacities of OKP when compared to untreated and reference extrudes (Li et al., 2012). In addition, steam blasting technology is widely used. It puts fibrous raw materials in high pressure steam for a certain period of time. When high pressure is released instantly, the superheated steam in the raw material gap quickly vaporizes and the volume expands rapidly (Yu, Zhang, Yu, Xu & Song). Use steam is blasting to treats bean dregs to make tough cookies. The results demonstrate that steam explosion has a greater impact on the composition and content of dietary fiber in bean dregs. At 1.5 MPa/30 s, the maximum soluble dietary fiber reached 36.28%. After steam blasting, the amount of bean dregs added is 10%, and the quality of biscuits is significantly improved. Therefore, the appropriate strength of steam explosion treatment can greatly improve the SDF in bean dregs and improve the quality of bean dregs in tough cookies (Kang et al., 2018).

Extrusion technology is used to process bean dregs to prepare soluble dietary fiber. When the liquid-solid ratio is 26: 1, at 89 ℃, for 68 min, and alkali concentration is 1.12%. The soluble dietary fiber in extruded bean dregs were 34.12%, which was significantly higher than that of untreated (13.51%) (Lou & Chi, 2009). Enzymatically prepared bean dregs dietary fiber is processed by IHP, and treated at 40, 90 and 120 MPa, respectively. The water holding capacity, expansion ratio and combined hydraulic strength was increased. The viscosity of the prepared dietary fiber solution was measured the pressure increases and rises in used rheometer. Microscopic observation of light transmittance, loose tissue, finer fibers, improved the quality of the bean dregs dietary fiber, and there was no deterioration during refrigeration for one month. IHP can improve the quality of the bean dregs fiber, but the cost of enzymatic preparation is higher (Liu, Xiong, Liu, Ruan &Tu, 2005).

In recent years, great progress has been made in the research of high pressure and ultrafine grinding technology it has become a research focus in the field of enhancing the quality of bean dregs. Ultrafine grinding can effectively pulverize fiber particles to the submicron level. Insoluble dietary fiber was converted to soluble dietary fiber, and the antioxidant activity was improved (Zhu et al., 2010). Ultrafine grinding sets of different pulverization frequencies and time to process the bean dregs. Based on the physical and chemical characteristics of bean dregs, the crushing optimal parameters were obtained at a frequency of 80 Hz, and once processed. The water solubility, swelling, viscosity, and cation exchange capacity of bean dregs is significantly improved. The water and oil holding capacity of bean dregs has decreased to some extent (Xie, Tian & Ma, 2014). High pressure has a significant impact on the soluble dietary fiber and functional properties of bean dregs. At 400

MPa and 60 °C under high pressure, the content of soluble dietary fiber increased 8 times when treated with bean dregs, compared with untreated. Swell ability and water holding (oil) properties are improved (Mateos-Aparicio, Mateos-Peinado & Rupérez, 2010). After high hydrostatic pressure treatment at 600 MPa for 30 min, the solubility of bean dregs dietary fiber is improved, which makes it more suitable for functional food processing (Pérez-López, Mateos-Aparicio & Rupérez, 2016). High pressure homogenization strength is related to the solubility of bean dregs. Under high strength pressure, the structure of bean dregs particles is destroyed, and the fiber and protein of bean dregs are released (Fayaz, Plazzotta, Calligaris, Manzocco & Nicoli, 2019). Using lactic acid bacteria fermentation method and dynamic high pressure to treat bean dregs, the content of soluble dietary fiber in bean dregs was correspondingly increased, being (9.7, 14) g/100 g. Insoluble dietary fiber content decreased from 11.6 g/100 g to (7.8, 4.5) g/100 g, respectively. It can be observed that soluble dietary fiber and insoluble dietary fiber can be converted into each other under different processing conditions. There were no significant differences in dietary fiber content when bean dregs were treated under dynamic high pressure. Microstructure discovery dynamic high pressure can break down the cellulose structure and make the surface rough. The lactic acid bacteria fermentation method results in modification of the fiber structure and reduction of crystallinity (Tu et al., 2014).

In addition, microwave technology and high temperature cooking technology. Microwaves (M) mainly transmit energy through high-frequency electromagnetic waves and cause molecular electromagnetic oscillations to accelerate molecular motion. The dissolution rate of soluble polysaccharides in bean dregs increased 70% after microwave treatment at 200 ◦C for 7 min, and new polyphenolic compounds that have antioxidant activity were observed above 180 °C (Tsubaki, Nakauchi, Ozaki, & Azuma, 2009). High temperature cooking technology is a commonly method of physical modification, but there are few reports of its use with bean dregs except in China.

Currently, the application of combined methods may be the development trend. (Ciccoritti et al., 2018) reported hydrothermal grain preprocessing and ultrafine milling for the production of durum wheat flour fractions with high nutritional value (Tsubaki et al., 2009). A combination of high hydrostatic pressure (HHP) and ultraflo® L (a food grade enzyme) was used to improve the solubility of dietary fiber of okara (Tsubaki et al., 2009). High-pressure technology (HP) combines heat and pressure to process materials. The physicochemical properties of okara treated under different high hydrostatic pressure conditions were significantly different (Mateos-Aparicio, Mateos-Peinado & Rupérez, 2010). A combination of high hydrostatic pressure and heating treatment provided a slight increase in the total dietary fiber in white cabbage (Wennberg & Nyman, 2004).

It can be observed that these physical methods have significantly increased the content of soluble dietary fiber in bean dregs. The biggest advantages come from short processing time, simple process, no solvent residue, and low cost. It is possible to damage the structure of the soybean b-products during physical processing. For example, extrusion technology changes the structure of fiber molecules through intense pressure, friction and shear force, thus exposing the molecules to more soluble groups, thus increasing the content of soluble dietary fiber. Microwave has a strong penetration ability, the electromagnetic wave act on the material, resulting in the increase of the material cell pressure and expansion and rupture, the soluble dietary fiber content of bean dregs is increased. However, excessive treatment affects the content of soluble dietary fiber should pay attention to the control of treatment conditions. Typically, a combined method may have greater effects than any single approach. However, the combination of multiple technologies is rarely applied to bean dregs, especially the combination of multiple physical technologies. Therefore, it is necessary to explore novel combinations that can increase the nutritional and functional characteristics of bean dregs.

Removal of ant-nutritional factors

Ant-nutritional factors (ANF) are substances that adversely affect the digestion, absorption, and utilization of nutrients, as well as adverse reactions that cause humans and animals. Soy was full of nutrients, but there are also a variety of ant-nutritional factors affecting the use. Ant-nutritional factor in soybean is a limiting factor, which not only hinders the body's absorption of nutrients, but also limits the comprehensive development and utilization of beans. Therefore, effectively controlling or eliminating ant-nutritional factors is one of the important ways to increase the utilization of soybeans (Gao, Wang & Li, 2019). Few types of ant-nutritional factors found in legumes that usually inhibit the bioavailability of many nutrients, such as hydrocyanic acid, trypsin inhibitors activity, phytic acids, hemagglutinins etc. However, the bean dregs contain three ant-nutritional factors: trypsin inhibitor, lectin and goitrogen, the most important is the trypsin inhibitor. These ant-nutritional factors limit the nutritional properties and affect the digestibility of certain nutrients (Akpapunam & Sefa-Dedeh, 1997). When the researchers used bean dregs to make cookies, ant-nutritional components rise by the bean dregs ratio increase in cookies composition. The removal or degrade of the ant-nutritional factors in the bean dregs is of profound significance for improving functional food of bean dregs. Hence, further research has to initiate to decrease the ant-nutritional factors in bean dregs (Hawa, Satheesh & Kumela, 2018). However, trypsin inhibitor, soybean lectin, glycinin and conglycinin are the most important ant-nutritional factors in soybean. The bean dregs mainly contain three anti-nutritional factors: trypsin inhibitor, goitrogen and prothrombin.

Trypsin inhibitor. Trypsin inhibitor is a protein and about 7–10 species are found in soybeans. Among them, Kunitz trypsin inhibitor and Bowman-Birk trypsin inhibitor are the two most representative and important inhibitors. Soybean trypsin inhibitory factor (STI) is one of the main ant-nutritional factors in soybean. The content is about 2%. The anti-nutritional effects of trypsin inhibitors are mainly as follows: reducing protein digestion, inhibiting animal growth, and causing pancreatic enlargement (Machado et al., 2008). The removal of anti-nutritional factors is mainly through physical, chemical and biological methods. In recent years, many scholars have focused on researching new and efficient methods of inactivation, such as chemical methods and high temperature transient methods, gene breeding methods, it has been able to reduce the content of trypsin inhibitors in soybeans and has been extensively studied.

With bean dregs as the main raw material, used single screw extrudes in the content of bean dregs (0%, 15%, 30%, 45%), material moisture (40%), extrusion temperature (two zones: 140 ℃~150 ℃, three Area: 170 ℃~180 ℃) extrusion preparation of tissue protein. The results showed that the content of phytic acid and soluble dietary fiber increased, the activity of total phenol, total flavonoids and trypsin inhibitor decreased, the in vitro digestibility increased, and the correlation coefficient between various nutrient factors decreased after extrusion (Bin et al., 2016). The trypsin factor in soybean milk was treated at a high temperature of 93 C for 60–70 min, and the inactivation rates reached 90%. It takes 5-10 min at 121 ℃, but excessive temperature and time make Maillard reaction between basic amino acids such as lysine and reducing sugar, reduce the content of free amino acids, protein digestibility and nutritional value of protein (Kwok, Qin & Tsang, 2010). In addition to, high pressure treatment can inactivate trypsin inhibitor and lipoxygenase in soybean or soy milk, and a higher pressure at 800 MPa was required for the treatment of lipoxygenase, or the combined temperature is 60 ℃ at 600 MPa (Linsberger-Martin, Weiglhofer, Phuong & Berghofer, 2013). During the germination process of broad beans, use of 0.171M saline can reduce the activity of trypsin inhibitors (El-Mahdy, Moustafa & Mohamed, 1981).

Heat process is widely used for food preparation, which is one of an effective method used to inactive heat liable ant-nutritional factors. The heating was efficient trypsin inhibitors and lectin inactivation, being 15 min at 121 ℃ sufficient to reduce more than 90% of these compounds (Machado et al., 2008). The trypsin inhibitor was completely inactivated after soaking soybeans in 24.3% humidity for 1 hour, and after being treated with microwave frequency at 2450 MHZ for 4 minutes, which was shorter than the heating period (6 min) needed for unsoaked soybeans (Yoshida & Kajimoto, 2010). Microwave treatment is an effective way for inactivation of protease inhibitor activity in cracked soybeans, roasting for only two minutes reduced the trypsin inhibitor activity to 13.33% of the initial (Barać & Stanojević, 2005). The microwave cooking reduced anti-nutritional factors in bean thus improved the protein digestibility, while the cooking method is not studied extensively yet (El-Adawy, 2002). Roasting treatment, the processing under 230 ℃ for 25 min presented more decrease in trypsin inhibitor from soybeans (Zhou, Cai & Xu, 2017). Extrusion process was the best method to abolish trypsin inhibitors (99.54%), phytic acid (99.30%) and tannin (98.83%) (Rathod &Annapure, 2016). Ultrasound treatment at 20 kHz about 20 min inactivates trypsin inhibitor by 55% (Entezari & Pétrier, 2005). High pressure processing (HPP) is another emerging novel processing technique followed in the food industry and evaluated as an alternative for the inactivation of Trypsin inhibitors. The researchers suggest that temperatures at 77-90 ℃ and pressures at 750–525 MPa less than 2 min, about 90% trypsin inhibitors inactivation (Van Der Ven, Matser & Van den Berg, 2005).

Lectin. The physiological activity of lectin has two side. Most lectins are resistant to digestion in human proteases, and even have adverse effects, such as stimulating the intestinal wall and impeding the digestion and absorption of nutrients. Therefore, lectins were deemed to be ant-nutrient substance. How to eliminate anti-nutrition is a matter of concern in the food processed field. Thrombin is a common anti-nutritional factor in bean dregs. It can hinder the absorption of animals. In soybean, lectin is attended by a concentration of 10–20 g/kg, which can stimulate the intestine Wall, hinder digestion, absorb nutrients and affect the metabolism of small intestinal mucosal cells, and affect the bacterial ecology in the intestine (Clarke & Wiseman, 2000). It is a glycogen protein. Defat soybean meal contains about 3% of prothrombin and is under a molecular weight of 120,000. It comprises of 4 identical subunits, each with a molecular weight of 30,000, each molecule (Desai, Allen & Neuberger, 1988). The presence of toxic phytic acid, hemagglutinin, trypsin inhibitors and hydrocyanic acid in beans, it affects the use of food in the human body (Akpapunam & Sefa-Dedeh,1997). Ant-nutritional factors in velvet beans processed by ultraviolet radiation. Studies have shown that UV treated seed has lower levels of phytic acid, hydrogen cyanide and total oxalate compared to seeds soaked overnight. Ultraviolet radiation (60–90 min) completely eliminated the trypsin inhibitor activity in the seed. Both treatments completely eliminated plant hemagglutination activity (Kala & Mohan, 2012). Soybean hemagglutinin is not heat-resistant, and can be inactivated quickly under hot and humid conditions. Even the activity completely disappears. Studies have shown that when purified prothrombin was dissolved in 25% sodium citrate solution. It can inhibit thrombin formation (Alkjaersig, Deutsch & Seegers, 1955). In the conventional processing, the heating method was generally adopted to remove the anti-nutrition of the lectin in the legume food, and the physiological activity of the lectin was also completely lost.

Goitrogen. The thyroid hormone is extremely small in soybean, and its precursor substance is glucosinolate, which was enzymatically hydrolyzed by glucosinase, and the resulting ligand further generates cyanogen, thiocyanate and isosulfur, wherein the isothiocyanate is automatically cyclized to an oxazolidinethione under neutral conditions, and the latter three substances mainly affect the morphology and function of thyroid gland, which is the main substance leading to goiter. The pathogenic mechanism of goitre is that it preferentially binds to iodine in the blood, resulting in an insufficient source of iodine for thyroxine synthesis, leading to compensatory hyperplasia of the thyroid gland.

Soy can inactivate glucosinolates by dry heat to prevent it prevent it from producing goiter. At (90 °C, 15 min) or (100 °C, 10 min) or (110 °C, 5 min), the residual rate of enzymatically degradable glucosinolates was above 98%, but in the case of tissue breakage and the presence of aqueous media (such as germination, wet heat treatment, etc.), it was recommended that the first step of dry heat kills glucosinolates (Gu, Li, Yu, 2000). Dry heat treatment has an obvious effect on the removal of soybean goiter, and warm heat treatment has obvious effects on prothrombin and protease inhibitor. Soybean germination combined with heating treatment can remove somatostatin and protease inhibitors. Used 90 °C dry heat treatments, 15min or more, and then used 125 °C wet heat treatments for more than 10min, the ant-nutritional factor removal rate reaches 95% (Chen, Yu, Cen, 2002). Dry heat treatment has a significant effect on the removal of thyroxine from soybeans, while wet heat treatment has a beneficial effect on soybean prothrombin and protease inhibitors. Dry heat treatment at 90 °C for more than 15 minutes, then the best heat treatment at 125 °C for 10 minutes, the removal rate was as high as 95%, it's convenient and energy-saving (Li, Gu, Yu, 1998). The dry heat treatment conditions were 90℃ for 15min, 100℃ for 10min, 110℃ for 5min. Inactivate glucosinolase in soybean so that it cannot enzymatic digest glucosinolates. Therefore, no goiter is produced and the residual glucosinolates can reach 98% (Gu, Li, Yu, 2000).

The above researchers, whether using chemical or physical methods, can effectively remove ant-nutritional factors in beans. However, the chemical method is under a large residual amount and low safety. The sensible method commonly used is heating treatment, such as dry heat treatment or wet heat treatment, which can eliminate different ant-nutritional factors. This method is low in cost, good in effect, simply in the process, and widely used, but it takes a lot of time. The trypsin inhibitor can be inactivated under the effect of atmospheric pressure steam. If the temperature is lower than 100 ℃ for 30min, the trypsin inhibitor activity in soybean can be reduced by about 90%. In the case of high-pressure treatment, the heating time depends on temperature, pressure, and material properties. At present, pressure baking is often used in the industry. When the temperature is between 130 °C and 133 °C, 2500 kPa, soy lectin and trypsin inhibitor can be inactivated, but the disadvantage is that the cost is high and the color of the product cannot be effectively controlled. The soaking method can remove ant-nutritional factors, but it takes time and is not suitable for large-scale production processes. The extrusion puffing method inactivates the ant-nutritional factors of soybeans, ruptures the cell wall of the raw material, and increases the digestibility of nutrients, but damages the raw material itself. Microwave treatment can penetrate into the inside of the untreated material, causing the inactivation of anti-nutritional factors. Mechanical processing includes crushing, dehulling, etc. Many anti-nutritional factors mainly exist in the epidermal layer of crop seed. Separation through mechanical processing can reduce ant-nutritional factors. But this method is only suitable for the treatment of seed.

Conclusions on section 1

Bean dregs has high nutritional value, but it has a rough taste and has low soluble dietary fiber. Therefore, in the production of bean dregs products, special consideration should be paid to the nutrition, taste and appearance of the products, especially in baked goods. In addition, some anti-nutritional factors in bean dregs, it affects human health. At present, the most commonly used removal methods are dry heat treatment and wet heat treatment, so it is necessary to explore new processing methods, eliminate the anti-nutritional factors in the bean dregs, improve the quality of the bean dregs, and increase the added value of the products. Relevant research shows, that high pressure technology can effectively reduce microorganisms in products and extend the shelf life. The new technology of ultrafine grinding has been proven to improve the roughness of the cereals, make the power fine and improve the flavor of the product. Microwave technology is convenient and fast, which has replaced the traditional heating method. However, this method is not fully adapted to the traditional process formula, so more research is needed in the development of the product.

Therefore, physical modification will broaden the application of bean dregs in food and feed to a certain extent, and combined treatment is the preferred method. It is necessary to explore novel combinations that can increase the nutritional and functional characteristics of bean dregs. However, the effect of ultrafine grinding combined with high-pressure processing, microwave irradiation or high-temperature cooking on bean dregs has been less frequently reported. Moreover, the effects of these individual technologies or combinations of technologies on the compositions, characteristics and functional characteristics of bean dregs have not been well characterized. Therefore, the combination of these technologies is called upon to choose a new type of processing technology to treat bean dregs that will contribute to the development of functional biscuits and promote the progress of baked goods. This study provided innovative ideas for further research on the physical and chemical properties of bean dregs treated by combination technology and its application in baked food.

SECTION 2
ORGANIZATION, SUBJECTS, MATERIALS AND METHODS RESEARCH

2.1 Objects of research

Materials

Bean dregs are by-product of the soy milk industry and composed of insoluble components which remain in the filtration bag of soybean meal during soybean milk production. The development of soybeans has brought great economic benefits to the food industry, which can produce bean dregs of 15 million tons per year. However, fresh okra has high moisture content, bad taste and mouth feel, and is difficult to store, and low soluble fiber, and contain certain anti-nutrient factors-trypsin inhibitors, and most of them are used as feed or discarded as waste disposal.

Wet bean dregs were obtained at local market.

The physicochemical properties of the bean flour used in the studies, are presented in Table 2.1.

Table 2.1 – Analysis of the physicochemical properties of bean dregs

SDF	Protein	Ash	Water(Wet,Dry)	Fat adsorption capacity	Water solubility	Swelling capacity	Trypsin inhibitors
1.63%	23.46%	0.83%	88%, 2.91%,	1.48 (g/g)	10.13 (%)	13.99 (g/mL)	7365 TIU/g

Glucan standards were purchased from Beijing Wanjiashouhua Biotech Co. Ltd., China. Protein markers were purchased from Beijing Solaris Science & Technology Co. Ltd. China. High-temperature-resistant alpha-amylase solution (30 U/mg) and glycosylase solution (100 U/mg) were purchased from Shanghai Regal Biology Technology Co. Ltd. (China). Alkaline protease solution (100 U/mg) was purchased from Shanghai Lanji Technology Development Co. Ltd. China. Trypsin 1:250 (from bovine pancreas) was used and exhibited an activity of 250 U/mg, was purchased from Sigma-Aldrich (Corp. St. Louis, USA). Other reagents and chemicals were of analytical grade.

Make crisp biscuits

Bean dregs powder: Ultrafine grinding -Microwave (U-M): Ultrafine grinding (30Hz), and then high heat modes were selected for microwave conditions, and the treatment time for 6min, then dried by the oven at 50 °C for 48 h and sieved with 80 mesh (Wang, Zeng, Gao & Sukmanov, 2021); Low-gluten flour, powdered sugar, butter, corn starch, egg yolks, salt, baking powder were collected from local markets.

Make hard biscuits

Bean dregs powder; Wheat flour: Cofco International (Beijing) Co. LTD; Starch: Kunshan Zhenlemen Food Co., LTD; Powdered sugar: Jiangxi Qiaosao Food Co., LTD; Soybean oil; Salt: Hubei Xiangheng Salt Chemical Co., LTD; Baking powder: Guilin Kesheng Food Co., LTD; Eggs: commercially available.

Equipment

1. Constant temperature drying oven (DHG-9140A, Jiangsu Yutong Drying Equipment Factory, Changzhou, China);

2. Ultrafine grinder (Beijing Yujie Yucheng Machinery Equipment Co., Ltd., Beijing, China);

3. High static pressure processing device (FPG5620YHL, Stansted fluid power Ltd., Stansted, UK);

4. P70D20N1P-G5 microwave oven (Guangdong Galanz Microwave Life Electric Appliance Manufacturing Co., Ltd., Zhongshan, China);

5. LDZX-50BS vertical high pressure steam sterilizer (Shanghai Shenan Medical Equipment Factory, Shanghai, China);

6. Inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Perkin–Elmer, Model NexlON2000, USA, with auto sampler);

7. Laser particle size analyzer (BT-9300H, Dandong Baxter Instrument Co., Ltd., Dandong, China);

8. Scanning electron microscopy (FEI Co., USA);

9. Water bath thermostatic oscillator (JDS-BA, Changzhou Jintan Jingda Instrument Manufacturing Co. Ltd, Changzhou, China);

10. Low field nuclear magnetic resonance (LF-NMR) (NMI20–040 V-I, Shanghai Niumay Electronic Technology Co., LTD., China);

11. Rapid viscosity analyzer (RVA) (TecMaster, Newport Scientific Instruments LTD., Australia);

12. Rotary rheometer (HAAKE MARS III006–1576 Version 1.3, Thermo Scientific, Germany); Minolta Chroma Meter (CR-40, Japan);

13. TA-XT Plus Texture Analyzer (Stable Micro Systems, London, UK).

2.2 Research methods

2.2.1 Physical technology treatment of bean dregs

Control sample: the wet bean dregs were dried by the constant temperature drying oven (DHG-9140A, Jiangsu Yutong Drying Equipment Factory, Changzhou, China) at 50 °C for 48 h, after which they were ground and sieved with an 80 mesh screen.

Single treatments

Ultrafine grinding (U): the wet bean dregs were dried with constant temperature drying oven at 50 °C for 48 h, then ultrafine ground frequency of 30 Hz by an ultrafine grinder (KCW-701S, Beijing Yujie Yucheng Machinery Equipment Co., Ltd., Beijing, China).

High Pressure (HP): wet bean dregs were treated by a high static pressure processing device (FPG5620YHL, Stansted fluid power Ltd., Stansted, UK) at 300 MPa for 10 min at 30 °C, then dried by the oven at 50 °C for 48 h and sieved with 80 mesh.

Microwave (M): wet bean dregs were treated in a P70D20N1P-G5 microwave oven (W0) (Guangdong Galanz Microwave Life Electric Appliance Manufacturing Co., Ltd., Zhongshan, China) at a medium heat level for 4 min, then dried by the oven at 50 °C for 48 h and sieved with 80 mesh.

High-temperature cooking (HTC): wet bean dregs were treated with an LDZX-50BS vertical high-pressure steam sterilizer (Shanghai Shenan Medical Equipment Factory, Shanghai, China) at 115 °C for 25 min, then dried by the oven at 50 °C for 48 h and sieved with 80 mesh.

Combination technology

The bean dregs treated by ultrafine grinding were used as the raw material for combination with high pressure treatment, microwave treatment and high temperature cooking treatment. The ratio of bean dregs to water was set as 1:3, 1:5, 1:7, 1:9 and 1:11. The other conditions were designed as follows:

Ultrafine grinding- High Pressure (U-HP): The high pressure ranged from 50 MPa to 300MPa, and the treatment time ranged from 5 min to 25 min at 30 °C.

Ultrafine grinding-Microwave (U-M): Low, M-Low (Between low and medium heat), Med, M.High (Between medium and high heat), High heat modes were selected for microwave conditions, and the treatment time ranged from 2 min to 10 min.

Ultrafine grinding- High temperature cooking (U-HTC): The temperature of high temperature cooking ranged from 105 °C to 126 °C and the treatment time ranged from 10 min to 30 min.

The above treated samples were vacuum freeze dried, ground, sieved with an 80 mesh screen and stored for further analysis.

Determination of SDF in bean dregs

The protein content of bean dregs was analyzed as described in the AOAC reference method (1995).

Determination of protein in bean dregs

The protein content of bean dregs was analyzed as described in the AOAC reference method (1997).

Mineral analyses

The mineral content of bean dregs was determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Perkin–Elmer, Model NexlON2000, USA, with auto sampler). Bean dregs (0.5 g) were put into PTFE (poly tetra fluoro ethylene) digestion tubes; 10 mL of nitric acid was added, and the tube was put into a microwave digestion system. The parameters of microwave digestion were set as follows: power, 600 W; climbing time, 10-15 min; holding time, 10-15 min; temperature, 180 ℃; and whole tank temperature monitoring system, 195 ℃. Then, the sample was put on the acid eliminator for 1 h. The solution was cooled and transferred into a 20 mL graduated flask; then, deionized water was added, and the levels of potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), chromium (Cr), selenium (Se), titanium (Ti), strontium (Sr), tin (Sn) and arsenic (As) were determined. The mineral concentrations of the samples were determined from a standard graph and expressed in mg/kg.

Determination of particle size of bean dregs

A sample (0.5 g) was gently mixed with 50 mL of distilled water in a 100 mL beaker with whirlpool oscillation. Then, an appropriate volume of sample liquid was slowly added to the laser particle size analyzer (BT-9300H, Dandong Baxter Instrument Co., Ltd., Dandong, China) to ensure that the shading ratio was in the range of 15%-18%. The recorded particle size parameters included the specific surface area, largest particle size (D90), mean particle volume (D50), smallest particle size (D10), area equivalent mean diameter (D [3, 2]) and volume equivalent mean diameter (D [4, 3]).

Scanning electron microscopy (SEM) observations

The microstructure of bean dregs was observed by scanning electron microscopy (FEI Co., USA) according to the method of Li et al. (2019) with minor modifications. The samples were placed on a specimen holder with double-sided scotch tape and sputter coated with gold. Then, the samples were scanned and photographed at an accelerating voltage of 15 kV at magnification (2500 ×).

Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) analysis

The SDS-PAGE was measured according to the methods of Hu et al. (2017) with some modifications (Hu, Wang, Zhu & Li, 2017). Tris-HCl buffer (0.5 mol/L Tris-HCl, pH=8.0) was mixed with degreased bean dregs (10:1/g) in a 50 mL beaker, and the suspension was stirred with a magnetic stirrer for 9 h. After centrifugation at 8000 rpm for 5 min, the supernatant was collected. Using 12% separation glue and 5% concentration glue, 16 μL of sample was loaded into each lane, and the gel was stained and decolorized. Using a gel imaging system (UVP), the gel was scanned, and the protein bands were analyzed.

Trypsin inhibitors

Trypsin inhibitor activity was measured according to the method of Kakade, Rackis, Mcghee and Puski (1974) with some modifications Kakade, Rackis, Mcghee and Puski (1974). Utilizing benzoyl-DL-arginine-p-nitroanilide (BAPA) as the substrate. A sample (1 g) of bean dregs was dispersed with 40 mL of NaOH solution (0.01 M), and shaken at 25°C and 150 r/min for 2 h. Then, the samples were centrifuged at 3000 r/min for 10 min. The supernatant was collected and diluted 4 times with deionized water for further determination. Four centrifuge tubes (I_1, I_2, I_3, I_4) were used to prepare solutions by the following methods:

(I_1) Standard blank: 5 mL of BAPA solution (0.4 mg/mL), 3 mL of deionized water and 1 mL of CH_3COOH solution (5.3 mol/L) were combined and mixed well. This solution was used as the reference.

(I_2) Standard solution: BAPA solution (5 mL) and deionized water (3 mL) were combined and mixed well.

(I_3) Sample blank: BAPA solution (5 mL), sample diluent (1 mL), deionized water (2 mL) and CH_3COOH (1 mL of 5.3 mol/L solution) were combined and mixed well.

(I_4) Sample solution: BAPA solution (5 mL), sample diluent (1 mL) and deionized water (2 mL) were combined and mixed well.

Centrifuge tubes were placed in a constant temperature water bath for 10 min ± 5 s at 37 °C, and then 1 mL of trypsin solution (0.4 mg/mL) was added to each centrifuge tube; the solutions were mixed and kept for 10 min ± 5 s. 1 mL of CH_3COOH solution (5.3 mol/L) was added to the (I_2) and (I_4) tubes to terminate the reactions. The absorbance of each solution was determined by spectrophotometry at 410 nm. Absorbances should be between 0.38 and 0.42. The inhibition rate (I%) for trypsin and trypsin inhibitor activity (TIA) of bean dregs were calculated using equations (2.1) and (2.2):

$$I\ (\%) = A_2 - (A_4 - A_3) A_2 \times 100\% \quad (2.1)$$

$$TIA\ (TIU/g) = [A_2 - (A_4 - A_3)] \div 0.01 \times 40 (D \div M) \quad (2.2)$$

where I is the percentage of trypsin inhibition; A_2 is the absorbance of the standard solution; A_3 is the absorbance of the sample blank; A_4 is the absorbance of the sample solution; D is the dilution ratio of supernatant after centrifugation, here is 4; M is the weight of the sample; One trypsin unit is defined as an increase in absorbance of 0.01 per 10 mL of the reaction mixture at 410 nm. TIA is expressed in terms of trypsin units inhibited (TIU), that is, the amount of inhibiting trypsin unit per gram of sample.

Processing performance indexes

Water solubility

Water solubility (%) of bean dregs was determined according to the method described by Zhang et al. (2009).

Swelling capacity

The swelling capacity was measured according to the method of Mateos-Aparicio and Mateos-Peinado (2010) with some modifications. 0.5 g of sample was placed in a 20 mL graduated test tube, and 10 mL of distilled water was added. The mixture was stirred gently to eliminate trapped air bubbles and allowed to sit for 24 h at room temperature (25 °C). Then the volume of the sample (V) was recorded, and the swelling capacity was calculated as equation (2.3):

$$\text{Swelling capacity (mL/g)} = \frac{V}{W} \quad (2.3)$$

where V is the final volume occupied by the sample and W is the weight of the sample.

Fat adsorption capacity

The fat adsorption capacity was evaluated following the method of Jia et al. (2020) with some modifications. Bean dregs (0.3 g, M_1) were gently mixed with 24 g peanut oil or lard in a 50 mL centrifuge tube. The samples with peanut oil were shocked in a water bath thermostatic oscillator (JDS-BA, Changzhou Jintan Jingda

Instrument Manufacturing Co. Ltd, Changzhou, China) at 37 ℃ for 2 h (for lard adsorption tests, 60 ℃ for 2 h were used) and then centrifuged at 3000 rpm for 15 min. The upper layer of free oil was removed, and the residue was weighed (M_2). The fat adsorption capacity was calculated as equation (2.4):

$$\text{Fat adsorption capacity (g/g)} = \frac{M_2 - M_1}{M_1} \quad (2.4)$$

Cationic adsorption capacity

Bean dregs (0.5 g) were gently mixed with 100 mL of 5% NaCl solution in a 150 mL beaker. After stirring with a magnetic agitator for 5 min, 1 mL of 0.1 mol/L NaOH solution was added slowly, and the pH value was recorded until the pH value of the solution changed by less than 0.3. The trend in pH value as a function of added NaOH volume was observed. The greater the change of pH value, the stronger the cationic adsorption capacity of bean dregs.

Water relaxation properties in bean dregs.

Water relaxation properties in bean dregs treated by different physical technologies were determined by low field nuclear magnetic resonance (LF-NMR) (NMI20–040 V-I, Shanghai Niumay Electronic Technology Co., LTD., China). One gram of bean dreg powder was weighed, 7 mL distilled water was added and mixed, and the sample was wrapped with a layer of plastic wrap and placed at room temperature for 20 min. Then, 5 g of the sample was removed and removed from the plastic wrap, placed into an LF-NMR detection tube and detected in a resonance detector. The parameters were set as follows: TD=400018, NS=4, TW=5500 ms, NECH=5000. The untreated bean dregs were used as a control.

Determination of viscosity of bean dreg slurry.

Bean dreg slurry was prepared for determination of viscosity with a rapid viscosity analyzer (RVA) (TecMaster, Newport Scientific Instruments LTD., Australia). Three grams of bean dreg powder was weighed and put into an aluminum jar, 21 mL of distilled water was added, and the mixture was stirred well. The determination parameters of viscosity were set as follows: constant temperature 30 °C, speed 160 rpm, and time 5 min. Then, the aluminum canister was put into the instrument, and the tower cap was pressed down when the temperature reached 30 °C.

Determination of stability of bean dreg slurry.

2 g of bean dreg powder was weighed and put into a tube, 14 mL of distilled water was added, and the slurry was stirred well. The slurries were placed at room temperature for 0.5 h, 8 h, 24 h, 48 h, 72 h and one week to observe the changes in the slurry.

Determination of dynamic rheological properties of bean dreg slurry.

3 g of bean dreg powder was weighed and put into a container, 21 mL of distilled water was added, and the sample was mixed well and allowed to stand for 3 h. The dynamic rheological properties of the above samples were determined by a rotary rheometer (HAAKE MARS III006–1576 Version 1.3, Thermo Scientific, Germany) according to the method of Kim and Yoo (2006) with some modification. The test temperature was 25 °C. Parallel plate geometry (40 mm diameter, 1 mm gap) was employed throughout the test. The target strain force was 1 Pa, and the dynamic scanning frequency range was 1–10 rad/s. The changes in the energy storage modulus (G'), loss modulus (G") and loss factor (tan δ) of bean dreg slurries with angular frequency were obtained.

Chrominance and whiteness index of bean dregs.

The chrominance difference and whiteness index of bean dregs were determined according to the method of Aguirre, Karwe and Borneo (2018). Chrominance parameters ($L*$, $a*$, $b*$ values) of the bean dregs were determined with a Minolta Chroma Meter (CR-40, Japan). A standard white plate was used as a reference ($L*$ =100). Measurements were performed under the standard illuminant D65. The results are reported in terms of $L*$ (lightness), $a*$ (redness to greenness-positive to negative values, respectively), and $b*$ (yellowness to blueness-positive to negative values, respectively) values. The net difference in color (with respect to control) (ΔE) and whiteness index (WI) were calculated according to the following equation:

$$\Delta \mathrm{E} = [(L^{*}\mathrm{c} - L^{*}\mathrm{t})^{2} + (b^{*}\mathrm{c} - b^{*}\mathrm{t})^{2} + (a^{*}\mathrm{c} - a^{*}\mathrm{t})^{2}]^{1/2} \quad (2.5)$$

where the lowercase c and t in Equation (2.5) refer to the control and treated samples, respectively.

$$\mathrm{WI} = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2} \tag{2.6}$$

Crispy dough preparation.

The crispy biscuits had the following formulation: Low gluten flour and bean dregs powder (100 g), butter (50 g), powdered sugar (20 g), corn starch (5g), Egg yolks (20 g), and salt (1 g), baking powder (0.75g). Whisk butter until creamy and pale after the butter is softened, powdered sugar, salt and egg yolks were mixed for 1 min at speed 4 using a KitchenAid Professional mixer KPM5 (St. Joseph, Michigan, USA) to make it smooth, add the flour mixture (low gluten flour, bean dregs powder, corn starch and baking powder) in batches to make a soft dough. Seal with plastic wrap and leave at room temperature for 10 min, and crispy dough was divided into 8 g samples for testing.

Crispy biscuits preparation.

Preheat the oven to be preheated (YXD-60C, Guangzhou Saisida Machinery Equipment Co., Ltd., Baiyun Branch, Guangzhou, China), the upper heat is 170°C, the lower heat is 160°C, weigh 8 g of the crispy dough, put it into a fixed mold, press it into a consistent biscuit shape and slowly the sample into the prepared baking pan. These samples were baked in an electric oven for 12 min. After baking, the Crispy biscuits were removed from the oven, left to cool for 1 hour at room temperature, and packed into hermetically sealed plastic bags to prevent drying. All quality measurements were performed 1 hour after baking.

Crisp dough measurements.

Pasting properties.

The gelatinization characteristics of mix flour with bean dregs were determined by RVA (TecMaster, Newport scientific instruments LTD., Australia). According to Jiang et al. (2020) method with minor modifications. 3 g of mixed powder and 25 mL of water were placed in an RVA- dedicated aluminum box. After stirring evenly, the aluminum box was put into the instrument for measurement. Heating and cooling procedures were adopted: Temperature was maintained at 50 °C for 1 min, then heated to 95 °C in 3.7 min. After that the temperature was maintained at 95 °C for 2.5 min and then cooled from 95 °C to 50 °C in 3.8 min. The tests were performed in the programming heat and cooling cycle of the STD1. The pasting parameters included peak viscosity, trough viscosity, breakdown viscosity, final viscosity (FV), setback (SB) which obtained from recorded curves.

Texture analysis.

Texture characteristics were measured by the TA-XT Plus Texture Analyzer (Stable Micro Systems, London, UK). The method was based on the research of Meng et al. (2021). Measurements were carried out at room temperature 30 min after the doughs were made. The instrument was calibrated with a 1 kg load cell. The P36R probe was used to calibrate the distance with the 30 mm return trigger path. Parameters were set as follows: pretest peed, 2 mm/s; test speed, 1 mm/s; posttest speed, 1 mm/s; strain, 70%; interval time, 5 s; trigger type, auto, 5 g. Textural parameters, such as hardness, cohesiveness, gumminess, chewiness, springiness and resilience were obtained.

Color of crisp dough and biscuits.

The color (*L*, *a**, *b**) values of the crackers were determined by portable color difference meter (Cr-400 chromatic aberration meter Minolta, Japan). Color measurements were made of crust. All measurements were conducted at least three times.

Crispy biscuits measurements.

Texture analysis.

Crispy biscuits texture was determined by the TA-XT Plus Texture Analyzer (Stable Micro Systems, London, UK). The complete biscuits were placed on the test bench of the texture tester, and The TPA test was carried out with the P/5 probe. Parameters were set as follows: pretest peed, 1.0 mm/s; test speed, 0.50 mm/s; posttest speed, 1 mm/s; strain, 30%; interval time, 5 s. Textural parameters, such as hardness, springiness, adhesiveness, chewiness were obtained. Measurements were performed on biscuits (5 mm thick), and the mean of the four measurements was recorded.

Scanning electron microscopy (SEM).

The microstructure of crispy biscuits was observed by scanning electron microscopy (FEI Co., USA). Take the cookie fracture surface and fix it on the sample table. Then, the samples were scanned and photographed at an accelerating voltage of 15 kV at magnification (400 ×).

Sensory evaluation.

The sensory evaluation was measured according to the method of Bose and Shams-Ud-Din (2010) with some modifications. A sensory evaluation of biscuits containing various levels was evaluated initially for color, flavor and texture by a panel of 10 panelists (Qiu & Qi, 2018). All the panelists were the post graduate students of the Department of Food Science and Technology before evaluation. In this case, 100- point hedonic rating test was performed to asses the degree of acceptability of these biscuits. Three pieces from each biscuit lot was presented to 10 panelists as randomly coded samples. The test panelists were asked to rate the sample on a 100-point hedonic scale for color, flavor, texture and overall acceptability.

Single factor test.

According to the above experimental study, the maximum amount of bean dregs powder added to crisp biscuits was 20 g, a total weight of 100 g of bean dregs powder and low-gluten flour, with butter, powdered sugar, egg yolk, corn starch, baking powder and salt as the auxiliary ingredients.

The butter was set as 40 g, 45 g, 50 g, 55 g and 60 g respectively, and the single factor test was carried out in five gradients to obtain the influence of the dosage of butter on the sensory evaluation of crisp biscuits.

After the optimal butter dosage was determined, the powdered sugar was set as 16 g, 18 g, 20 g, 22 g and 24 g respectively, and the single factor test was carried out in five gradients to obtain the influence of the dosage of powdered sugar on the sensory evaluation of crisp biscuits.

After the optimal powdered sugar dosage was determined, the baking temperatures were set as 160 °C, 170 °C, 175 °C, 180 °C and 185 °C respectively, and the single factor test was carried out in five gradients to obtain the influence of baking temperature on the sensory evaluation of crisp biscuits.

After the optimal baking temperature was determined, the baking time were set as 10 min, 11 min, 12 min, 13 min and 14 min respectively, and the single factor test was carried out in five gradients to obtain the influence of baking time on the sensory evaluation of crisp biscuits.

Orthogonal test and determine the optimal formula.

According to the single factor test, the amount of butter (A), powdered sugar (B), baking temperature (C) and baking time (D) were selected for orthogonal test. Horizontal design of orthogonal experimental factors is shown in Table 2.2.

Table 2.2 – Horizontal design of orthogonal experimental factors of bean dregs crisp biscuits

Level	Factors			
	A Butter (g)	B Powdered Sugar (g)	C Temperature (℃)	D Time (min)
1	45	18	170	10
2	50	20	175	11
3	55	22	180	12

Sensory and texture evaluation of bean dregs crisp biscuits.

The determination method was the same as 2.2.19

Production process basic recipe for hard biscuits.

Mix flour (100 g), powdered sugar (25 g), starch (5 g), baking powder (1 g) and salt（0.5 g）evenly, then add egg yolk (20 g) and water (30 mL), grasp and mix evenly, and finally add soybean oil (5 g) to mix into dough, then put into a noodle making machine, place the dough in a tablet press and shape using biscuit cutter. Preheat the oven in advance, bake at upper heat 190 ℃, lower heat 180 ℃, bake for 10min. Leave to cool at room temperature for 1 hour, then put the biscuit in an airtight bag to prevent drying.

Operating essentials.

a. The dough should rest at 35 ℃-40 ℃.

b. After the dough is left to rest, knead, rub, drop and knead vigorously until the dough is smooth and cover with cling film and leave to rest for 10 min.

c. Continue to knead for 2 min, make gluten to achieve the strongest structure, soft and hard moderate, the surface has a beautiful luster.

d. Divide it into dosage forms, adjust the dough press to 3 g, roll it into dough with uniform thickness, complete shape and smooth surface, and press it into shape with biscuit mold.

Hard dough measurements.

Pasting properties.

The gelatinization characteristics of mix flour with bean dregs were determined by RVA (TecMaster, Newport scientific instruments LTD., Australia). According to Jiang et al. (2020) method with minor modifications. 3 g of mixed powder and 25 mL of water were placed in an RVA -dedicated aluminum box. After stirring evenly, the aluminum box was put into the instrument for measurement. Heating and cooling procedures were adopted: Temperature was maintained at 50 °C for 1 min, then heated to 95 °C in 3.7 min. After that the temperature was maintained at 95 °C for 2.5 min and then cooled from 95 °C to 50 °C in 3.8 min. The tests were performed in the programming heat and cooling cycle of the STD1. The pasting parameters included peak viscosity, trough viscosity, breakdown viscosity, final viscosity (FV), setback (SB) which obtained from recorded curves.

Rheological analyses.

The rheological properties were determined by Li, Hou, Chen and Gehring (2013). In brief, the rheometer (HAAKE MARS III006–1576 Version 1.3, Thermo Scientific, Germany) was used to analyzed the dough rheological behavior. The measurement system adopted the geometry of parallel-plate (40 mm diameter), to maintain the temperature at 25 ℃. The thawed dough was placed between two parallel plates and compressed into a gap (1 mm). The samples were then pushed between the plates for 5 min and measured. The frequency sweep test was performanced to determine the elastic modulus (G'), viscous modulus (G″) and ranged from 0.1 to 10 Hz, the target strain force was 12 Pa, and loss tangent (tan δ) was used as a function of frequency.

Texture analysis.

The method was based on the research of Meng et al. (2021). Measurements were carried out at room temperature 30 min after the doughs were made. The instrument was calibrated with a 1 kg load cell. The P36R probe was used to calibrate the distance with the 30 mm return trigger path. Parameters were set as follows: pretest peed, 2 mm/s; test speed, 1 mm/s; posttest speed, 1 mm/s; strain, 70%; interval time, 5 s; trigger type, auto, 5 g. Textural parameters, such as hardness, cohesiveness, gumminess, chewiness, springiness and resilience were obtained.

Color of hard dough and biscuits.

The color (*L*, *a**, *b**) values of the crackers were determined by portable color difference meter (Cr-400 chromatic aberration meter Minolta, Japan). Color measurements were made of crust. All measurements were conducted at least three times.

Hard biscuits measurements.

Texture analysis.

Hard biscuits texture was determined by the TA-XT Plus Texture Analyzer (Stable Micro Systems, London, UK). The complete biscuits were placed on the test bench of the texture tester, and The TPA test was carried out with the P/5 probe. Parameters were set as follows: pretest peed, 1.0 mm/s; test speed, 0.50 mm/s; posttest speed, 1 mm/s; strain, 30%; interval time, 5 s. Textural parameters, such as hardness, cohesiveness, gumminess, chewiness were obtained. Measurements were performed on biscuits (5 mm thick), and the mean of the four measurements was recorded.

Scanning electron microscopy (SEM).

The microstructure of hard biscuits was observed by scanning electron microscopy (FEI Co., USA). Take the cookie fracture surface and fix it on the sample table. Then, the samples were scanned and photographed at an accelerating voltage of 15 kV at magnification (400 ×).

Sensory evaluation.

The sensory evaluation was measured according to the method of Kang et al. (2018) with some modifications. The baked biscuits were cooled to room temperature 25 °C for sensory evaluation. The sensory evaluation panel consisted of 10 food graduate students, who were asked to rate the cookie samples on a 100-point scale for their shape, color, taste and texture (Table 2.3).

Table 2.3 – Sensory evaluation of bean dregs hard biscuit

Evaluation of project	Criteria and Points
Shape (a-d) 20 points)	a. The shape is very complete, the thickness is very uniform, no shrinkage, no deformation, no foaming, concave bottom is very few - 17-20, b. The shape is more complete, the thickness is basically uniform, less shrinkage and deformation, less foaming, concave bottom is very few - 14-17, c. Shape is not too complete, thickness is not too uniform, shrinkage and deformation, more bubbles, more concave bottom - 11-14, d. Incomplete shape, uneven thickness, shrinkage and deformation, a lot of bubbles, concave bottom is very much - 8-11,
Color (e-h) (20 points)	e. The color is very uniform, shiny, no coke, too white phenomenon - 17-20, f. The color is basically uniform, luster is not obvious, there are few too coke, too white phenomenon - 14-17, g. The color is not uniform, poor luster, a small amount of coke, too white phenomenon - 11-14, h. The color is not uniform, the luster is very poor, there are a lot of over-coke, over-white phenomenon - 8-11.

Flavor and taste (i-l) （40 points）	i. The palate is crisp, not sticky to teeth, strong fragrance, no peculiar smell, moderate sweet and light - 34-40, j. The taste is crunchy and not sticky, with strong fragrance and slight odor. It is sweet or light - 28-34, k. The taste is not too crunchy, a little sticky, weak, smelly, too sweet or too bland, tasteless in the mouth - 22-28, l. The taste is not brittle, sticky teeth, very weak fragrance, a great smell, very sweet, strong discomfort after the mouth - 16-22.
organization (m-p) （20 points）	m. The cross - section structure is clear, crisp and loose, not greasy 17-20 n. The cross - section structure level is clear, the crispness is poor or slightly greasy - 14-17, o. The cross - section structure is quite clear, the crispness is poor, hard or greasy - 11-14, p. The cross section structure is not clear, hard and greasy texture, more cracked biscuits, easy to slag - 8-11.

Single factor test.

According to the above experimental study, the maximum amount of bean dregs powder added to hard biscuits was 10 g, a total weight of 100 g of bean dregs powder and flour. With flour, powdered sugar, egg yolk, starch, baking powder and salt as the auxiliary ingredients, using water and soybean oil mix.

The water was set as 26 mL, 28 mL, 30 mL, 32 mL and 34 mL respectively, and the single factor test was carried out in five gradients to obtain the influence of the dosage of water on the sensory evaluation of hard biscuits.

After the optimal water dosage was determined, the powdered sugar was set as 21g, 23 g, 25 g, 27g and 29 g respectively, and the single factor test was carried out in five gradients to obtain the influence of the dosage of powdered sugar on the sensory evaluation of hard biscuits.

After the optimal powdered sugar dosage was determined, the baking temperatures were set as 180 ℃, 185 ℃, 190 ℃, 195 ℃ and 200 ℃ respectively, and the single factor test was carried out in five gradients to obtain the influence of baking temperature on the sensory evaluation of hard biscuits.

After the optimal baking temperature was determined, the baking time were set as 8 min, 9 min, 10 min, 11 min and 12 min respectively, and the single factor test was carried out in five gradients to obtain the influence of baking time on the sensory evaluation of hard biscuits.

Orthogonal test and determine the optimal formula.

According to the single factor test, the amount of water (A), powdered sugar (B), baking temperature (C) and baking time (D) were selected for orthogonal test. Horizontal design of orthogonal experimental factors is shown in Table 2.4.

Table 2.4 – Horizontal design of orthogonal experimental factors of bean dregs hard biscuits

Level	Factors			
	A Water (mL)	B Powdered Sugar (g)	C Temperature (℃)	D Time (min)
1	28	23	185	8
2	30	25	190	9
3	32	27	195	10

Sensory and texture evaluation of bean dregs hard biscuits.

The determination method was the same as 2.2.27.

2.3 Planning an experiment and conducting a research

On Fig. 2.1 presents a scheme for conducting research and planning experiments.

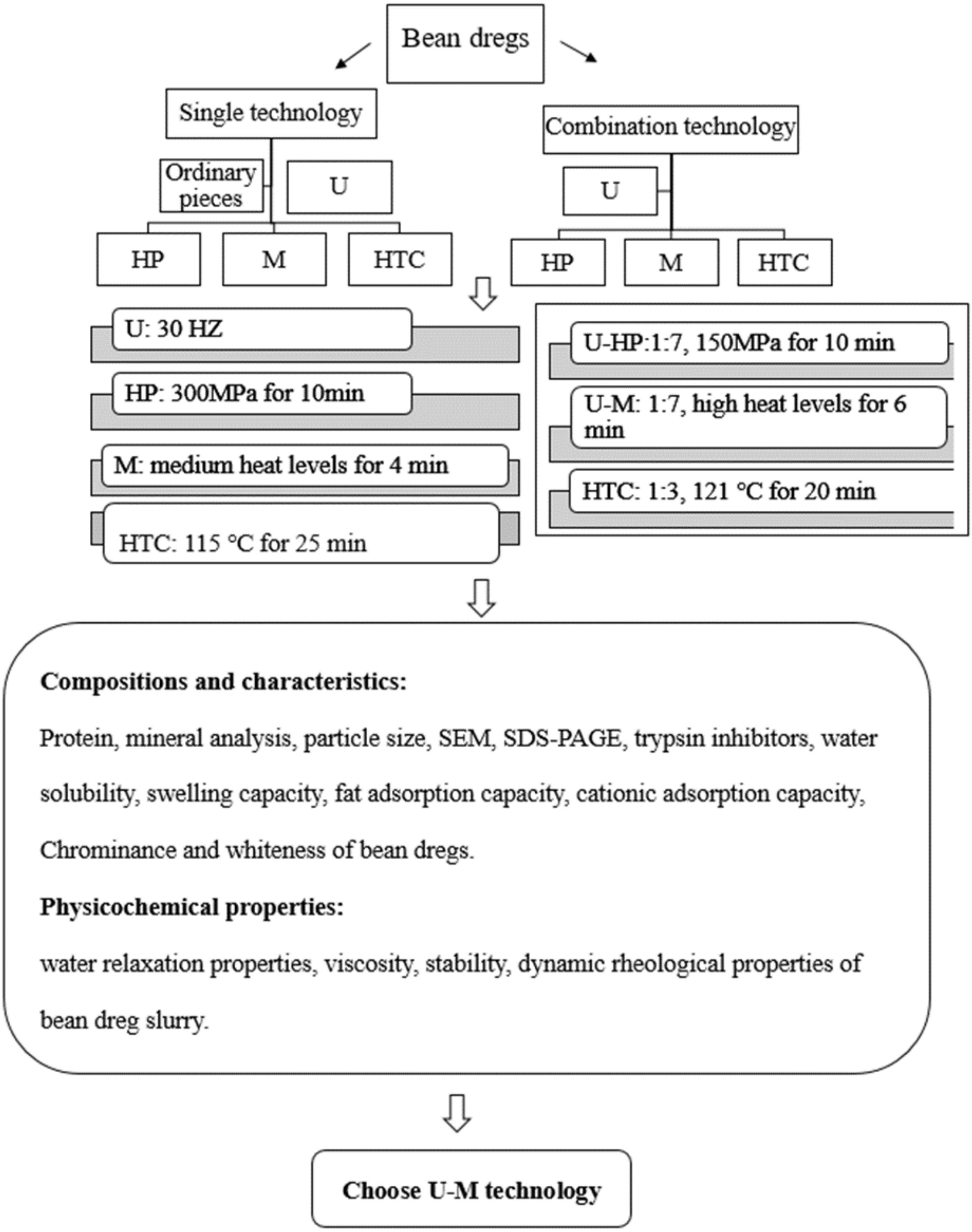

Figure 2.1 – Planning an experiment and conducting a research

Figure 2.2 presents the Technology Roadmap

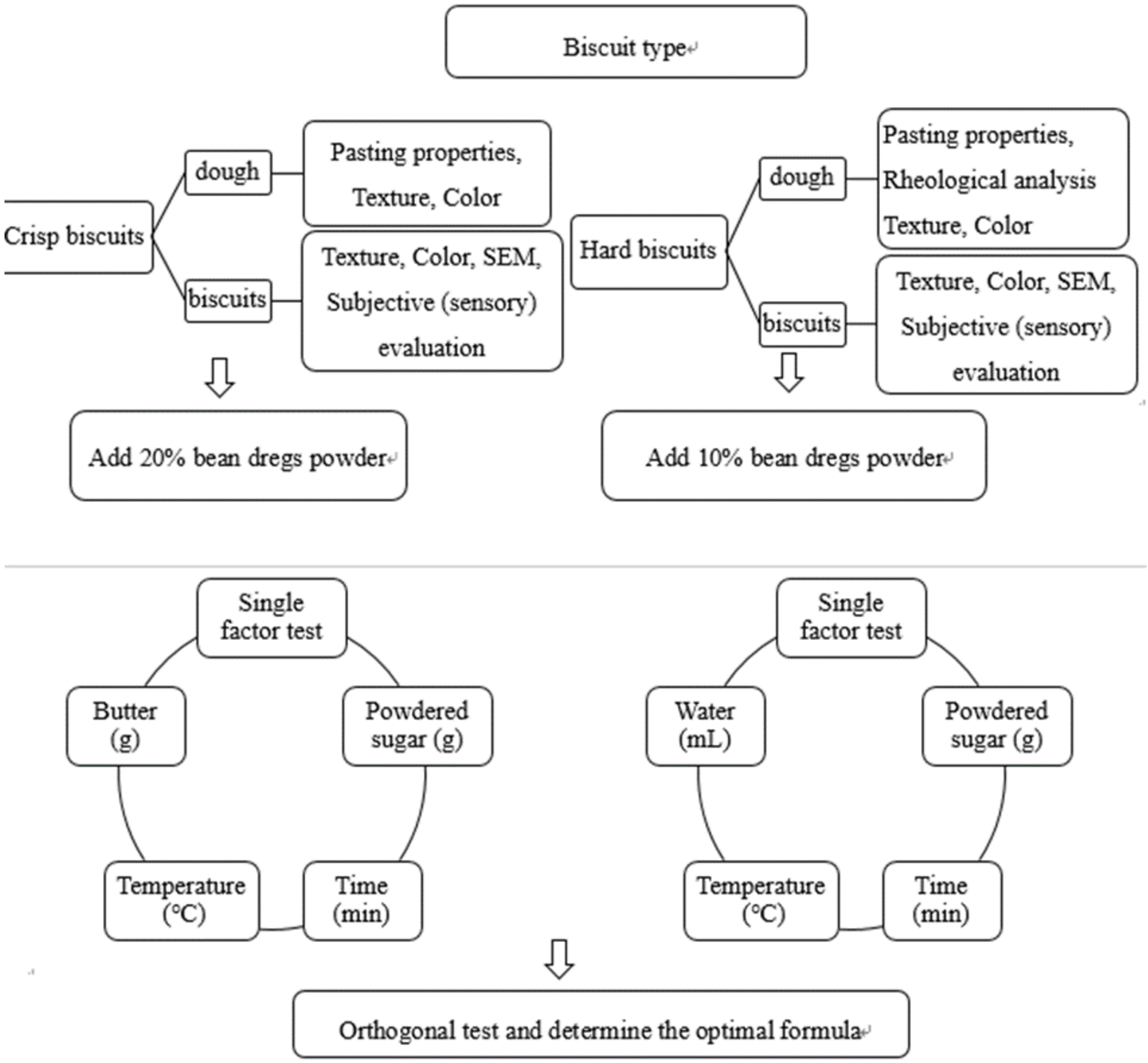

Figure 2.2 – Technology roadmap

2.4 Statistical processing of research results

Experiments were conducted in triplicate, and the obtained data were statistically analyzed and expressed as the means ± standard deviation (SD). Data were subjected to analysis of variance (ANOVA) using the software package SPSS 12.0 for Windows (SPSS Inc., Chicago, USA) and $p < 0.05$ was used as the standard for significance.

Conclusions on section 2

1. This work was financed by Central government guiding local scientific and technological development projects (No. 2021), the Program of Xinxiang Major Scientific and Technological Project (No. ZD2020003); and Science and Technology Projects in Henan Province (grant number 19A550007).

2. The work was carried out for the period from 2018 to 2019 at the departments of Sumy National Agrarian University, and the period from 2019 to 2021 at the food department of Henan Institute of Science and Technology.

3. Objects of the study - Bean dregs: wet bean dregs were obtained at local market (Fresh okra has high moisture content, bad taste and mouth feel, and is difficult to store).

4. The subject of the study – is the effects of different physical technology on compositions and characteristics of bean dregs; effect of ultrafine grinding technology combined with high-pressure, microwave and high-temperature cooking technology on the physicochemical properties of bean dregs; effect of bean dregs powder treated by U-M on dough properties and quality of crisp biscuits; effect of bean dregs powder treated by U-M on dough properties and quality of hard biscuits.

SECTION 3.

EFFECT OF ULTRAFINE GRINDING TECHNOLOGY COMBINED WITH HIGH-PRESSURE, MICROWAVE AND HIGH TEMPERATURE COOKING TECHNOLOGY ON COMPOSITIONS, CHARACTERISTICS AND THE PHYSICOCHEMICAL PROPERTIES OF BEAN DREGS

3.1. Effect of physical technology on SDF content of bean dregs

Several physical techniques were applied to increase the SDF content of bean dregs in this work. The influence of U combined with HP, M or HTC treatments on the SDF content of bean dregs were shown in Fig. 3.1. The changes in SDF content were related to the ratio of solid to liquid of the samples. The SDF content increased with increasing moisture content in the bean dregs during U-HP treatment at 150 MPa for 10 min (Fig. 3.1A). When the ratio of solid to liquid was 1:7 (W/V), the content of SDF was the highest (18.86%). However, the SDF content decreased when the ratio of solid to liquid was greater than 1:7. The SDF content of bean dregs increased with increasing pressure but decreased when the pressure was higher than 150 MPa under the solid-liquid ratio1:7 for treatment 10 min (Fig. 3.1B). Thus, an appropriate pressure of 150 MPa should be chosen to obtain the maximum SDF content. The content of SDF in bean dregs increased with increasing U-HP treatment time and reached a maximum value at 10 min under the solid-liquid ratio1:7 and at 150 MPa (Fig. 3.1C). Therefore, the optimal conditions for the combined U-HP treatment were as follows: solid-liquid ratio of 1:7, pressure of 150 MPa, and treatment time of 10 min. The highest SDF content in the bean dregs was 18.86%.

In the U-M treatment, the trend for the SDF content in bean dregs with different solid-liquid ratios was the same as that of the U-HP treatment, and the SDF reached 13.71% when the solid-liquid ratio was 1:7 (W/V) at medial heat for 6 min (Fig. 3.1D). When the microwave was operated at the high power level for 6 min under the solid-liquid ratio1:7, the maximum value of SDF in bean dregs rose to 19.23% (Fig. 3.1E, F).

The SDF content in the bean dregs treated with U-HTC decreased with increasing water content; the highest SDF content was obtained when the solid-liquid ratio was 1:3 (W/V), and the lowest SDF content was found at a solid-liquid ratio of 1:7 at 121 ◦C for 20 min (Fig. 3.1G). Interestingly, the content of SDF in bean dregs first increased and then decreased with increasing temperature, and the SDF content reached a maximum (16.89%) after heating at 121 ◦C for 20 min under the solid liquid ratio1:7 (Fig. 3.1H, I).

The above results show that the optimal conditions for U-HP were a 1:7 ratio of ultrafine bean dregs to water and a pressure of 150 MPa applied for 10 min. The optimal conditions for U-M were a 1:7 ratio of ultrafine bean dregs to water and high power irradiation for 6 min. The optimal conditions for U-HTC were a 1:3 ratio of ultrafine bean dregs to water and heating at 121 ◦C for 20 min.

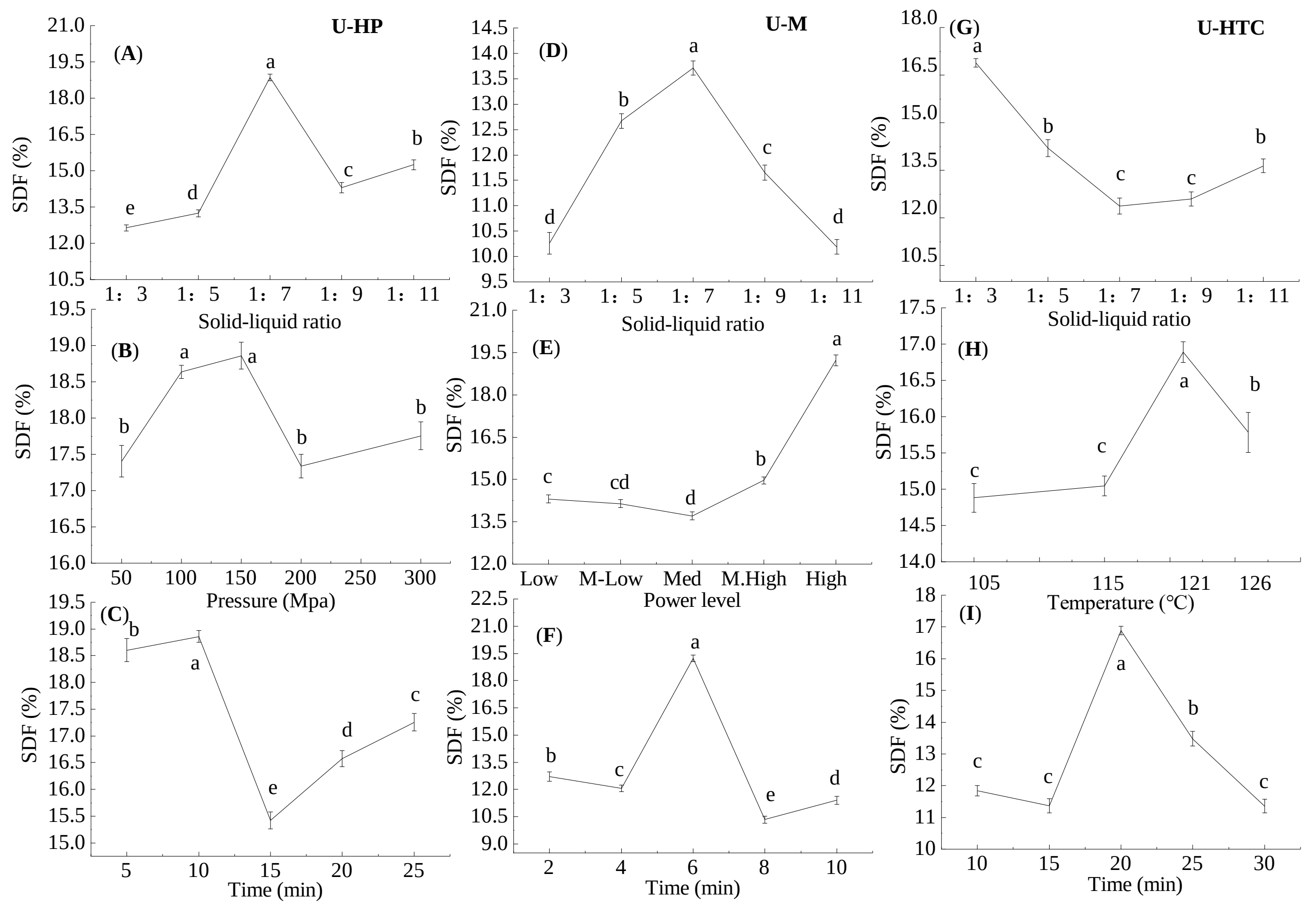

Figure 3.1 - The effect of physical combined technology on the contents of SDF in bean dregs

Fig. 3.2 compared the effect of optimal combined technology and single technology with control on the SDF content in bean dregs. The content of SDF in bean dregs increased after single and combined techniques. For the single treatments, the highest SDF content was obtained in ultrafine grinding samples, and the SDF increased from 1.63% (in the control sample) to 15.15%; the SDF content for the M and HTC technology was 13.84% and 13.87%, respectively. The lowest value was found for high pressure technology, which only provided an increase to 10.40%. Zhang et al. (2009) reported that the dietary fiber content of OSDF (oat bran soluble dietary fiber) increased in steam heating, superfine grinding, extrusion, and untreated oat bran compared with raw oat bran. It was claimed that HHP (high hydrostatic pressure) and HPH (high pressure homogenization) treatments could influence on the characteristics of dietary fiber obtained from purple potatoes and increase the soluble dietary fiber content (Xie et al., 2017).

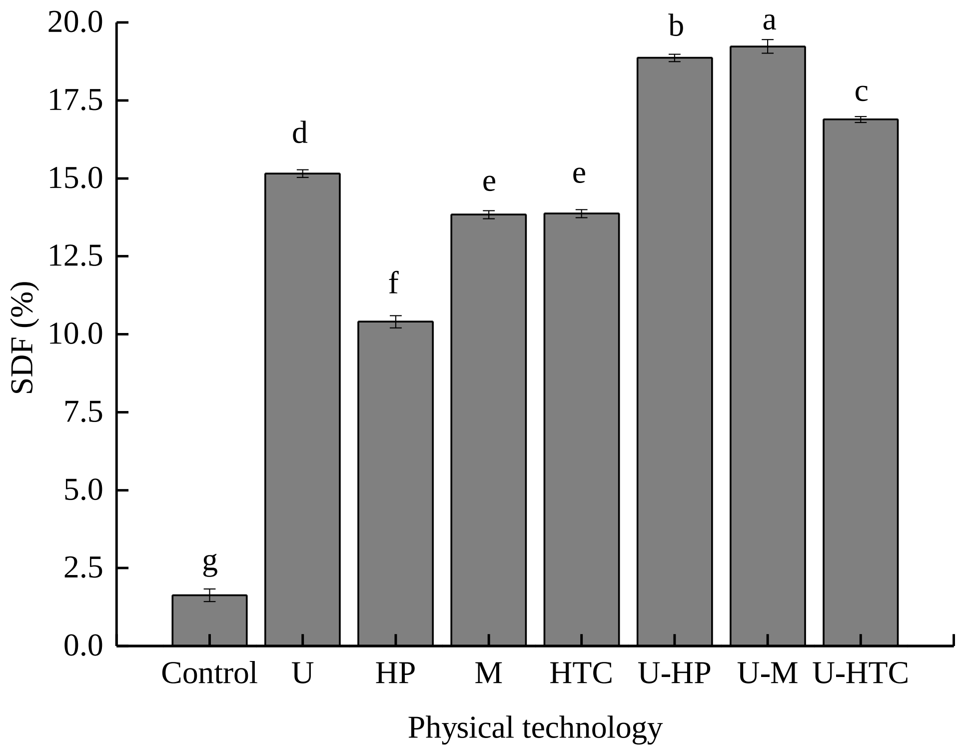

Figure 3.2 - The effect of physical technology on the contents of SDF in bean dregs

Fig. 3.2 showed the combined technology may have greater effects than any single technology. The maximum content of SDF was found in the sample treated with the

U-M combination, and the SDF content was 19.23%, which increased 91.52% compared with the control, and the value was increased by 28.03% compared with that of single M treatment. There was significant ($p < 0.05$) difference between combinations U-HP and U-M for SDF increase in bean dregs, while the amount of SDF produced in the combination U-HTC was lower than U-HP and U-M technologies. Therefore, the combination of physical technology could be chosen to obtain the maximum SDF content. The reason for the enhancement in SDF content might be that different physical treatments loosened the tight structure of fiber, and thus, some substances binding with fiber were depolymerized. Obviously, ultrafine grinding has been proven to be an effective way redistributing fiber components from insoluble to soluble fractions (Zhu, Huang, Peng, Qian & Zhou, 2010). In addition, the conversion of insoluble to soluble fiber might depend on water, treatment time and temperature. Wet-heat treatment could increase accessibility to the cell wall matrix and facilitate cleavage of some bonds between polysaccharides (Mateos-Aparicio & Mateos-Peinado, 2010), in this article, U-M and U-HTC treatments could further enhance this effect. These results revealed that the combined technique had a better effect than any single technique in increasing SDF content, which was attributed to the secondary destruction of HP, M and HTC treatments on ultrafine grinding bean dregs. Especially under wet-heat conditions such as M or HTC treatments, bean dreg particles expanded, resulting in fiber fracture and outflow of soluble components.

3.2. Effect of physical technology on the protein content of bean dregs

Fig. 3.3 showed that the protein content in bean dregs decreased greatly after physical technology treatment with either single techniques or with combined techniques. In the single technical treatments, the protein content in bean dregs after U, HP, M and HTC treatments decreased from 23.46% to 11.96%, 16.30%, 12.85% and 13.09%, respectively. The protein contents in bean dregs were further reduced after combination treatments. The U-M and U-HTC combinations exhibited no difference in protein content compared with the single techniques, while the U-HP treatment greatly decreased the protein content. Interestingly, the results of the single HP treatment differed significantly from those of the combined U-HP treatment. Single treatment with U and the combination U-HP had the greatest impact on protein content, as compared with that of the control sample, since protein content was decreased by 49.02% and 57.80%, respectively. These results were consistent with the report of Zhang et al. (2009), who found that the total protein content of OSDF decreased after steam heating, superfine grinding and extrusion treatments. However, Li et al. (2012) reported that extrusion had no significant ($p > 0.05$) effect on protein level (Li et al., 2012). The drop in protein level during the U-HP combination treatment may be the result of isopeptide bond formation between ε-amine groups of lysine and amide groups of asparagines or glutamine, which is accompanied by the release of ammonia during the processes of grinding and applying pressure (Sobota, Sykut-Domańska & Rzedzicki, 2010). The effects of different treatments on the content and functional properties of protein were different, possibly because the protein contained in the samples denatured, stretched or aggregated under these treatment (Spotti & Campanella, 2017).

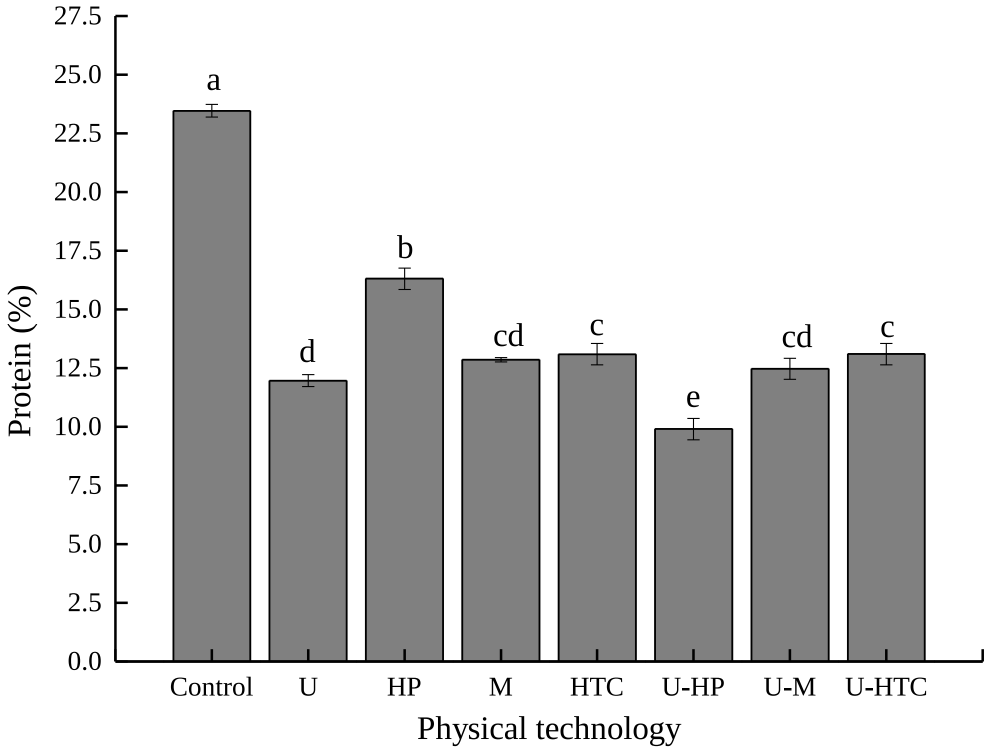

Figure 3.3 - The effect of different treatments on the contents of protein in bean dregs

3.3. Particle size distributions of bean dregs treated by different techniques

The laser particle size analyzer (LPSA) technique is an effective method by which the particle size distribution of a powder sample can be determined. Table 3.1 listed the effects of different treatments on the particle size distribution of bean dregs.

Table 3.1 - Particle size distribution of bean dregs treated by different treatments

Treatment	Particle size parameters (μm)						
	D (4, 3)	D (3, 2)	D10	D25	D50	D75	D90
Control	144.70±1.36a	40.95±0.3a	25.79±0.21a	63.61±0.88a	131.30±1.18a	214.00±11.41a	289.40±3.32a
U	93.07±1.36d	25.28±0.30de	13.03±0.53e	30.89±0.88e	69.52±1.18f	133.60±1.41c	212.55±3.32b
HP	134.95±0.49b	39.23±1.78a	23.19±0.04b	55.65±0.42b	119.40±0.71c	199.60±0.57b	277.30±0.28a
M	127.30±1.70c	32.97±0.06c	16.11±0.59d	41.94±1.30c	109.75±2.33d	194.35±2.05b	274.60±1.84a
HTC	138.60±2.97b	36.75±0.48b	19.19±0.51c	53.87±1.92b	124.65±3.18b	208.50±5.09a	285.65±4.74a
U-HP	35.67±5.22e	14.53±0.39f	5.99±0.14g	12.54±0.54f	27.43±1.78g	51.75±7.50d	79.55±16.42d
U-M	95.76±4.66d	26.42±0.78d	13.27±0.65e	35.29±1.78d	78.91±4.35e	137.35±6.58c	204.75±9.69bc
U-HTC	90.04±1.65d	23.72±1.38e	10.78±0.35f	30.27±0.70e	72.66±1.56f	131.00±2.55c	196.55±3.32c

As expected, some parameters were decreased significantly ($p < 0.05$) by different physical technologies as compared with those of the control. The D (4, 3) diameters were 35.67 μm, 95.76 μm and 90.04 μm after U-HP, U-M, and U-HTC treatments, respectively. It is worth noting that the combined U-HP treatment had the greatest effect on the particles of bean dregs. As shown in Table 3.1 the particle size of bean dregs was smallest (69.52 μm) after ultrafine grinding among all single technology treatments. U-HP treatment significantly ($p < 0.05$) reduced the particle size of bean dregs (27.43 μm), and the difference between D (3,2) and D (4,3) was the smallest. These results indicated that the apparent shape and particle size distribution of bean dregs treated with U-HP were more regular than those of dregs treated with the other techniques. D50, the median particle size, is a typical parameter used to represent particle size, and it indicates that 50% of the particles measured in the sample have a particle size greater than this value. As shown in Table 3.1 the D50 of bean dregs by U treatment decreased compared with that of the control. However, D50 of bean dregs significantly increased ($p < 0.05$) after combined with M or HTC treatments. It was probably because the van der walls forces and electrostatic attractions on the surface of fine particles increased, which promoted the aggregation of dietary fiber particles (Antoine, Lullien-Pellerin, Abecassis & Rouau, 2004; Zhang et al., 2016).

3.4. Mineral content analysis of bean dregs

Minerals are the inorganic chemical elements necessary to maintain the normal physiological functions of the human body. Table 3.2 summarized the effects of physical technology on the mineral content of bean dregs. Both single treatments and combination treatments significantly affected the mineral content of bean dregs. The highest contents of Se and Sn were found in the samples by U treatment. The combination technology could significantly increase ($p < 0.05$) the contents of K, Ca, Na and Fe of bean dregs. HP technology significantly increased ($p < 0.05$) the contents of K, Mg, Zn, Cu, Mn and As, and U-HP combination increased the contents of Ca, Na, Fe, Ti and Sr. The highest mineral contents in the control bean dregs were those for K (9130 mg/kg) and Ca (2591 mg/kg). However, compared with the control group, the K content reached 13,283 mg/kg in the sample subjected to the HP treatment, an increase of 31.27%, and the Ca content in the combination U-HP treatment reached 3804 mg/kg, an increase of 31.89%. Single-treatment M and HTC techniques reduced the contents of K, Ca, Mg and Zn element, consistent with Alajaji and El-Adawy (2006), who found that cooking treatments and microwave cooking decreased mineral contents of chickpea seeds.

Table 3.2 - The effect of different treatments on the contents of minerals in bean dregs (mg/kg)

Elements	Control	U	HP	M	HTC	U-HP	U-M	U-HTC
K	9130±20.00d	10867±122.05b	13283±103.91a	8285±64.05e	7813±87.03f	7660±62.56f	10458±114.37c	10989±99.08b
Ca	2591±33.72d	3004±36.91b	3014±24.21b	2492±93.22d	2226±95.60e	3804±37.50a	2776±82.89c	2785±97.08c
Na	91± 3.53d	412± 10.50b	123± 12.22cd	147± 10.15c	136± 4.04cd	2372±69.90a	422± 13.20b	431± 12.34b
Mg	1300±31.58e	1520± 25.24c	1908± 76.53a	1124±88.07f	1024±40.26f	1800±78.68b	1346± 60.85de	1414± 91.28d
Zn	11± 1.00b	8± 0.58c	14± 2.02a	5± 0.50d	5± 0.57d	10± 1.00bc	8± 0.69c	9± 0.57c
Fe	50± 4.04d	66± 3.51b	58± 2.50e	53± 2.52cd	46± 1.53d	77± 3.21a	73± 4.53ab	67± 3.51b
Cu	9± 1.00b	9± 1.04b	12± 1.50a	8± 1.53b	5± 0.73c	10± 1.15b	8± 0.53b	9± 0.73b
Mn	9± 1.00a	7± 0.73b	10± 1.01a	6± 0.75c	5± 0.66c	5± 0.67c	6± 1.03c	6± 1.02c
As	33± 2.08b	19± 1.01c	47± 2.01a	16± 2.51c	-	30± 2.08b	34± 2.08b	45± 2.51a
Se	45± 1.05c	62± 3.00a	55± 2.53b	30± 2.52e	11± 2.01f	43± 2.56cd	38± 5.01d	55± 6.66b
Sn	36± 2.65b	58± 3,54a	41± 1.01b	21± 2.00c	38± 2.52b	40± 4.04b	55± 4.16a	23± 2.00c
TI	113± 2.52c	63± 4.50d	110± 1.50c	171± 6.51a	67± 3.51d	131± 1.53b	109± 4.04c	130± 2.52b
Sr	16± 2.56c	21± 1.60b	19± 2.00bc	16± 2.52c	11± 0.51d	49± 1.51a	21± 1.53b	22± 0.55b

While the combination of U-M and U-HTC treatments greatly increased the K and Ca contents. Microwave technology (M) and the combination of U-HTC greatly decreased the content of Sn. The element, as was not detected in the samples treated by HTC treatment. It was reported that the particle size could influence the release and dissolution of active components. Since the initial particle size of the ultrafine bean dregs was small, and the release of mineral elements in samples might be enhanced by the high-temperature conditions (Zhang et al., 2016), such as U-M and U-HTC techniques. Hence, the loosened microstructure of bean dregs treated with combination treatments might help the exposure of mineral elements in the samples. As a result, the amount of some elements measured increased dramatically.

3.5. Scanning electron microscopy (SEM) observation

SEM images of bean dregs subjected to different treatments are shown in Fig. 3.4. The surface of the control sample had a loose sheet structure with many folds, and the fiber bundle exhibited an ordered structure (Fig. 3.4a). This is consistent with the results of Li et al. (2019). After various physical treatments, the microstructure of bean dregs had changed greatly. The surfaces of treated bean dregs were rough, irregular and full of holes compared with those of control samples. Whole layered structures and the internal structure of bean dregs treated by U treatment were strongly stirred and ground by the machine, and the lamellar structure of the bean dregs was degraded into scattered small fragments (Fig. 3.4b). After HP treatment, the lamellar structure became loose, and the number of surface gullies increased (Fig. 3.4c). Under U-HP, the honeycomb structure of the bean dregs was more obvious and the structure became more uniform, porous and fluffy (Fig. 3.4d). The molecular structure of bean dregs was destroyed due to the strong thermal effect imposed during microwave treatment, leading to formation of more gullies and skeletons, but the lamellar layer was relatively flat (Fig. 3.4e). After the combined U-M treatment, particles were small and the internal structure was fragmented (Fig. 3.4f). Comparison with control bean dregs showed that the HTC treatment destroyed the integrity of the surfaces of the dregs and made the structure coarser and more irregular (Fig. 3.4g). This might be due to that the aggregation reaction by the wet heat of HTC treatment. After the U-HTC treatment, the large sheet structure was cracked into small fragments, and the internal nucleated structure was disintegrated into small particles at high temperature and frequency (Fig. 3.4h). The results of SEM were consistent with the results of particle size distribution. The particle sizes of bean dregs were significantly reduced ($p < 0.05$) by the application of ultrafine grinding technology. The porous structure of treated bean dregs might be due to the cell rupture caused by U, HP, M energy absorption or HTC treatments. The specific surface area of bean dregs increased with the increase of porosity, and more hydrophilic groups were exposed (Huang, Ma, Peng, Wang & Yang, 2015), which might enhance the function and physicochemical properties of bean dregs. The porous structures were very important for improving the adsorption and other functional properties of dietary fiber (Lin et al., 2020).

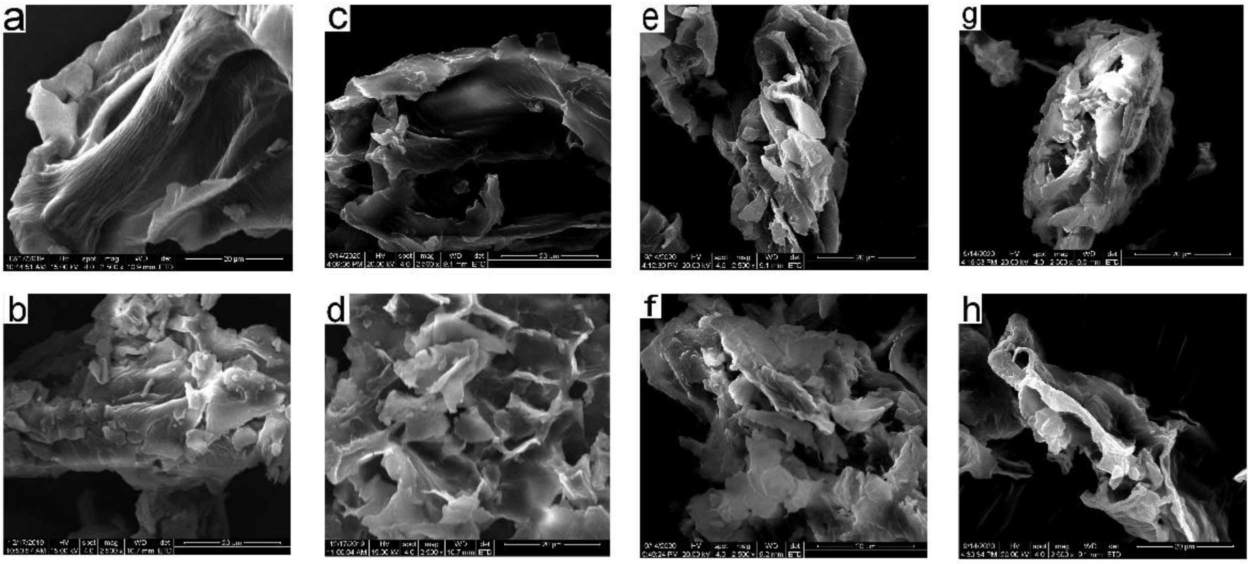

Figure 3.4 - Scanning electron micrographs of bean dregs treated with different treatments

(a: control bean dregs; b: ultrafine grinding; c: high pressure; d: ultrafine grinding-high pressure; e: microwave; f: ultrafine grinding- microwave; g: high temperature cooking; h: ultrafine grinding- high temperature cooking. All 2500 × magnification).

3.6. Analysis of SDS-PAGE

SDS-PAGE was used to detect the molecular weight distribution of proteins. As shown in Fig. 3.5 the number of protein bands from bean dregs treated by ultrafine grinding, high pressure and both was the same as that of the control sample. (Fig. 3.5, bands 1, 2 and 5). However, the number of bands in bean dreg samples treated by M, HTC, U-M and UHTC treatments decreased considerably (Fig. 3.5, bands 3, 4, 6 and 7). The U treatment had no effect on the content of protein subunits in bean dregs. HP and U-HP treatments had some effect on the molecular weights of the proteins, and the colors of the bands in the molecular weight range 55–180 kD were obviously less intense (Fig. 3.5, bands 2 and 5).

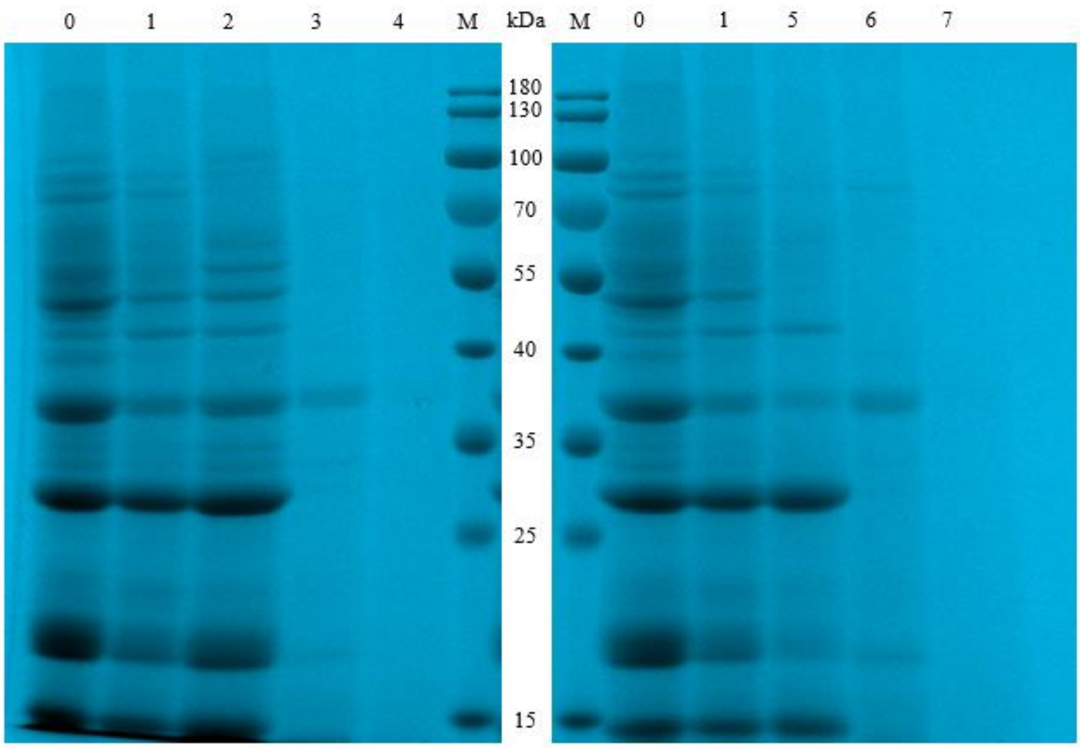

Figure 3.5 - SDS-PAGE pattern of bean dregs at different treatments (Lanes: M, molecular weight standard; 0, control bean dregs; 1, ultrafine grinding; 2, high pressure, 3, microwave; 4, high temperature cooking; 5, ultrafine grinding-high pressure; 6, ultrafine grinding-microwave; 7, ultrafine grinding-high temperature cooking)

With the application of high pressure, water molecules entered the binding regions of each subunit, resulting in the formation of noncovalent bonds and unstable connections between subunits in these regions and ultimately leading to depolymerization (Silva, Foguel & Royer, 2001). After the M and U-M treatments, the protein bands for molecular weights above 90 kD became lighter in color (Fig. 3.5, bands 3, 4 and 7). It was reported that superheat treatment caused the proteins to agglomerate and form protein polymers, which made it difficult to enter the separation glue (Hu, Wang, Zhu & Li, 2017). Moreover, bands for proteins with molecular weights ranging from 15 to 40 kD were lighter in color in the samples treated by the microwave and U-M methods. This is probably because of the large amount of protein involved in protein polymers (Wang, Guo & Zhu, 2016) or the exchange of hydrophobic-disulfide bonds and noncovalent bond reactions occurring during superheat treatment (Lagrain, Brijs, Veraverbeke & Delcour, 2005). After HTC and U-HTC treatment, the protein bands had disappeared completely (Fig. 3.5, bands 4 and 7). It can be seen from the figure that the single treatments M and HTC and the combined treatments U-M and U-HTC had great influence on the molecular weights of protein.

3.7. Changes in trypsin inhibitors in bean dregs after treatment

Anti-nutritional factors (ANFs) are substances that have a negative effect on the digestion, absorption, and utilization of nutrients, as well as adverse reactions that affect humans and animals. Few anti-nutritional factors are found in legumes that usually inhibit the bioavailability of many nutrients, such as trypsin inhibitors, phytic acids, and hemagglutinins. These anti-nutritional factors limit the nutritional properties of bean dregs and influence the digestibility of certain nutrients (Akpapunam & Sefa-Dedeh, 1997). Bean dregs contain three antinutritional factors: trypsin inhibitors, lectins and goitrogens, and the most important is trypsin inhibitors, which typically reduce protein digestion, inhibit animal growth and cause pancreatic enlargement. They mainly exist in legumes and can be eliminated or diminished by heating and other physical techniques. Reducing the content or activity of anti-nutritional factors effectively improves the utilization of soybean nutrients. The changes in trypsin inhibitor in the control sample and bean dregs caused by combined treatments are shown in Fig. 3.6. The TIA was significantly ($p < 0.05$) reduced by single treatments and combination treatments. The lowest TIA was produced by U-HTC, followed by HTC treatment. Similar results were obtained by Alajaji and El-Adawy (2006), who found a significant reduction in trypsin inhibitor activity after cooking treatment ($p < 0.05$). Under the conditions of HTC and UHTC treatments, the TIA was decreased from 7365 TIU/g to 1210 and 96 TIU/g, respectively. However, the effects of non-heating treatments (U, HP and U-HP) on the reduction of trypsin inhibitor content were much inferior to those involving heat treatment. This indicated that heat treatment effectively reduced trypsin inhibitor activity, which was consistent with the research of Machado et al. (2008). Therefore, trypsin-inhibiting factors were reduced during heat treatment and this promotes the digestion and absorption of soybean nutrients by humans and animals.

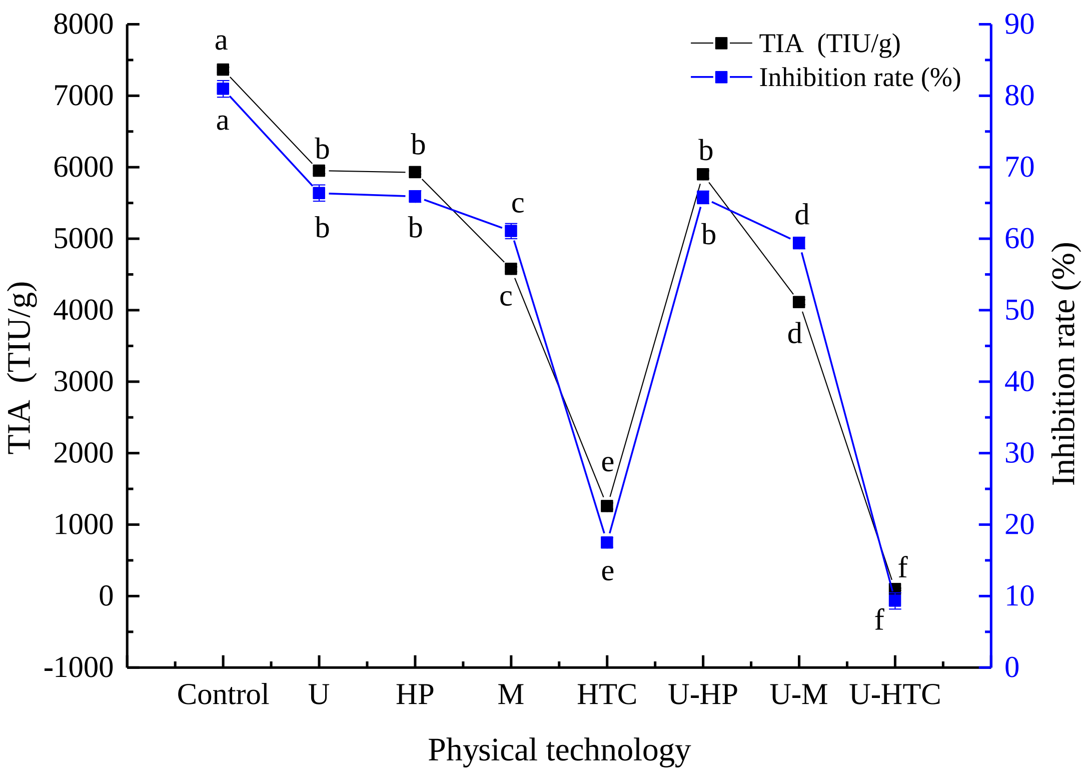

Figure 3.6 - Effect of combination treatment on the trypsin inhibitor in bean dregs

3.8. Processing performance of bean dregs

The solubility and hydration properties of dietary fiber are closely related to its structure, porosity, particle size and the type of treatment exerting on it (Foschia, Peressini, Sensidoni & Brennan, 2013). The water solubility of bean dregs enriches their application in water-soluble foods and improves their physiological function. As shown in Table 3.3. different treatments increased the water solubility of bean dregs. The water solubility of bean dregs made by U treatment increased by 16.56% compared with that of the control. The solubilities of bean dregs from the combined treatment were higher than those from the single treatment. This might be because the dense structure of bean dregs was loosened and more hydrophilic groups were exposed during the applications of pressure, crushing or heat treatment. As reported by Li et al. (2019), the solubility of bean dregs increased significantly after steam explosion treatment. The swelling capacity of bean dregs after treatments with the single techniques U, HP, M and HTC decreased by 8.56%,17.16%, 5.71% and 2.79%, respectively, compared with the control, and the combined treatments U-HP, U-M and U-HTC reduced the swelling capacity of bean dregs by 40.03%, 31.45% and 37.17%, respectively. Obviously, the combined treatments had greater effects on the swelling capacity of bean dregs than the single treatments, which might be attributed to particle size reduction or the alteration of the fiber matrix structure, thus resulting in the changes of physical structures and hydration properties of dietary fiber (Sangnark & Noomhorm, 2003; Zhu et al., 2010). Table 3.3 listed the absorption capacities of bean dregs for peanut oil and lard. It was found that the fat absorption capacities of bean dregs for peanut oil and lard were similar. Among all of the treatment methods, only the M treatment significantly increased ($p < 0.05$) the adsorption capacity of bean dregs for lard. The fat adsorption capacities of bean dregs treated by different technologies were significantly different ($p < 0.05$). The bean dregs treated by a single technology had high fat adsorption capacities, while the combined technologies led to relatively low fat adsorption capacities. On the one hand, this was mainly related to the changes in bean dreg particle sizes. In this paper, the particle sizes after the combined treatments were smaller than those produced after the single treatments, and the oil absorption capacities of the combined treatments were lower than those of the single treatments. This is inconsistent with the report of Jia et al. (2020). They studied the oil absorption capacity of Auricularia polytricha-derived dietary fiber and found that the oil absorption capacity of the sample with smaller particle sizes was larger. On the other hand, this was closely related to the protein structures of bean dregs. The depolymerization of proteins in bean dregs might lead to decreases in fat absorption capacity. These results showed that the absorption capacities of bean dregs for peanut oil and lard treated with U-HP were reduced by 47.97% and 44.78%, respectively, compared with the control.

Table 3.3 - Hydration characteristics and fat absorption capacity of bean dregs

Physical technology	Water solubility (%)	Swelling capacity (g/mL)	Fat absorption capacity (g/g)	
			Peanut oil	Lard
Control	10.13±0.13g	13.99±0.13a	1.48±0.03a	1.34±0.02b
U	12.14±0.16d	12.79±0.12d	1.00±0.0.03c	1.05±0.03c
HP	11.09±0.18f	11.59±0.22e	1.36±0.04b	1.33±0.02b
M	11.73±0.12e	13.19±0.16c	1.48±0.01a	1.49±0.03a
HTC	11.63±0.14e	13.60±0.19b	0.95±0.02c	0.86±0.03e
U-HP	13.40±0.22b	8.39±0.15h	0.77±0.03e	0.74±0.04f
U-M	13.89±0.14a	9.59±0.17f	0.97±0.02c	0.93±0.03d
U-HTC	12.98±0.13c	8.79±0.11g	0.86±0.03d	0.82±0.02e

3.9. The effect of different treatments on cationic adsorption capacity of bean dregs

As shown in Fig. 3.7 the order of cationic adsorption capacity of bean dregs treated by different methods was M < HTC < Control< HP < U-HTC < U < U-HP. Different processing techniques had different effects on the cationic adsorption capacities of bean dregs. Relevant literature showed that cationic adsorption capacity is related to particle size; the smaller the particles are, the stronger the cationic adsorption capacity of the sample (Wang, Ciou & Chiang, 2009). Different treatment methods could change the particle size distribution of the bean dregs, especially the bean dregs treated by the combination technology contained smaller particles, so they had stronger cationic absorption capacity. In addition, when bean dregs dietary fiber in high pressure treatment, under the action of high-speed impact, shear, cavitation, instantaneous pressure droped, etc., exposed more hydroxyl, carboxyl, amino and other attractive cationic groups. Generally, the adsorption of ions onto cellulose occurs via displacement reactions. The samples by different treatments might expose more surface area, uronic acids or ion binding sites on the dietary fiber and consequently increase the cation-exchange capacity to different extents (Chau, Wang, & Wen, 2007). It can be exchanged with Ca_2^+, Zn_2^+, Cu_2^+, and Pb_2^+ plasma and can exchange Na^+ and K^+; that is, bean dreg powder in the intestinal tract can absorb Na^+ and discharge it from the body, thereby reducing the incidence of cardiovascular and other diseases. Therefore, the processing methods were also crucial to the final properties of bean dregs.

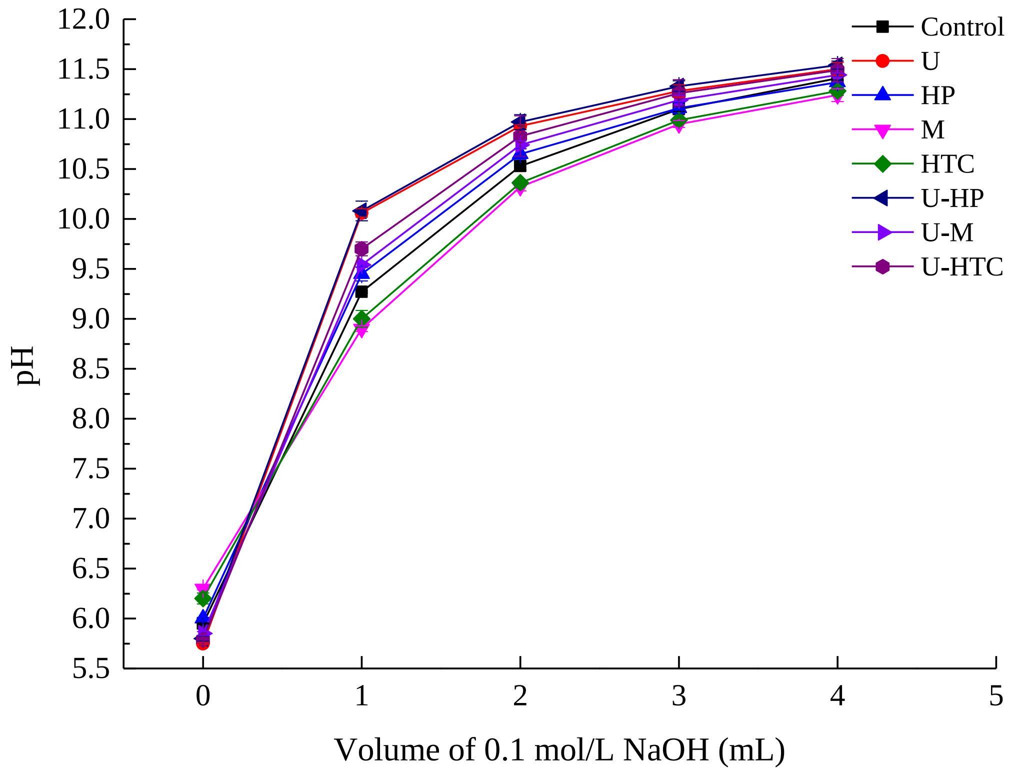

Figure 3.7 - The effect of different treatments on cationic adsorption capacity of bean dregs

3.10. Water distribution in bean dregs by different treatments based on low-field nuclear magnetic resonance (LF-NMR)

LF-NMR has been widely used in the study of water distribution and migration in food samples (Chen, Tian, Tong, Zhang & Jin, 2017) and beef (Kang, Gao, Ge, Zhou & Zhang, 2017). This technique can effectively and nondestructively determine the change of water relaxation in samples. Fig. 3.8 shows the relaxation times (T_2) of bean dregs with rehydrating bean dregs after different processing treatments. The whole and segmented relaxation times are summarized in Table 3.4. In the relaxation time range of 0.01–10000 ms, all of the bean dregs showed four peaks of T_{21}, T_{22}, T_{23} and T_{24} appear from left to right, respectively. T_{21} and T_{22} represent the bound water, including the constitution water, the water in the interspace area of the molecules, and the water combined with polar group of some molecules in bean dregs through hydrogen bonds; T_{23} represents the water that did not easily flow, including water that was distributed outside the monolayer of water molecules which were bound to ions or ionic groups; T_{24} represents free water (Jiang et al., 2021).

As shown in Fig. 3.8 and Table 3.4 the T_{21} of bean dregs treated with HP, M, HTC, and U-HP moved to the left, indicating that this part of the water was more tightly bound with other molecules. In addition, the peak area of the bean dregs treated with HP and HTC increased slightly, indicating that the amount of bound water increased. The T_{22} of all treated bean dregs moved toward the right compared with the control, indicating that the mobility of this bound water was enhanced. The T_{23} and T_{24} of the U-HP samples were both shifted to the left, indicating the reduced fluidity of these two fractions of water. Compared with the control, the binding degree of the bean dregs treated with U treatment to the nonflowing water (T_{23}) was not changed, but there was a great change compared with other treatments. The spatial structure of macromolecules such as protein affected the degree of nonflowing water (T_{23}) (Sanchez-Alonso, Moreno & Careche, 2014). The T_{24} of bean dregs treated by U, M, HTC and U-HTC treatments had no difference and shifted to the right, while T_{24} of bean dregs treated by HP and U-HP treatments shifted to the left. The influencing the mobility of free water might be related to the size of the interstitial space between macromolecules. The mobility of free water of the bean dregs treated by HP and U-HP enhanced due to the smaller interstitial space. The T_{23} and T_{24} of bean dregs treated by U-HP treatment were the lowest, indicating that the degree of freedom of water decreased.

A_{21}, A_{22}, A_{23} and A_{24} represents the proportion of water in different states to the total water content of the sample. The proportion of A_{21} in bean dregs treated with HP and HTC slightly increased and the proportion of bound water (A_{21}+A_{22}) in bean dregs after different treatments increased compared with the control. The proportions of A_{22} in the bean dregs by combination treatment were higher than those in single treatment samples and the control. Moreover, the proportions of immobile water (A_{23}) in the samples by combination treatments were lower than those in the single treatment samples and the control. However, the proportions of free water (A_{24}) in the samples by the combination treatment were higher than those in the single treatment samples and the control. The main reason that affects the restraint degree of the combination water is the hydrogen bonding between the hydrophilic groups in the bean dregs and the hydrogen protons in the water molecules (Yang et al., 2015). It is speculated that different experimental parameters could alter the physical structure of fibers, thus resulting in great changes in their hydration properties (Sangnark & Noomhorm, 2003; Zhu et al., 2010). In addition, the free water content (A_{24}) is positively correlated with the water content (W %) of dried bean dregs.

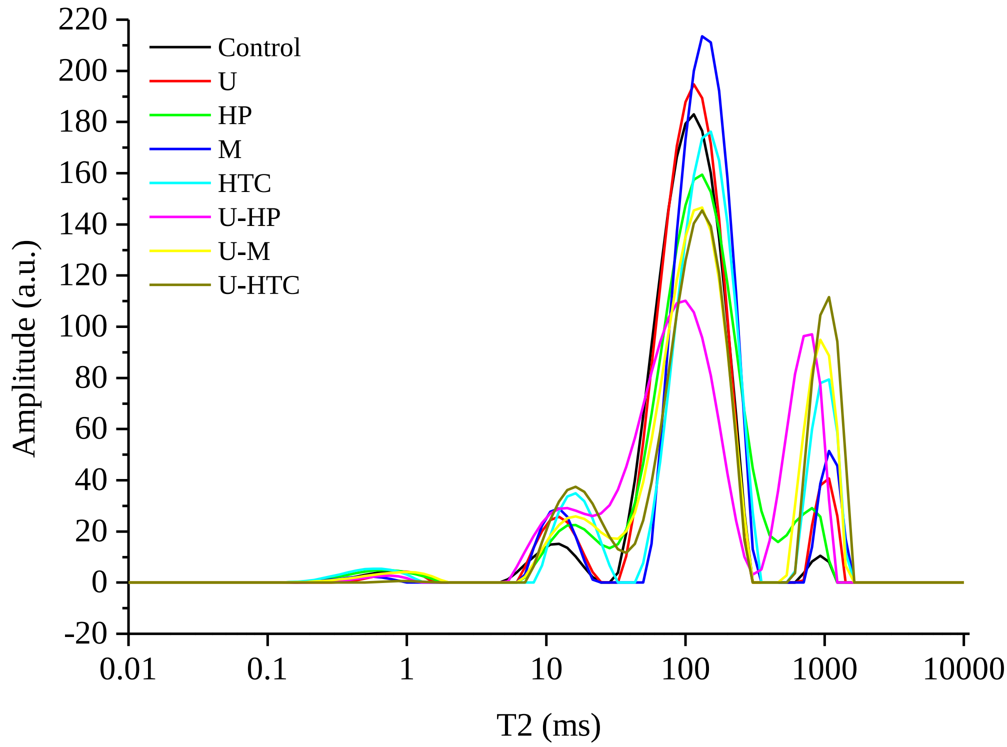

Figure 3.8 - The water distribution in the bean dregs by different physical technology

Table 3.5 - The relaxation time (T_2) and peak ratio (A_2) of bean dregs with different physical treatments determined by LF-NMR

Physical technology	T_2, (ms)				A_2, (%)				W, (%)
	T_{21}	T_{22}	T_{23}	T_{24}	A_{21}	A_{22}	A_{23}	A_{24}	
Control	0.87	12.328	114.976	932.603	2.136	5.263	90.947	1.654	2.91
U	1	12.328	114.976	1072.267	1.389	7.423	84.724	6.464	2.65
HP	0.658	16.298	132.194	811.131	2.425	8.403	82.523	6.65	3.54
M	0.498	12.328	132.194	1072.267	0.908	7.574	83.057	8.461	3.50
HTC	0.572	16.298	151.991	1072.267	2.435	10.12	71.059	16.386	3.00
U- HP	0.756	14.175	100	811.131	0.946	11.698	61.436	25.92	4.33
U- M	1	16.298	132.194	932.603	1.996	10.979	65.455	21.57	4.06
U- HTC	1	16.298	132.194	1072.267	0.168	14.777	60.017	25.039	4.35

T_{21}, T_{22}, T_{23} and T_{24} are the peak relaxation time of four peaks from left to right respectively. A_{21}, A_{22}, A_{23} and A_{24} are the peak areas of the corresponding four peaks respectively; W (%), Moisture content in dried soybean dregs; Peak area (A_2) represents the water content at the corresponding relaxation time; Total area represents total water content.

3.11. The effect of different treatments on the viscosity of bean dreg slurry

The viscosity of bean dreg slurry is an important index to assay its rheological properties, which represent the frictional resistance generated by the relative movement between the molecules in the slurry. The effect of the viscosity of bean dregs is mainly concentrated in the intestine of human. High viscosity of soybean dregs influences fecal formation. It becomes more gel-like, and gels are evidenced to provide lubrication to stool (Lyu et al., 2021). The slurry viscosities of bean dregs under different treatments are shown in Fig. 3.9. For single treatments, the U, HP and

HTC treatments reduced the viscosity of bean dregs compared with the control, but the M treatment enhanced the viscosity of bean dregs. There was no difference between the combination treatments, and the viscosity of bean dregs by U-HP, U-M, and U-HTC treatments was obviously lower than that of the single treatments. These results were not completely consistent with the report of Fayaz et al. (2019). They found soybean okara treated by high-pressure homogenization (HPH) 5 times at 150 MPa and revealed an apparent viscosity approximately 3 times higher than that of the sample treated at 100 MPa. It has been reported that the viscosity of okara cellulose increased when treated by chemical methods and high-pressure homogenization. Perhaps because many small fibers in the suspension effectively disrupt the flow (Wu et al., 2021).

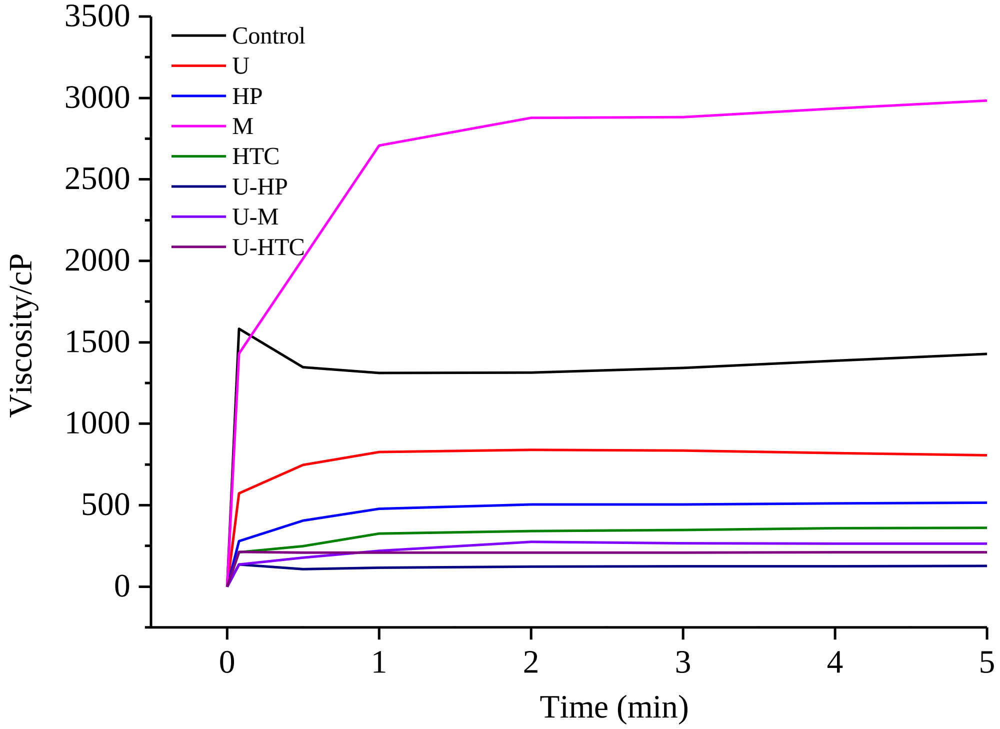

Figure 3.9 - The effect of physical technology on viscosity of bean dregs slurry

3.12. The effect of different treatments on the stability of bean dreg slurry

The bean dreg slurries were placed at room temperature and the changes were observed at different times. The results were shown in Fig. 3.10. The slurry of bean dreg by different treatments appeared faint yellow and creamy, and there was obvious stratification after standing for 0.5 h. However, the supernatant volume of bean dregs with different treatments was obviously different (Fig. 3.10a), and the supernatant became clearer after 8 h (Fig. 3.10b). The difference in supernatant volume may be related to the solubility, swelling properties or particle size distribution of bean dregs because the bean dregs were modified after different treatments. The supernatant volume of the control (Tube 1, Fig. 3.10b) was the smallest. It might be due to that there were fewer soluble components in fresh bean dregs with larger particle sizes, and more voids in bean dreg slurry, resulting in a larger precipitation volume. The supernatant volume of bean dregs treated with different treatments was higher than that of the control samples. In addition, the supernatant volumes of bean dregs by single treatments were lower than those of the combined treatments. The supernatant volume of bean dregs in the U treatment (Tube 2, Fig. 3.10b) was the smallest, while the supernatant volume of bean dregs in the U-HP treatment (Tube 6, Fig. 3.10b) was the largest.

After standing for 24 h, the precipitation volume in tube 1 and tube 2 increased, which may be caused by microbial fermentation, and tube 2 was obviously porous, while the supernatant volume of other tubes changed little (Fig. 3.10c). After standing for 48 h and 72 h, microbial infection occurred in tubes 4, 5 and 8, and the supernatant volume decreased or disappeared (Fig. 3.10d and e). The bean dregs under HP (Tube 3) and U-HP treatment (Tube 6) were the most stable, with little change in supernatant volume after 72 h (Fig. 3.10e). This is consistent with the report of Xie et al. (2017), who reported that high hydrostatic pressure (HHP) and high-pressure homogenization (HPH) treatments decreased the water holding capacity of dietary fibers, but increased emulsion activity and stability in a manner that could be useful in the food industry to prolong the shelf life of foods. After standing for a week, there was an odor in every tube, indicating that each tube was corrupted (Fig. 3.10f).

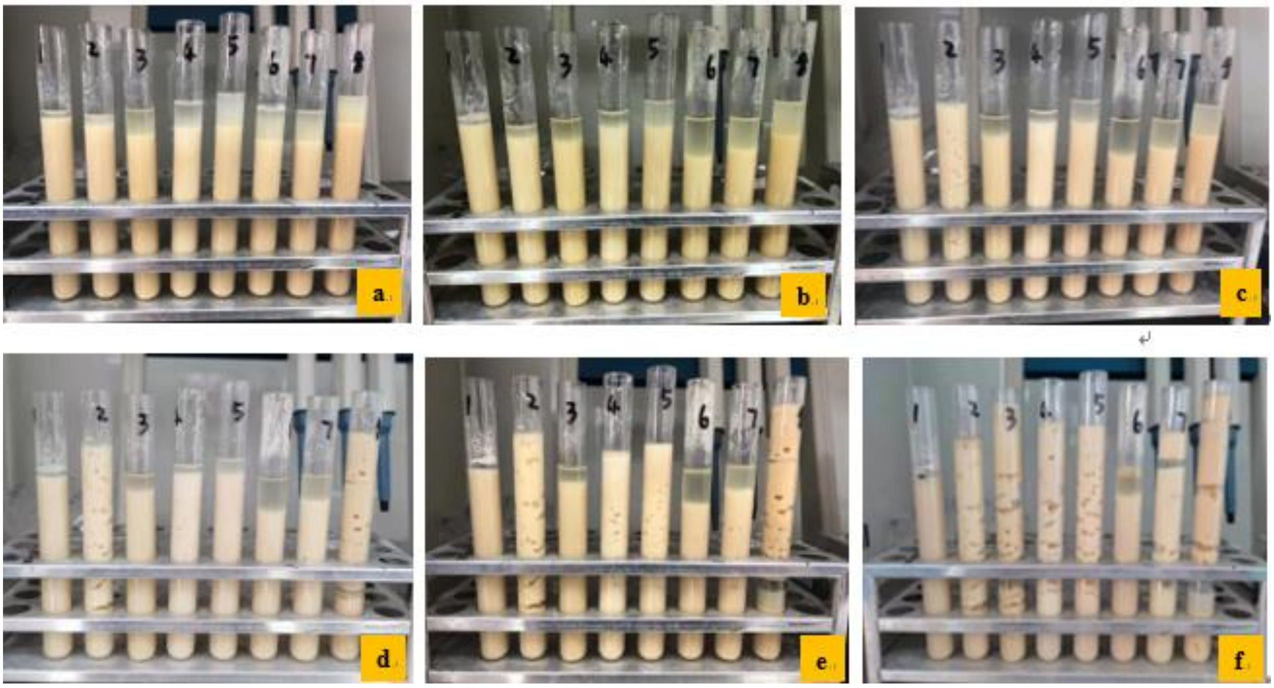

Figure 3.10 - The effect of different treatments on the stability of bean dregs slurry a: 0.5 h; b: 8 h; c: 24 h; d: 48 h; e: 72 h; f: one week. The number of test tube represents: Tube 1 (control bean dregs); Tube 2 (ultrafine grinding); Tube 3 (high pressure); Tube 4 (microwave); Tube 5 (high temperature cooking); Tube 6 (ultrafine grinding-high pressure); Tube 7 (ultrafine grinding -microwave); Tube 8 (ultrafine grinding- high temperature cooking)

3.13. Effect of different treatments on the rheological properties of bean dreg slurry

The dynamic rheology parameters, storage modulus (G′) and loss modulus (G″), reflected the viscoelastic behavior of the sample in a dynamic force field. Fig.3. 11. showed the variation curves of the G′, G″ and tan δ values with the angular frequency of aqueous suspension bean dregs under different treatments. All of the bean dreg slurries exhibited higher values of G′ than those of G″, showing more elastic characteristics. The G′ and G″ of bean dreg slurry significantly decreased after different treatments compared with the control, and the highest values of G′ and G″ were shown in the sample by M treatment. The lowest viscoelastic values were found in the U-HP treatment. These rheological patterns were in great agreement with the viscosity results (as shown in Fig. 3.11). In comparison, the G′ and G″ of the bean dregs treated with U and HP were lower than those of M and control samples, and higher than those of the samples by HTC and all combined treatments. However, except the M treatment, HTC and all the combined treatments (U-HP, UM and U-HTC) were at a lower level, and the change trend of the loss factor (tan δ) and G″ have the same trend. The G′ of all samples showed a gradually increasing trend, while the G″ of all samples showed a gradually decreasing trend.

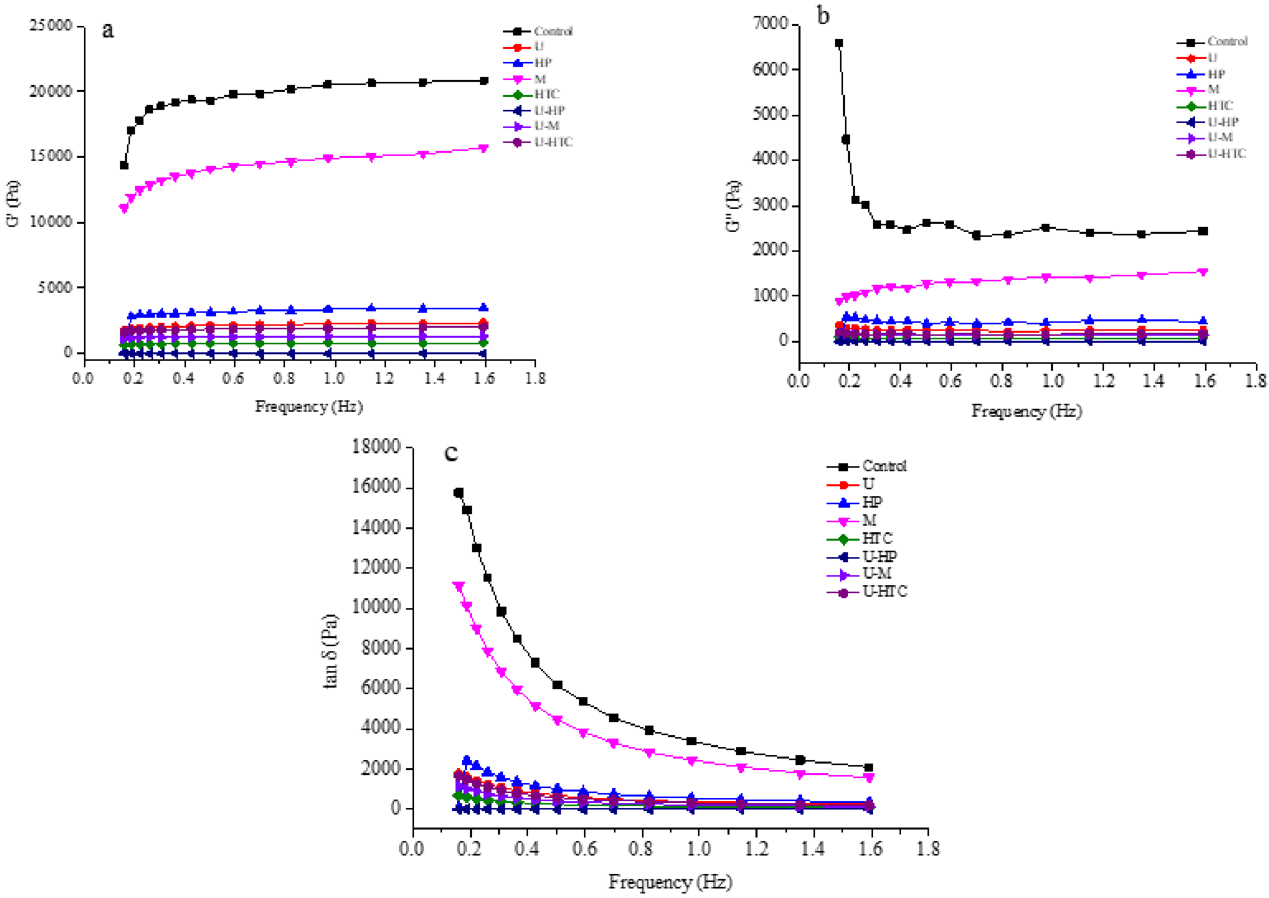

Figure 3.11 - The effect of different treatments on rheological properties of bean dregs slurry

Cespi et al. (2011) and Yang, Liu, Li and Tang, (2019) reported that the elastic properties of cellulose suspensions determined their viscosity. Our results demonstrated this correlation, and the combination treatments reduced the viscous and elastic properties of bean dreg suspensions. However, Ma et al. (2019) found that an increase in the number of small fibers after chemical and/or mechanical treatment would increase the viscous (liquid) and elastic (solid) properties (Ma et al., 2019). In our study, it was found that the combined treatment could reduce the granularity of bean dreg fiber, but its viscosity and elasticity did not increase. Furthermore, an increase in the collision force between particles may also lead to an increase in G'. In addition, the content of dietary fiber in different treated bean dregs was different, and its water absorption and swelling properties were different. The enhancement of molecular fluidity can easily lead to a decrease in G".

3.14. Changes in the chrominance and whiteness index of bean dregs after different physical technology treatments

Chrominance is one of the main factors influencing food quality, which is an important trait that strongly influences consumer acceptance of end products (Hu, Wang, Zhu and Li, 2017). Table 3.6 listed the chrominance parameters of bean dregs treated by different physical technologies. The bean dregs treated by thermal treatments (M, HTC, U-M, and U-HTC) had lower values of *L**, with dark color and broiled fragrance. There were no significant differences in the *L** parameters of the U, HP and U-HP groups. Que et al. (2008) reported that hot-drying pumpkin reduced light color, as indicated by lower L-values than freeze-drying (Que, Mao, Fang & Wu, 2008). Guimares et al. (2020) reported that forced-air oven drying (FAD) okara reduced light color, as indicated by lower L-values than microwave drying (MWD) and freeze-drying (FRD), indicating that great browning occurred during heating. Meanwhile, the low drying temperature did not change the *L**, *a**, and *b** parameters.

Significant differences in the *a** and *b** parameters were observed between the control and treated samples. Except for the U-HP treatment, the *a** and *b** values of the other treatments were significantly greater than those of the control group. These changes in the color parameters may be related to the Maillard reaction, which is a temperature dependent nonenzymatic reaction between reducing sugars and the amino groups of amino acids or proteins, resulting in the formation of brown pigments (melanoidins) (Muliterno et al., 2017).

The HP, M, HTC and U-HTC treatments resulted in higher values in the ΔE (total color difference) of the samples. The whiteness index (WI) was also significantly affected by different physical treatments. These results demonstrated that different physical treatments had definite effects on the chrominance of bean dregs.

Table 3.6 - Effect of different physical treatments on chrominance and whiteness index of bean dregs

physical treatments	*L**	*a**	*b**	ΔE	WI
Control	87.62± 1.55a	0.46± 0.17e	16.36± 16.36e	-	79.47± 2.10a
U	78.44± 2.14b	1.61± 0.14cd	20.65± 20.65c	9.76± 1.12cd	70.07± 1.37c
HP	78.81± 2.15b	2.27± 0.18b	27.25± 27.25a	10.41± 3.33bc	65.38± 1.31de
M	74.50± 3.28cd	1.63± 0.28cd	20.46± 20.46c	15.44± 1.47bc	67.24± 2.97cd
HTC	74.05± 2.83d	2.05± 0.70bc	22.32± 22.32b	16.20± 1.11b	65.69± 2.95de
U-HP	81.26± 2.21b	0.43± 0.04e	17.77± 17.77d	2.56± 3.75d	74.15± 1.90b
U-M	78.02± 0.85bc	1.37± 0.20d	20.07± 20.07c	8.98± 1.30cd	70.20± 0.98c
U-HTC	70.12± 0.69e	3.14± 0.27a	22.71± 22.71b	16.54± 2.10a	62.33± 0.56e

Conclusions in Section 3

1. Suitable U, HP, M and HTC treatments could significantly improve the SDF content of bean dregs. The combined method had greater effects than single treatment in improving the SDF content of bean dregs. However, the U-HP treatment showed the greatest reduction in protein. The mineral content in bean dregs increased after proper physical treatment. U-HTC treatment significantly decrease the TIA from 7365 TIU/g to 96 TIU/g compared with that of control. The particle size and morphological structure of bean dregs by different treatments changed greatly. The

combined treatment obviously improved the water solubility and cationic absorption capacity of bean dregs. In short, combination technologies (U-HP, U-M and U-HTC) were effective methods to improve the quality of bean dregs, increase the SDF, form honeycomb porous texture, reduce anti-nutritional factors and improve some processing performances.

2. Bean dregs were modified by different physical methods and showed different water distribution. Comparatively speaking, bean dregs had higher water binding capacity after combined treatments modification. M treatment significantly increased the viscosity of bean dregs. The viscosity and G′, G″ and tan δ of bean dregs by combined treatments showed lower levels, however, combined treatments plays a positive effect in improving the stability of bean dreg slurry. Additionally, HP, M, HTC and U-HTC treatments resulted in great changes in the chrominance and whiteness index of the sample. Therefore, physical modification will broaden the application of bean dregs in food and feed to a certain extent, and combined treatment is the preferred method.

SECTION 4

EFFECT OF BEAN DREGS POWDER TREATED BY U-M ON DOUGH PROPERTIES AND QUALITY OF CRISP BISCUITS

4.1 Crisp dough characteristics

Pasting properties.

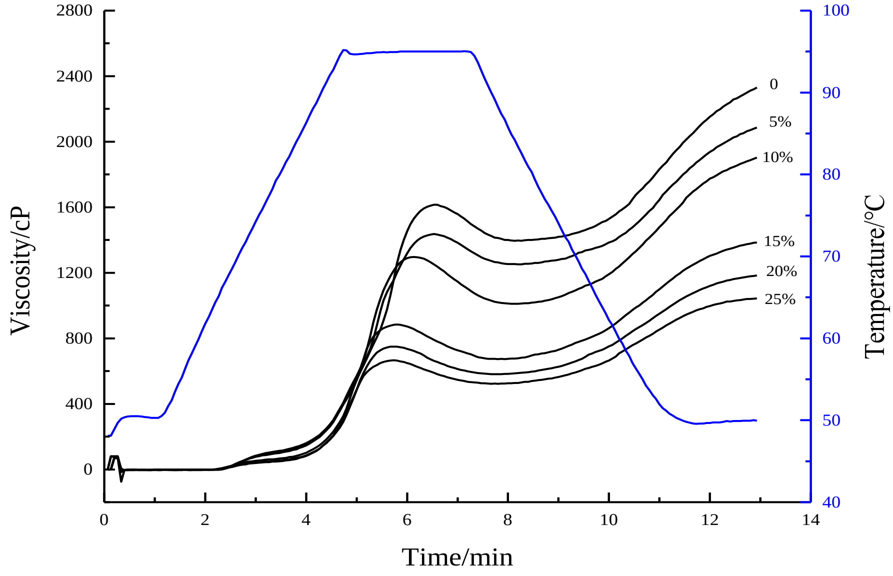

Fig. 4.1. Pasting curve with different amount of bean dregs powder

Table 4.1 - Effects of adding amount of bean dregs powder on viscosity properties of flour-bean dregs mixture

Bean dregs (%)	Peak Visc (cP)	Trough Visc (cP)	Breakdown (cP)	Final Visc (cP)	Setback (cP)
0	1618±4a	1403±10a	215±6b	2346±21a	943±11a
5	1448±17b	1250±3b	198±20bc	2101±21b	851±24b
10	1293±5c	1007±4c	286±1a	1895±11c	888±7b
15	881±5d	674±1d	207±6bc	1382±5d	708±6c
20	768±25e	587±8e	182±18c	1201±23e	614±16d
25	675±12f	532±13f	143±1d	1062±25f	530±13e

The values are mean plus/minus standard error (n = 3). Different letters in the same column indicate significant difference ($P < 0.05$).

The effects of bean dregs powder on pasting properties. As can be seen from Fig. 4.1 and Table 4.1, the gelatinization properties of the bean dregs mixture changed greatly. With the increase of bean dregs addition, gelatinization characteristics showed a significant downward ($p < 0.05$) (Table 4.1). The peak viscosity decreased by 58.28%, the trough viscosity decreased by 62.10%, and the final viscosity decreased by 54.73% compared with the control group. The breakdown value of bean dregs increased first and then decreased. The maximum value was 286 cP when the amount of bean dregs was 10%. When the bean dregs content is added to 25%, the breakdown value is 143 cP, which indicated that the stability of the paste enhanced with the increased of the bean dregs. The setback value of bean dregs showed a downward trend, from 943 cP to 530 cP, decreased by 43.80% ($P<0.05$) compared with the control group. From the point of view of setback, if the setback is higher, the biscuit will be harder and taste worse. The experimental results show that the addition of bean dregs powder can effectively improve the gelatinizing characteristics of flour and increase the crispness of biscuits. The determination results the trend of this index showed a consistent trend with that of hard biscuits. Therefore, the reasons and conclusions described are not repeated here. The difference between the two recipes comes from the protein content of the flour. In this chapter, the low-gluten flour was used. At the same amount of bean dregs powder (0%, 5%, 10%), except for the trough viscosity, the peak viscosity, breakdown value, final viscosity and setback were all lower than the gelatinization characteristics of the flour used in hardness biscuit.

Texture analysis.

Measurement of crisp biscuits dough texture in the texture analyzer showed that the hardness value increased when bean dregs content in the biscuit formulation was increased. The hardness was 5019.95±114.01 g when the bean dregs addition level of 15%, which was 54.78% higher than the control. However, above 20% of the bean dregs the dough hardness decreases. Sudha et al. (2007) reported that fat coats the surface of the flour particles inhibiting the development of the gluten proteins.

The free fat therefore disrupts the gluten network resulting in softer doughs (Menjivar & Faridi, 1994). However, the addition of the bean dregs will neutralize the texture of the dough, and the butter and flour mixture will be diluted, in the absence of sufficient fat, would therefore result in dough hardness (O'Brien et al., 2003).

Table 4.2 - Effect of bean dregs powder on texture of crisp dough

Bean dregs (%)	Hardness, N	Cohesiveness	Gumminess	Chewiness	Springiness	Resilience
0	2270.68± 234.87c	0.13± 0.01a	302.46± 64.59c	23.64± 3.45b	0.08± 0.01a	0.03± 0.00a
5	3397.75± 262.6b	0.12± 0.00ab	401.91± 40.93bc	31.09± 2.29ab	0.08± 0.00a	0.03± 0.00a
10	4741.6± 181.25a	0.11± 0.01b	512.82± 59.99ab	48.50± 6.72a	0.08± 0.00a	0.03± 0.00a
15	5019.95± 114.01a	0.13± 0.01ab	626.36± 29.04a	47.66± 5.77a	0.08± 0.01a	0.04± 0.00b
20	3781.45± 235.17b	0.12± 0.00ab	446.96± 46.15b	41.83± 15.85ab	0.09± 0.03a	0.03± 0.00a
25	3744.64±191.79b	0.11± 0.00ab	427.46± 34.18bc	32.01± 3.88ab	0.08± 0.00a	0.03± 0.00a

The values are mean plus/minus standard error (n = 3). Different letters in the same column indicate significant difference ($P < 0.05$).

From Table 4.2 the gumminess values of the doughs with bean dregs were significantly higher than that of the control and significantly ($P < 0.05$), and the chewiness was positively correlated with hardness and gumminess. The chewiness was 48.50±6.72 when the bean dregs addition level of 10%, which was 51.26% higher than the control. Springiness is the height or volume ratio of the deformed sample to the condition before the deformation after removing the deformation force. For the resilience and springiness of the crisp dough, no significant (P > 0.05) changes were observed after the addition of bean dregs. This may be due to butter's hydrophobicity prevents the proteins in the flour from absorbing water and expanding, controlling the formation of gluten, which reduces the cohesion of the dough and makes the cookie dough soft and malleable.

4.2 Color analysis of crisp dough and biscuit

Table 4.3 - Effects of bean dregs powder on the color of crisp biscuits and dough

Bean dregs (%)	Crisp dough			Crisp biscuit		
	*L**	*a**	*b**	*L**	*a**	*b**
0	66.33± 0.40a	0.70± 0.18f	33.82± 0.25a	75.59± 0.74a	1.00± 0.10f	34.14± 0.26c
5	64.81± 0.98b	0.44± 0.07e	34.08± 0.40a	74.31± 0.26a	1.01± 0.07e	36.17± 0.13a
10	63.48± 0.22bc	1.16± 0.08d	33.77± 0.42a	72.30± 1.06b	1.78± 0.19d	34.67± 0.44bc
15	63.54± 0.44bc	1.79± 0.02c	34.18± 0.63a	70.59± 1.11c	2.93± 0.38c	34.86± 0.34b
20	64.62± 0.02b	2.52± 0.06b	34.72± 0.49ab	70.57± 0.30c	3.83± 0.14b	34.14± 0.22c
25	66.25± 0.40a	2.88± 0.08a	34.77± 0.64a	69.70± 0.69c	4.17± 0.06a	34.28± 0.33c

The values are mean plus/minus standard error (n = 3). Different letters in the same column indicate significant difference (P < 0.05).

Table 4.3 shows the results of the study of crisp dough and biscuit color. On the whole, the *L** and *a** values color of the crisp dough and biscuit vary widely. However, *b** values had no obvious trend of change. The color trend of dough is similar to that of biscuits. As a whole, the biscuit has a higher *L** and *a**values than the dough, except for the *b** values. This result is consistent with the color trend of hard dough and biscuits.

The low brightness of the pastry comes down to the raw materials. On the one hand, modified bean dregs powder, on the other hand, butter. The modified bean dregs powder has a certain color, and the brightness of dough decreases with the increase of bean dregs. The addition of a lot of butter in the dough will change the color of the dough and make it look golden. The redness of baked biscuits is increased due to the effect of sugar, and the biscuits are brighter than unbaked color.

With the increase of the amount of bean dregs decreased *L** and increased *a** crisp biscuits values, indicating more dark and yellowish, *b** values decreased added bean dregs at 5-25%. Concerning the crisp biscuits color, it became darker (lower *L**), more reddish (higher *a** values), and less yellowish (lower *b** values) when bean dregs was added at 15-25%. The crust of the crisp biscuits was caramelized by Maillard and sugar during baking and was responsible for the final color of the crust. The Maillard reaction involves complex sequence of reactions, including condensation, cyclization, dehydration, rearrangement, isomerization, and polymerization. Thus, these changes in the color parameters may be related to the Maillard reaction, which is a temperature-dependent nonenzymatic reaction between reducing sugars and the amino groups of amino acids or proteins, resulting in the formation of brown pigments (melanoidins) (Muliterno et al., 2017).

Data reported as mean± standard deviation (SD) of 3 determinations. Values followed by different lower-case letters in the same column are significantly different from each other ($p \leq 0.05$).

Biscuit texture is an important index to evaluate the biscuits quality, lower in hardness and chewiness of biscuit indicated less work to be consumed when chewing (Yang et al., 2019). However, biscuits with a certain hardness require more saliva when chewing, taste better and also aging rate can be delayed. The effect of different contents of bean dregs on biscuit texture are presented in Table 4.4. Hardness of the bean dregs crisp biscuits significantly higher than the control ($p<0.05$). When the bean dregs were added at 15%, the hardness reached the maximum of 2328.49 (N). This may be the content of bean dregs increased, more fiber was able to absorb water or oil of dough, and filled in the gluten network and led to the increase of dough hardness (Yang et al., 2019). In addition, above 20% biscuits was decreased to hardness and became very dark with bean flavor. At higher content of bean dregs (10-20%), Gumminess and Chewiness of the biscuit were increased higher than the control. Similar results were also reported in the evaluation of banana powder on biscuit texture (Li et al., 2015). Bean dregs content showed great correlation with the cohesiveness and gumminess properties of crisp biscuits.

4.3 Crispy biscuits properties

Analysis of texture of crisp biscuits.

Table 4.4 - Effect of different amount of bean dregs texture of crisp biscuits

Bean dregs (%)	Hardness, N	Cohesiveness	Gumminess	Chewiness
0	926.62±83.66d	0.04±0.00a	34.78±2.77ab	13.87±1.03a
5	1266.18±38.32cd	0.04±0.03a	55.15±40.59ab	12.28±3.02a
10	1920.73±206.13b	0.05±0.01a	90.74±18.01a	29.24±11.80a
15	2328.49±19.10a	0.04±0.01a	84.61±22.92a	27.70±16.38a
20	1513.89±175.01c	0.03±0.00a	46.15±0.65ab	20.84±4.06a
25	1469.12±106.69c	0.01±0.00a	14.57±489b	5.58±3.10a

Scanning electron microscopy (SEM).

As can be seen from Figure 4.2(a-f) With the increase of the proportion of bean dregs powder, the internal structure of the biscuit changes greatly, the gap gradually becomes larger, and the surface becomes rough from fine. The proportion of low gluten flour decreased with the increase of bean dregs, while the ability of bean dregs to absorb oil and water was better than that of flour. The more bean dregs were added, the more difficult it was to form smooth dough with plasticity, thus affecting the dough shape and texture.

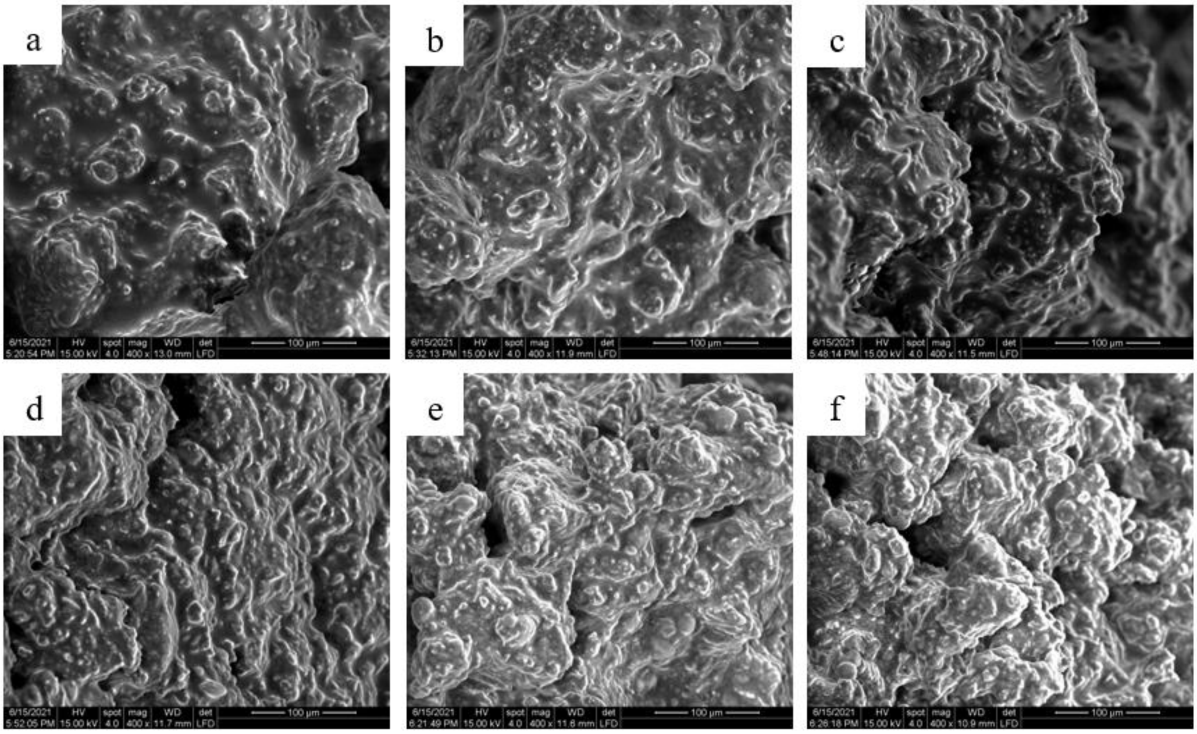

Figure 4.2 - Scanning electron micrographs of bean dregs crisp biscuit
(a-f: 0, 5%, 10%, 15%, 20%, 25%)

As can be seen from Figure 4.2(a-d). when the amount of bean dregs powder reaches 15%, the internal structure of biscuits is relatively smooth, enough to add 15% bean dregs without affecting the dough forming. When bean dregs powder was added to 20%, a small gap appears, but it hardly affects the shape of the cookie dough. When bean dregs powder is added to 25%, the butter in the dough is unable to coat the starch particles, gluten proteins and fibers present in the flour, affecting the quality of the crisp biscuits.

This indicates that the addition of bean dress powder in a certain proportion can improve the structure of biscuits and increase the crispness of biscuits, when the amount of bean dress powder is too large, it may change the rheology dough and affect the quality of crisp biscuits. At very high fat content the lubricating function is high thus less water is required and a softer texture is obtained (Deep Narayan, Neharika & Kappat Valiyapeediyekkal, 2012).

Subjective (sensory) evaluation of crisp biscuits.

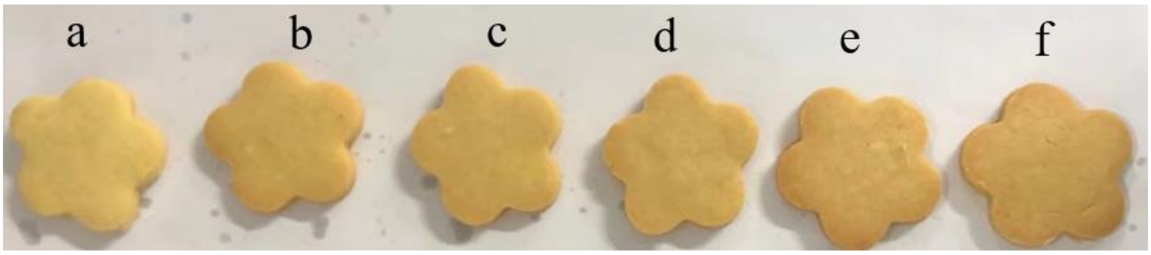

Figure - 4.3 - Hard biscuits with different amount of bean dregs

(a-f: 0, 5%, 10%, 15%, 20%, 25%)

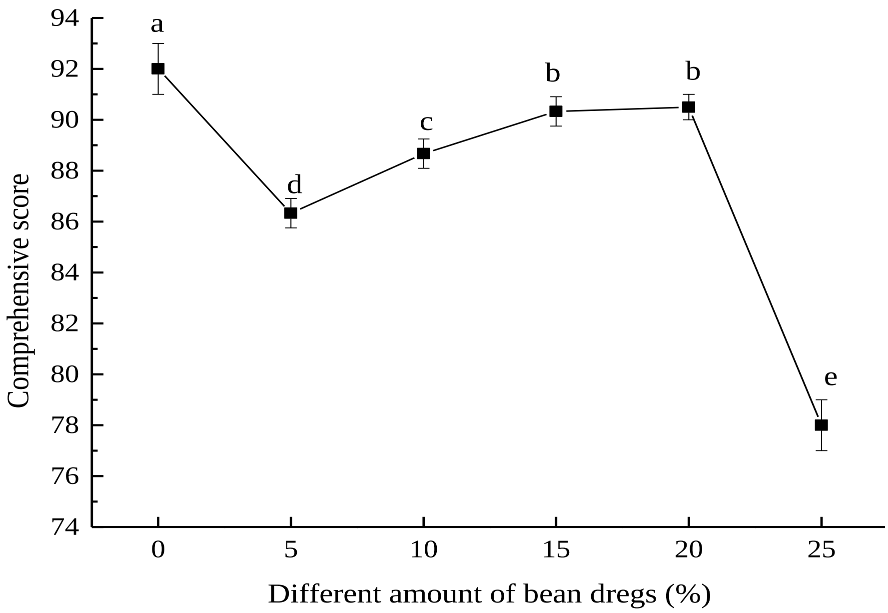

Figure 4.4 - The comprehensive score of crisp biscuits

Different letters on the top of a column indicated significant differences ($p < 0.05$).

The mean scores for overall acceptability of biscuits were presented in Fig. 4.3 and Fig. 4.4. A two-way analysis of variance indicated that these sensory attributes of the crisp biscuits were significantly affected ($p < 0.05$) by addition of different levels of bean dregs powder in biscuit formulations. As shown in Fig. 4.3 and Fig. 4.4 overall acceptability of the control crisp biscuits was the highest and it was significantly better than added bean dregs. Biscuits containing bean dregs (even up to 20% level of substitution) had superior scores, overall acceptability of biscuits were judged to be very good. And there was no significant difference between at 15%. Biscuits with higher bean dregs levels (25%) had the typical beany flavor, the scores of biscuits were affected adversely. Similarly, the color of biscuits became darker gradually with increasing levels of bean dregs. Therefore, among the processed crisp biscuits, 15% and 20% bean dregs containing biscuits was the most preferred one than the biscuits containing 5%, 10% and 25 % bean dregs respectively. The results of sensory evaluation indicated that the of wheat flour up to 20% substitution level with bean dregs was possible without adversely affecting the consumer acceptability of biscuits. Similar results were also reported in the evaluation of composite flours on Sensory characteristics of biscuits (Singh, Bajaj, Kaur, Sharma & Sidhu, 1993).

4.4 Single factor test results and analysis of bean dregs crisp biscuits

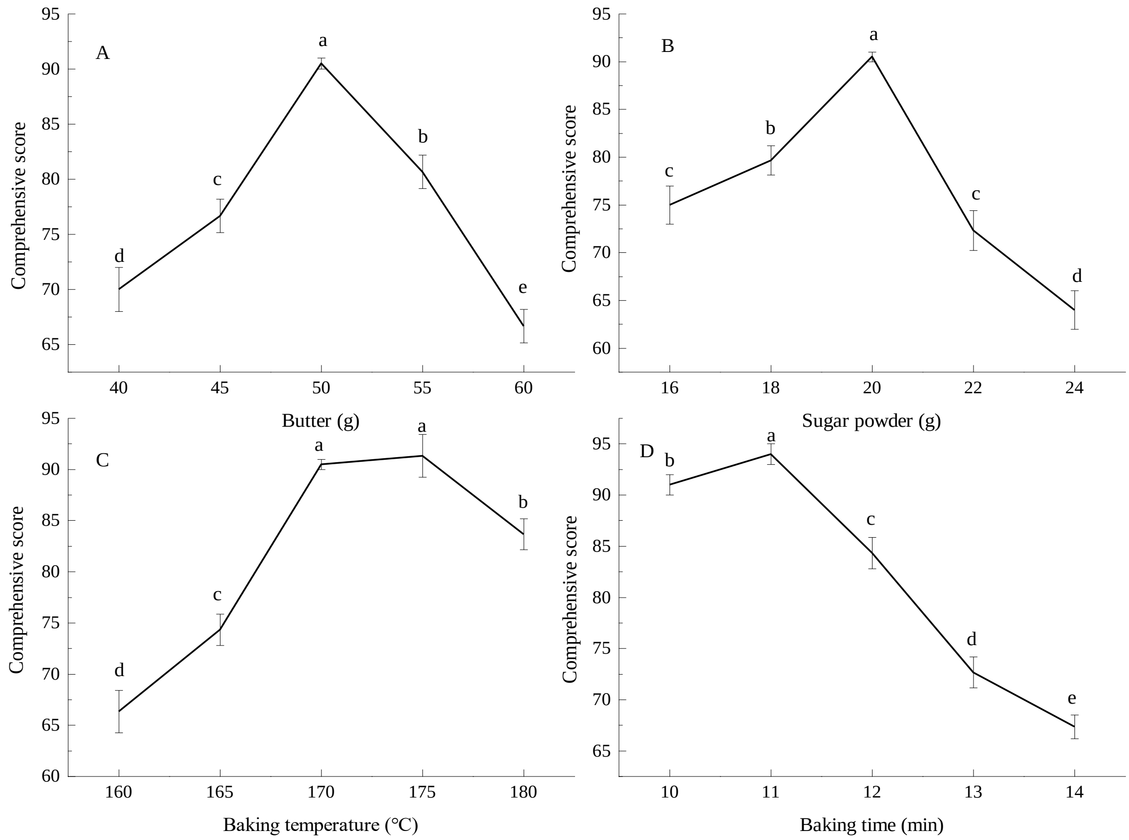

Figure 4.5 – The effect of different factors on bean dregs crisp biscuits

Different letters on the top of a column indicated significant differences ($p < 0.05$).

As shown in Fig. 4.5A the sensory score first increased and then decreased with the increase of butter content. When butter is used less than 50 g, the texture of the dough is dry and hard, and the grease and flour cannot fully bond to each other to form a smooth dough, thus making the biscuit products taste rough. When more than 50 g of butter, the butter flavor is more intense and the dough is soft and fluid, but the cookies tend to lose their shape during baking. Therefore, at 50 g butter, the dough was moderately stiff, and the bean crackers were crisp and flavorful, scoring highest on the sensory scale.

As shown in Fig. 4.5B the sensory score increased gradually with the increase of powdered sugar. When the amount of powdered sugar used is less than 20 g, the sweetness is weaker and the butter taste is more intense. When it is higher than 20 g, the sweet taste of biscuits is bigger and the finished product is darker, which affects the quality of biscuits. When the amount of powdered sugar was 20 g, the sweetness of biscuits was appropriate, which gave biscuits better taste and the highest sensory score.

As shown in Fig. 4.5C, the sensory score increased gradually with the increase of baking temperature. The sensory score is higher When baking temperature is between 170 ℃-175 ℃, the biscuit is golden in color, aroma filling nose. When the baking temperature is below 165 ℃, the color of the biscuit is shallow, and there are sticky teeth in the biscuits center. When the baking temperature is higher than 175℃, the color of the product is not uniform, and the edge of the biscuits is blackened.

As shown in Fig. 4.5D, when baked for 10-11 min, it can give the cookies even color and crisp texture, and has a high sensory score. When the baking time is more than 11 min, the sensory score decreases significantly, the surface color of the biscuit becomes darker, the texture of the biscuit is firm and easy to slag, and the taste becomes worse and worse.

4.5 Orthogonal test results and analysis of bean dregs crisp biscuits

Figure 4.6 - Orthogonal test diagram of bean dregs crisp biscuits

The overall acceptability was mainly based on hardness, mouthfeel and taste of the biscuit. Through single factor test, the addition of butter, powdered sugar, baking temperature and time were determined as variables to carry out orthogonal test, and the test results are shown in Fig. 4.6 and Table 4.5.

It can be seen from the analysis of orthogonal test results in Table 4.5. The primary and secondary relationship of sensory evaluation score was B>D>A>C, the best formula of bean dregs crisp biscuits $A_2B_2C_3D_1$ was obtained. The primary and secondary relationship of texture (hardness) is A>B>D>C, the best formula of bean dregs crisp biscuits $A_1B_1C_2D_1$ was obtained. According to sensory evaluation score and hardness in Table 4.5 the best formula of bean dregs crisp biscuits $A_2B_2C_3D_1$ was obtained, and $A_1B_1C_2D_1$was scored lower than $A_2B_2C_3D_1$ in the sensory validation test. Therefore, the optimal formula of bean dregs crisp biscuits was obtained: 80 g low-gluten flour, 20 g bean dreg powder (after U-M treatment), 50 g butter, 20 g powdered sugar, 5g corn starch, 20 g egg yolks, 1 g salt, 0.75 g baking powder, and baked at 175 ℃ for 11 min. Sensory score of bean dregs crisp biscuits was 94 points, and hardness value was 1597.41 N.

Table 4.5 - Orthogonal test results and analysis of bean dregs hard biscuits

Serial number	Factors				Sensory evaluation score	Texture Hardness
	A Butter (g)	B Powdered sugar (g)	C Temperature (℃)	D Time (min)		
1	45	18	165	11	79	3239.67
2	45	20	170	12	81	2947.91
3	45	22	175	13	83	2195.66
4	50	18	170	13	77	1760.50
5	50	20	175	11	94	1597.41
6	50	22	165	12	85	1500.04
7	55	18	175	12	73	1216.28
8	55	20	165	13	82	790.46
9	55	22	170	11	84	1126.23
Sensory score						
K_1	243	229	246	257		
K_2	256	257	242	239		
K_3	239	252	250	242		
k_1	81.00	76.33	82.00	85.67		
k_2	85.33	85.67	80.67	79.67		
k_3	79.67	84.00	83.33	80.67		
R	5.66	9.34	2.66	6.00		
Order	B>D>A>C					
Optimal combination	A_2	B_2	C_3	D_1		
Texture hardness						
K_1	8383.24	6216.45	5530.17	5963.31		
K_2	4857.95	5335.78	5834.64	5664.23		
K_3	3132.97	4821.93	5009.35	4746.62		
k_1	2794.41	2072.15	1843.39	1987.77		
k_2	1619.32	1778.59	1944.88	1888.08		
k_3	1044.32	1607.31	1669.78	1582.21		
R	1750.09	464.84	275.10	405.56		
Order		A >B>D>C				
Optimal combination	A_1	B_1	C_2	D_1		

Conclusions in Section 4

The processed bean dreg powder was added to the crisp biscuit, and the dough and products were measured and analyzed, and the following conclusions were drawn:

1. The addition of bean dregs powder changed the gelatinization characteristics of flour, reduced the viscosity of batter and improved the stability of batter.

2. The addition of bean dregs changed the texture of crisp dough and biscuits. The hardness, gumminess and chewiness are positively correlated. The hardness increases to some extent, but the hardness decreased when the bean dregs powder was added more than 20%.

3. The color of the dough and the product have the same trend in the corresponding recipe. The addition of bean dregs powder reduced the $L*$ value of crisp dough and biscuits, while $a*$ value increased greatly, $b*$ value changed little.

4. According to the characteristics of dough and the sensory evaluation of crisp biscuits, the maximum amount of bean dregs was 20%, which gave the biscuits a better taste.

5. Through single factor and orthogonal test results the optimal formula of bean dregs crisp biscuits was obtained: 80 g low-gluten flour, 20 g bean dreg powder (after U-M treatment), 50 g butter, 20 g powdered sugar, 5g corn starch, 20 g egg yolks, 1 g salt, 0.75 g baking powder, and baked at 175 ℃ for 11 min. The bean dregs crisp biscuits prepared by this processing technology got the crispy taste, golden color, and good bean fragrance.

SECTION 5

EFFECT OF BEAN DREGS POWDER TREATED BY U-M ON DOUGH PROPERTIES AND QUALITY OF HARD BISCUITS

5.1 Hard dough characteristics

Pasting properties.

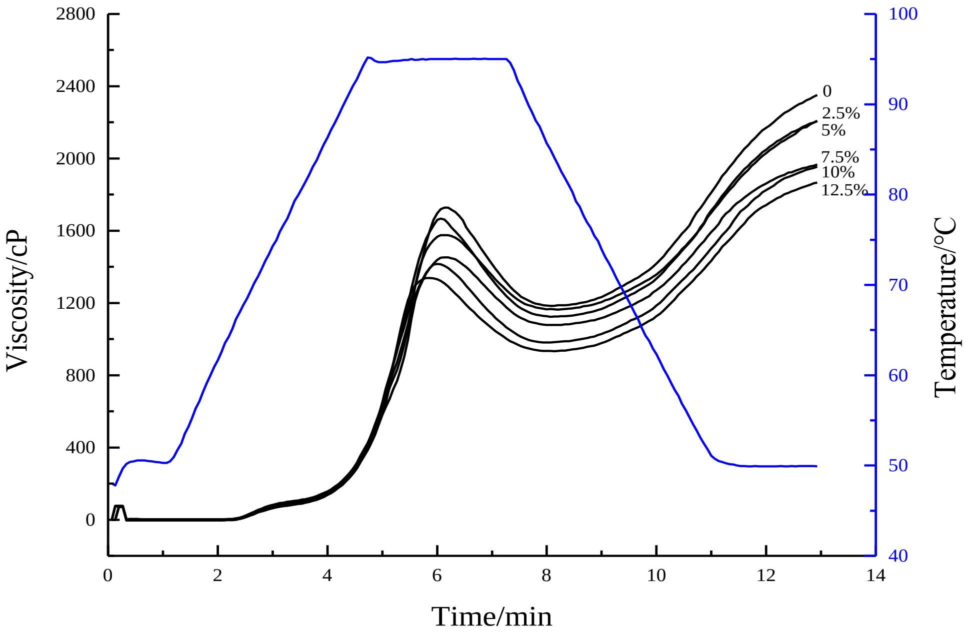

Figure 5.1 - Pasting curve with different amount of bean dregs powder

Table 5.1 - Effects of adding amount of bean dregs powder on viscosity properties of flour-bean dregs mixture

Bean dregs (%)	Peak Visc, (cP)	Trough Visc, (cP)	Breakdown, (cP)	Final Visc, (cP)	Setback, (cP)
0	1721±10a	1167±24a	554±14a	2325±38a	1158±14a
2.5	1665±3b	1114±15b	552±12a	2210±1b	1096±16ab
5	1566±14c	1153±16a	414±2bc	2184±32b	1031±16bc
7.5	1479±37d	1085±10b	394±27c	2019±75c	934±65d
10	1411±8e	983±3c	428±11b	1957±4cd	974±1cd
12.5	1336±4f	924±13d	412±9bc	1855±16d	931±3d

The values are mean plus/minus standard error (n = 3). Different letters in the same column indicate significant difference ($P < 0.05$).

The effects of bean dregs powder on pasting properties. As can be seen from Fig. 5.1 and Table 5.1 the gelatinization properties of the bean dregs mixture changed greatly. With the increase of bean dregs addition, gelatinization characteristics showed a significant downward ($p < 0.05$) (Table 5.1).

The peak viscosity decreased by 22.37%, the trough viscosity decreased by 20.82%, and the final viscosity decreased by 20.22% compared with the control group. The reason may be that bean dregs have strong water absorption capacity and compete with starch for more water, resulting in starch can't be fully gelatinized. In addition, there was a certain synergistic reaction between the bean dregs and starch, and the competition for water between bean dregs and starch, and limited the ability of the starch to absorb water and prevented the expansion of starch resulted in a lower peak viscosity of paste. Meng et al found the same changes in the konjac glucomannan (KGM)–wheat flour blends, high content (KGM of 20 g kg^{-1} flour) of KGM limited the ability of the paste to absorb water and prevented the expansion of starch resulted the peak viscosity decreased (Meng et al., 2021).

The breakdown value reflects the shear resistance of paste at high temperature and the stability of hot paste. The breakdown value of bean dregs showed a downward trend, from 554 cP to 412 cP, decreased by 25.63% compared with the control group, which indicated that the stability of the paste enhanced with the increased of the bean dregs. The setback was the difference between the final viscosity and trough viscosity, which represented the stability and short-aging trend of the paste.

The setback value was inversely proportional to the aging degree. The setback value of bean dregs showed a downward trend, from 1158 cP to 931cP, decreased by 19.60% ($P<0.05$) compared with the control group. Thus, the breakdown and setback values of the bean dregs paste decreased indicated that there was a great difference in the thermal stability and aging degree of the paste (Jiang et al., 2020). These changes could prevent the hard dough from aging and extend the shelf life of the products.

Rheological analyses.

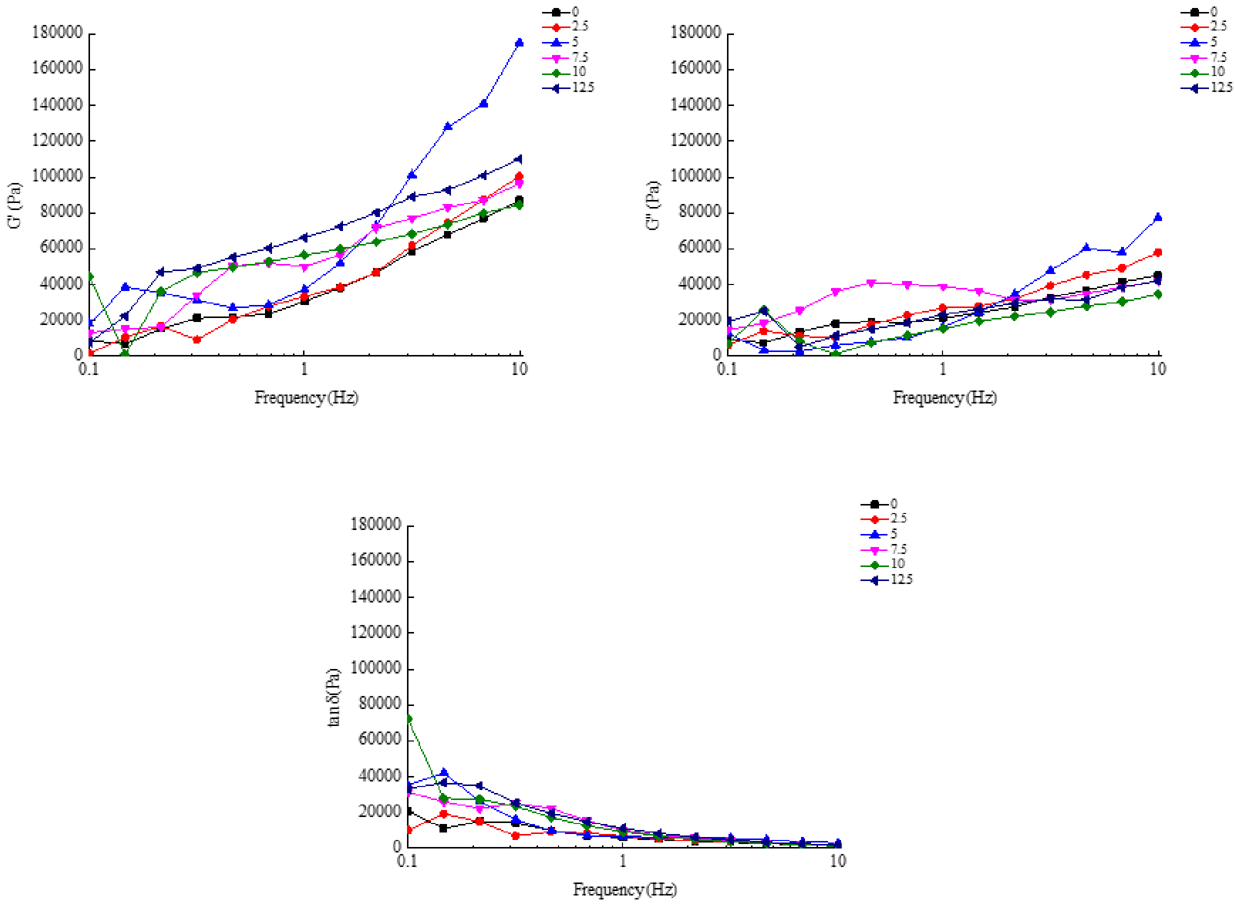

Figure 5.2 - Effect of bean dregs powder on the rheological properties of hard dough

The rheological properties of dough significantly influence the different stages of the baking procedure and play an important role for the production of high-quality baked products. The dynamic rheology parameters, storage modulus (G′) and loss modulus (G″) of the dough can be measured by scanning frequency under dynamic conditions, which can be used to indicate the elastic behavior and viscosity behavior of the dough (Khatkar &Schofield, 2002). Fig. 4 showed the variation curves of the G′, G″ and tan δ values with scanning frequency of in bean dregs dough. According to the dynamic oscillation tests, bean dregs doughs exhibit a solid elastic like behaviour with G′ values greater than G″ values. The G′ of dough significantly increased after different amount of bean dregs compared with the control, and the highest values of G′ was shown in the 12.5% bean dregs. The lowest viscoelastic values were found in the 2.5% bean dregs. Starch granules, the single largest component of flour, appear to be the source of the lower linear viscoelastic strain limits of flour doughs, since the strain limit of gluten-starch doughs increased exponentially with lower proportions of starch (Uthayakumaran, Newberry, Phan-Thien& Tanner, 2002). This is consistent with the report of Tsatsaragkou et al. (2014) and Izydorczyk et al. (2011), who reported that carob flour and barley increased the G′ of dough uniformly. The tan δ of all samples showed a gradually decreasing trend, it shows that at high frequencies, the dough tends to be more a solid character. In our study, it was found that the bean dregs increased could viscosity and elasticity of hard dough.

Texture analysis.

Table 5.2 - Effect of bean dregs powder on texture of hard dough

Bean dregs (%)	Hardness	Cohesiveness	Gumminess	Chewiness	Springiness	Resilience
0	1024.57± 99.79e	0.49± 0.00b	499.34± 84.34d	173.50± 79.18c	0.35± 0.00b	0.05± 0.00c
2.5	1278.63± 108.66e	0.61± 0.05a	774.34± 8.18cd	435.59± 70.58b	0.56± 0.10a	0.06± 0.00bc
5	1901.54± 6.19d	0.50± 0.05b	947.70± 94.81c	328.03± 124.93bc	0.34± 0.10b	0.07± 0.01bc
7.5	3080.41± 107.17c	0.50± 0.00b	1536.34± 53.46b	574.05± 19.05b	0.37± 0.03b	0.08± 0.00ab
10	3757.26± 266.29b	0.43± 0.04b	1622.32± 259.22b	404.33± 151.48bc	0.25± 0.05cb	0.08± 0.01b
12.5	7464.53± 219.99a	0.38± 0.00b	3064.08± 67.82a	829.70± 51.56a	0.27± 0.02b	0.11± 0.00a

The values are mean plus/minus standard error (n = 3). Different letters in the same column indicate significant difference ($P < 0.05$).

Table 5.2 lists the texture profile analysis (TPA) parameters of bean dregs hard dough. The parameters showed increases in the hardness, gumminess, chewiness and resilience of the hard dough compared with control because of bean dregs can dilute gluten protein and hinder the formation of gluten network due to the addition, and it increased with the increase of bean dregs. As shown in Table5.2, the hardness of all bean dregs group samples was higher than that of the control. The hardness was 7464.53±219.99 N when the bean dregs addition level of 12.5%, which was 86.27% higher than the control. This was probably due to fiber and protein of bean dregs compete with the flour for moisture, in a way that promotes gluten production until it suppresses the behavior causing an increase in the hardness of the dough, which was consistent with the results of RVA analysis. Gumminess is the amount of energy required to chew semisolid food before it is swallowed (Friedman, Whitney & Szczesniak, 1963). From Table 5.2, the gumminess values of the doughs with bean dregs were significantly higher than that of the control and significantly ($P < 0.05$). However, the gumminess values of the doughs with bean dregs additions of 7.5 % were not significantly different from additions of 10% ($P > 0.05$). Chewiness is the amount of energy required to chew semisolid food into a steady state when swallowed. From Table 5.2 chewiness was positively correlated with hardness and gumminess. The chewiness was 829.70±51.56 when the bean dregs addition level of 12.5%, which was 79.10% higher than the control. Resilience is the extent to which the altered sample recovers at the same speed and pressure as the resulting deformation. For the resilience of the dough, significant ($P < 0.05$) changes were observed after the addition of bean dregs. The resilience was 0.11 when the bean dregs addition level of 12.5%, which was 54.55% higher than that of the control. This may be due to the fact that bean dregs enters the backbone of the network structure in the form of filler, greatly increasing the elasticity of the dough (Peressini & Sensidoni, 2009; Uthayakumaran et al., 2002).

5.2 Color analysis of hard dough and biscuit

Table 5.3 - Effects of bean dregs powder on the color of hard biscuits and dough

Bean dregs (%)	Hard dough			Hard biscuits		
	*L**	*a**	*b**	*L**	*a**	*b**
0	71.98± 0.74a	-0.58± 0.08e	32.30± 0.16ab	81.49± 0.04a	0.65± 0.0c	31.37± 0.36bc
2.5	68.74± 0.33b	-.21± 0.04d	33.16± 0.84a	80.34± 0.1b	1.21± 0.16c	30.83± 0.42bc
5	67.29± 0.35bc	0.34± 0.07c	33.61± 0.10a	79.89± 0.69b	1.28± 0.02c	30.57± 0.42c
7.5	67.35± 0.01bc	0.79± 0.08b	30.51± 0.30c	78.16± 0.64c	1.47± 0.59c	28.60± 0.11d
10	65.39± 0.38c	1.18± 0.13a	32.69± 0.53ab	76.49± 0.14d	5.10± 0.64b	31.57± 0.33b
12.5	66.38± 1.39c	1.02± 0.08ab	31.76± 0.58bc	68.53± 0.62e	8.79± 0.12a	33.81± 0.30a

Table 5.3 shows the results of the study of hard dough and biscuit color. With the increase of the amount of bean dregs, the reduced *L** (became darker) and increased *a** (more reddish) of hard biscuits values, which changes from golden brown to caramel color. The cake crust temperature exceeded 150 ºC during baking, and thus Maillard and sugar caramelization reactions take place and are responsible for the final crust color (Purlis, 2010). The mixture of bean dregs and flour changed the ratio of starch and protein, which changed the color of the product. Barcenill et al. (2015) showed changes in starch structure and proteins increased can modify the presence of sugars and amino acids, resulting in changes to crust color. However, *b** values had no obvious trend of change, and was the lowest when bean dregs were 7.5%. The color trend of dough is similar to that of biscuits. As a whole, the biscuit has a higher *L** and *a** values than the dough, except for the *b** values. Therefore,

dough color must be the result of the modifications to color of raw materials, and it seems that ultrafine-microwave treatment modifies bean dregs color, thus improving the color of dough before baking. Barcenilla et al. (2016) showed both the raw materials and high pressure treatment modifies batter color before baking. Acosta et al. (2011) showed color of a baked good can be attributed to both the individual ingredients of the item and the color developed from ingredient interactions (Acosta, Cavender & Kerr, 2011). In fact, previous studies have shown that the different physical treatment can change the color of the bean dregs. The bean dregs treated by U-M had lower values of *L**, the *a** and *b** values were significantly greater than those of the control group (Wang, Zeng, Tian, Gao & Sukmanov, 2022), that may be the cause of changes obtained in hard dough color parameters.

5.3 hard biscuits properties

Analysis of texture of hard biscuits.

Table 5.4 - Effect of different amount of bean dregs texture of hard biscuits

Bean dregs, (%)	Hardness, N	Cohesiveness	Gumminess	Chewiness
0	2173.15± 176.55d	0.08± 0.00c	170.16± 18.47d	32.51± 2.72c
2.5	2500.17± 565.48d	0.17± 0.03abc	437.24± 160.05cd	173.34± 11.99bc
5	3330.56± 143.53c	0.15± 0.05bc	499.39± 200.72bcd	182.01± 89.59bc
7.5	4014.52± 153.94b	0.20± 0.05ab	800.10± 216.77bc	336.74± 15.10ab
10	4239.46± 309.01ab	0.21± 0.03ab	899.10± 56.34ab	267.33± 18.15b
12.5	4698.98± 97.71a	0.27± 0.04a	1260.48± 202.18a	473.57± 131.04a

Table 5.4 lists the texture profile analysis (TPA) parameters of bean dregs hard biscuits. The parameters showed increases in the hardness, cohesiveness, gumminess, chewiness of the biscuits compared with control. As shown in Table 5.4, the hardness of all bean dregs group samples was higher than that of the control. The hardness was 4698.98±97.71 g when the bean dregs addition level of 12.5%, which was 53.75% higher than the control. On the one hand, the water absorption of bean dregs was better than that of starch, and the cross-linking effect of gluten protein and starch was weakened, which affected the toughness of biscuits; on the other hand, when the soybean dregs were mixed with flour, protein content increased, starch content decreased, protein denaturated by heat, and hardness increased. This is consistent with the results of (TPA) dough analysis. From Table 5.4, the gumminess values of the biscuit with bean dregs were significantly higher than that of the control and significantly ($P<0.05$). However, the gumminess values of the biscuit with bean dregs additions of 2.5 % were not significantly different from additions of 5% ($P > 0.05$). The chewiness was 473.57±131.04 when the bean dregs addition level of 12.5%, which was 93.14% higher than the control. This is consistent with the results of (TPA) dough analysis.

Scanning electron microscopy (SEM).

Fig. 5.3 shows the effects of bean dregs on the microstructure of hard biscuit. It was found that the starch granules in the hard biscuits (Fig. 5.3a). were almost not exposed and closely bound to protein. There were no obvious differences between the bean dregs addition level of 2.5%, 5% (Fig. 5.3b, c). and the control (Fig. 5.3a). The network structure of gluten has continuity, the ability to wrap starch particles is relatively strong, and the texture of the biscuit is relatively smooth, the hard biscuits structure showed relaxation and lack of hardness (Fig.5.3a, b, c). When the bean dregs addition level of 7.5%, which showed slightly looser structures and more exposed starch granules than the control sample (Fig. 5.3d). This might be due to that the bean dregs compete for water in the dough, which inhibits the formation of gluten network, leading to protein fracture, starch can’t be completely wrapped by gluten network, affecting the quality of finished biscuits. When the bean dregs addition level of 10%, which showed small air stomata with the structure became more uniform and the fiber bundle exhibited with less exposed starch granules (Fig. 5.3e). Bean dregs with 12.5% (Fig. 5.3f). shows that the structure with many folds, irregular and full of holes. The molecular structure of bean dregs was destroyed due to the strong thermal effect imposed during microwave treatment, had a small amount of starch exposed out of the gluten protein leading to formation of more gullies and skeletons in hard biscuit. The SEM results further confirmed that bean dregs powder had a certain effect on the biscuits hardness, which was consistent with the TPA results of biscuit texture. In addition, it’s proved that the network structure of gluten can be destroyed by adding too much bean dregs powder.

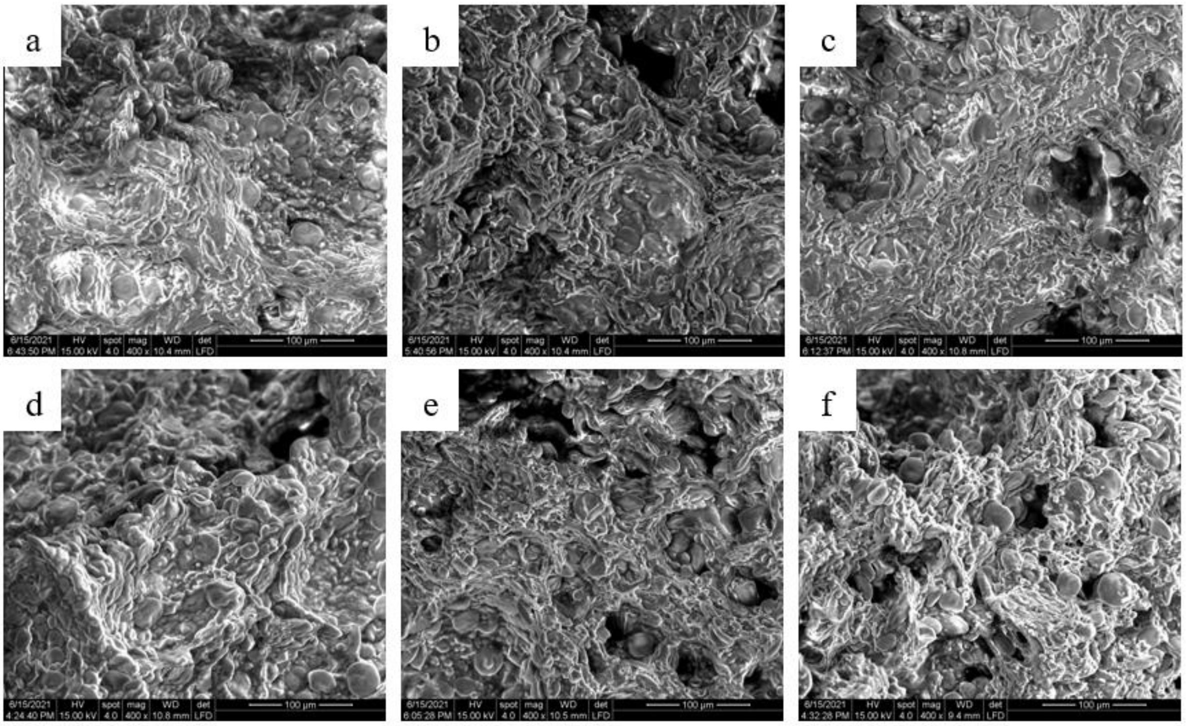

Figure 5.3 – Scanning electron micrographs of bean dregs hard biscuits
(a-f: 0, 2.5%, 5%, 7.5%, 10%, 12.5%)

Subjective (sensory) evaluation of hard biscuits.

The mean scores for overall acceptability of hard biscuits were presented in Fig. 5.4 and Fig. 5.5. A two-way analysis of variance indicated that these sensory attributes of the hard biscuits were significantly affected ($p < 0.05$) by addition of different levels of bean dregs powder in biscuits formulations. As shown in Fig. 5.5, the sensory score increased gradually with the increase of bean dregs, reaching the highest at 10%, while the sensory score was the lowest at 12.5%. However, the control received the highest comprehensive score rating of 86 score, which was significantly different from the 10% bean dregs hard biscuits with a comprehensive score rating of 84.33 score. From the perspective of morphology, each group of cookies is relatively complete. However, the addition of bean dregs above 7.5%, the texture of biscuits is relatively hard and without deformation, but the color is darkened. And from these picture (Fig. 5.4.) that the control was too light and 12.5% bean dregs hard biscuits was too dark. During the sensory testing, panelists also commented on the grainy texture of the products. It would be beneficial to process bean dregs using a smaller particle size (U-M) produce the baked goods. Walker et al. (2015) determined that smaller WGP (Wine grape pomace) particle size might also have an effect on the volume and texture of the baked items as well (Walker, Tseng, Cavender, Ross & Zhao, 2014). Thus, the maximum addition of 10% bean dregs increases the flavor of the bean dregs without providing a harsh chewing effect. Based on the sensory study, it might be concluded that bean dregs at 10% (w/w) replacement for flour for hard biscuits will be acceptable for consumers. Another study found that banana flour could replace wheat flour in brownies at 50% fortification (Danasunawal, Siriwong & Riebroy, 2011).

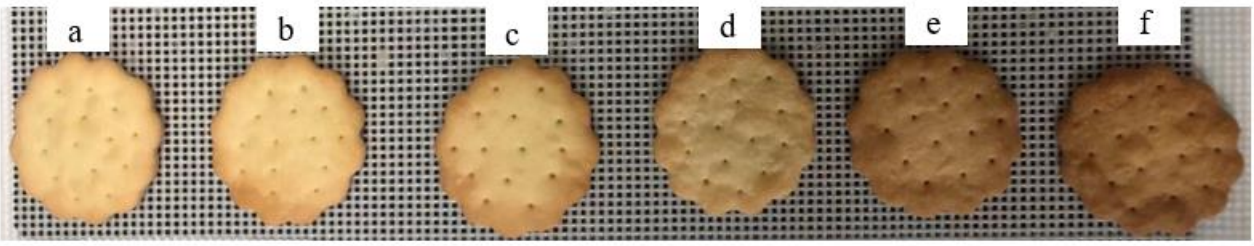

Figure 5.4 - Hard biscuits with different amount of bean dregs
(a-f: 0, 2.5%, 5%, 7.5%, 10%, 12.5%)

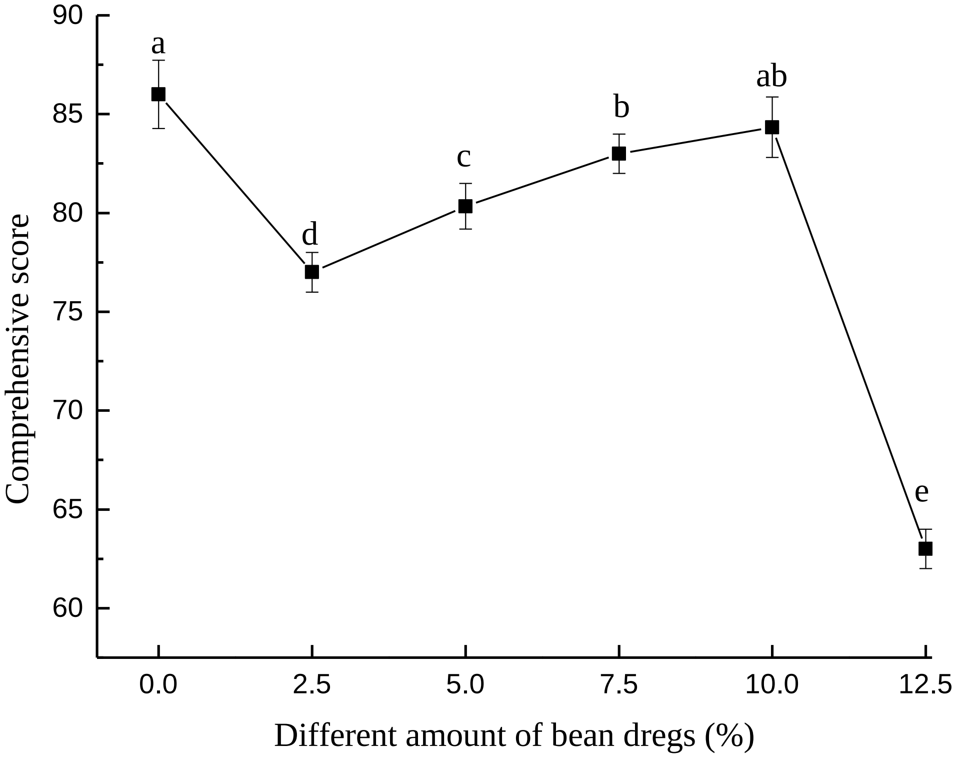

Figure 5.5 - The comprehensive score of hard biscuits

In every group of data, values with the same following letter do not differ significantly from each other ($p \leq 0.05$)

5.4 Single factor test results and analysis of bean dregs hard biscuit

As shown in Fig. 5.6A. the sensory score first increased and then decreased with the increase of water content. When the water consumption is less than 30mL, the dough is not easy to shape, resulting in uneven texture and dry taste. When using 30mL of water, the dough can form a smooth dough, which is easy to form an orderly gluten network structure by constant rubbing, making the biscuits tough and crisp without sticking to teeth, and the highest sensory score. The water consumption was more than 30 mL, and the dough was soft and poor in plasticity, which made the bean jelly cookies more brittle. However, the biscuit was not complete in shape, and it was easy to shrink and deform, which led to a gradual decline in sensory score.

Adding sugar to dough can improve the color, aroma, taste and shape of baked goods.

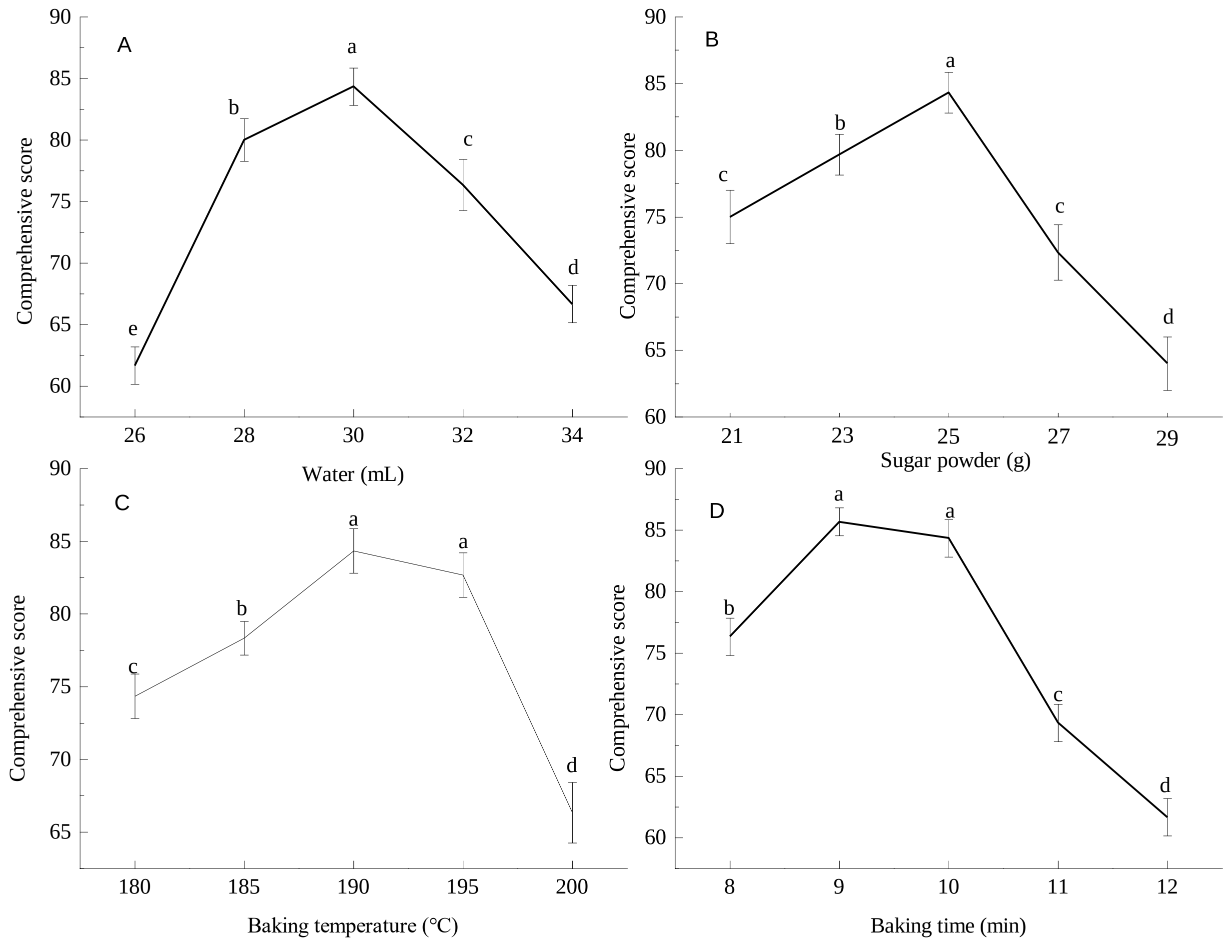

Figure 5.6 - The effect of different factors on bean dregs hard biscuits

As can be seen from Fig. 5.6B, sensory score increased gradually with the increase of powdered sugar content. With less than 25 g sugar content of tough biscuits, the reverse hydration effect is less, may cause the dough to form higher gluten, so that the product shrinkage deformation, reduce the surface area. When the amount of powdered sugar was 25 g, the biscuit had brittleness, suitable sweetness, good shape and the highest sensory score. When the amount of sugar was more than 25g, the biscuits were sweeter, darker in color, thinner in texture, hard and crisp in taste, and the sensory score decreased gradually.

Too low or too high temperature can affect the quality of biscuits. As can be seen from Fig. 5.6C, sensory score increases gradually with increasing oven temperature. However, biscuits had the highest sensory ratings when baked at 190 °C. When baked below 190 °C, biscuits are lighter in color and lack crisp texture.

When the baking temperature exceeds 195 ℃, the color of the biscuits is blackened, the smell is peculiar, and the sensory score is greatly reduced.

On the basis of controlling the baking temperature, the baking time is very important to the quality of the finished biscuits. As can be seen from Fig. 5.6D, the sensory score is the highest he baking time for 9 min. When the baking time exceeded 10 min, the sensory score decreased significantly ($p < 0.05$). This may be due to the short time of baking at high temperature, which makes the surface of the biscuit dry and hard, and the biscuit center is soft and white, thus affecting the taste of the biscuit. While for a long time baking, biscuits tend to appear scorched phenomenon, affecting the appearance and taste of products.

5.5 Orthogonal test results and analysis of bean dregs hard biscuit

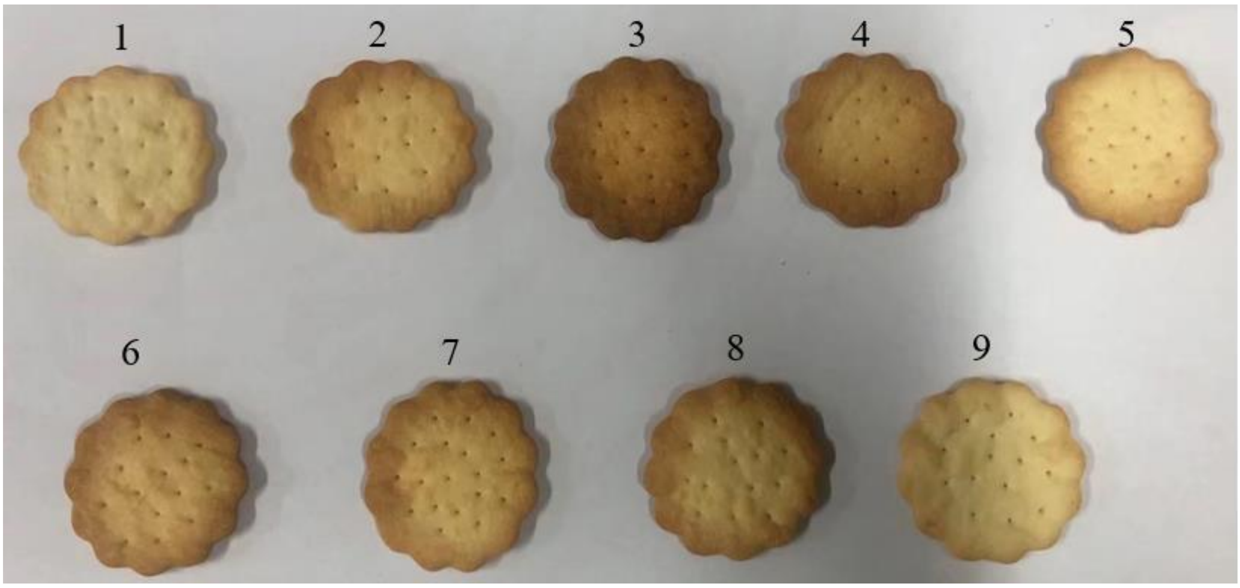

Figure 5.7 - Orthogonal test diagram of bean dregs hard biscuits

Through single factor test, the addition of water, powdered sugar, baking temperature and time were determined as variables to carry out orthogonal test, and the test results are shown in Fig 5.7 and Table 5.5. It can be seen from the analysis of orthogonal test results in Table 5.6. The primary and secondary relationship of sensory evaluation score was A>B>C>D, the best formula of bean dregs hard biscuits $A_2B_2C_3D_1$ was obtained.

Table 5.5 - Orthogonal test results and analysis of bean dregs hard biscuits

Serial number	Factors				Sensory evaluation score	Texture Hardness
	A Water (mL)	B Powdered Sugar (g)	C Tempera-ture (℃)	D Time (min)		
1	28	23	185	8	69	4214.09
2	28	25	190	9	70	8206.01
3	28	27	195	10	63	4996.38
4	30	23	190	10	82	4125.98
5	30	25	195	8	88	4344.95
6	30	27	185	9	73	6314.48
7	32	23	195	9	75	6980.39
8	32	25	185	10	76	4421.78
9	32	27	190	8	66	3287.39
Sensory score						
K_1	202	226	218	223		
K_2	243	234	218	218		
K_3	217	202	226	221		
k_1	67.33	75.33	72.66	74.33		
k_2	81	78	72.66	72.67		
k_3	72.33	67.33	75.33	73.67		
R	13.67	10.67	2.67	1.66		
Order		A>B>C>D				
Optimal combination	A_2	B_2	C_3	D_1		
Texture hardness						
K_1	17416.48	15320.46	14950.35	11846.43		
K_2	14785.41	16972.74	15619.38	21500.88		
K_3	14689.56	14598.25	16321.72	13544.14		
k_1	5805.49	5106.82	4983.45	3948.81		
k_2	4928.47	5657.58	5206.46	7166.96		
k_3	4896.52	4866.08	5440.57	4514.71		
R	908.97	791.50	457.12	3218.15		
Order		D >A>B>C				
Optimal combination	A_3	B_3	C_1	D_1		

The primary and secondary relationship of texture (hardness) is D>A>B>C, the best formula of bean dregs hard biscuits $A_3B_3C_1D_1$ was obtained. According to sensory evaluation score and hardness in Table 5.6 the best formula of bean dregs hard biscuits $A_2B_2C_3D_1$ was obtained, and $A_1B_1C_2D_1$was scored lower than $A_2B_2C_3D_1$ in the sensory validation test. Therefore, the optimal formula of bean dregs hard biscuits was obtained: 90 g wheat flour, 10 g bean dreg powder (after U-M treatment), 30 mL water, 25 g sugar powder, 5 g starch, 1 g baking powder and 0.5 g salt, then add 20 g egg yolk, 5 g soybean oil, surface fire temperature at 195 ℃ for 8 min. Sensory score of bean dregs hard biscuits was 88 points, and hardness value was 4344.95 g.

5.6 Developed technological schemes

The results of the conducted research allowed us to develop a technological scheme for cookies (Fig. 5.8).

Whe wet bean dregs were dried with constant temperature drying oven at 50 ◦C for 48 h, ultrafine ground frequency of 30 Hz by an ultrafine grinder. Then combination with microwave treatment, the ratio of bean dregs to water was 1:7, high heat levels for 6 min. Treated samples were vacuum freeze dried, ground, sieved with an 80 mesh screen and stored.

The crispy biscuits had the following formulation: Low gluten flour (80 g), and bean dregs powder (20 g), butter (50 g), powdered sugar (20 g), corn starch (5g), egg yolks (20 g), and salt (1 g), baking powder (0.75g). Whisk butter until creamy and pale after the butter is softened, powdered sugar, salt and egg yolks were mixed for 1 min at speed 4 using a KitchenAid Professional mixer KPM5 to make it smooth, add the flour mixture (low gluten flour, bean dregs powder, corn starch and baking powder) in batches to make a soft dough. Seal with plastic wrap and leave at room temperature for 10 min, then press into shape with a mold.

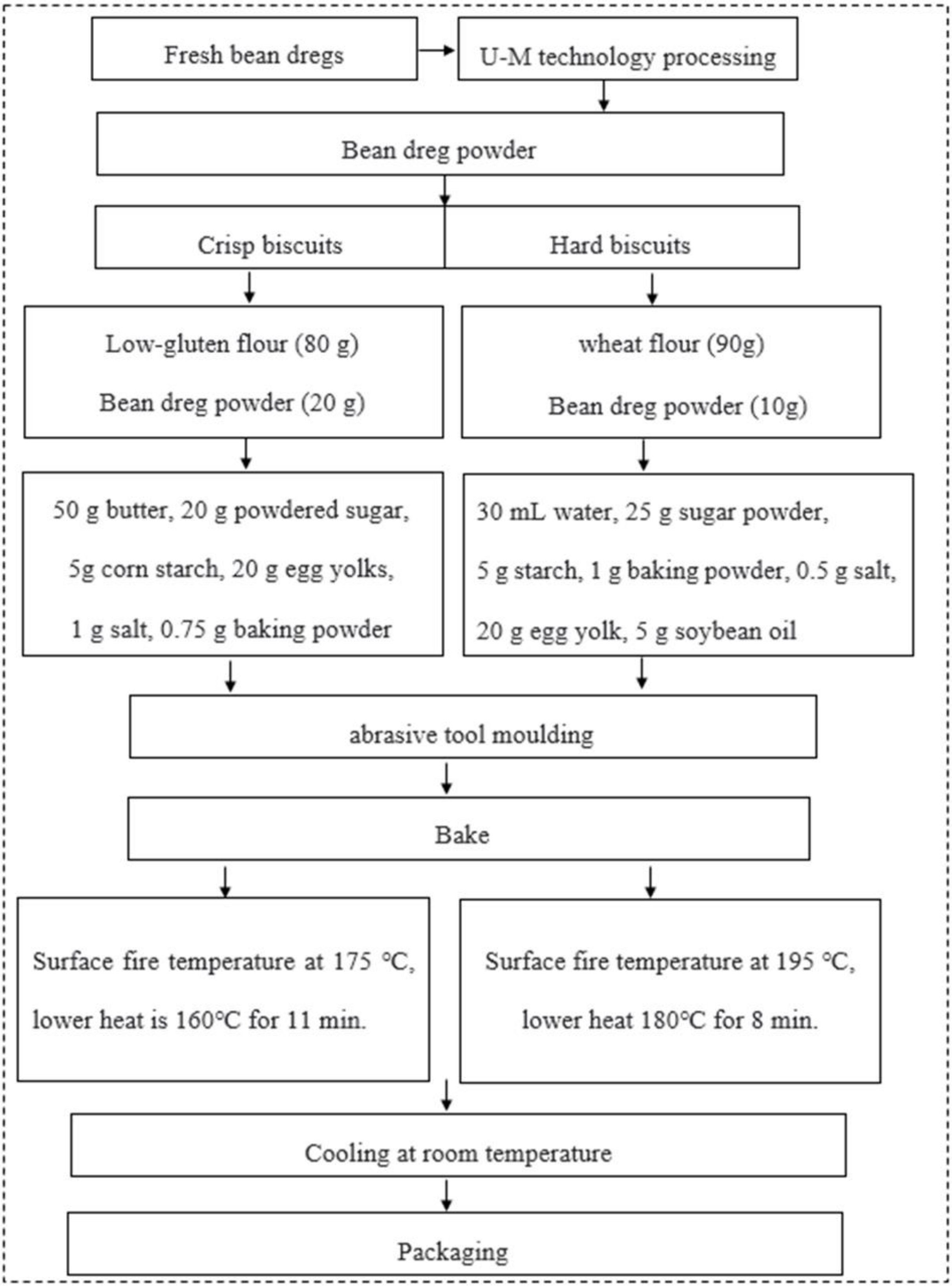

Fig. 5.8 Developed technological schemes

Preheat the oven to be preheated, the upper heat is 175℃, the lower heat is 160℃, weigh 8 g of the crispy dough, put it into a fixed mold, press it into a consistent biscuit shape and slowly the sample into the prepared baking pan. These samples were baked in an electric oven for 11min. After baking, the Crispy biscuits were removed from the oven, left to cool for 1 hour at room temperature, and packed into hermetically sealed plastic bags to prevent drying.

The hard biscuits had the following formulation: wheat flour (90 g), and bean dregs powder (10 g), powdered sugar (25 g), starch (5 g), baking powder (1 g) and salt（0.5 g）evenly, then add egg yolk (20 g) and water (30 mL), grasp and mix evenly, and finally add soybean oil (5 g) to mix into dough, then put into a noodle making machine, place the dough in a tablet press and shape using biscuit cutter. Preheat the oven in advance, bake at upper heat 195℃, lower heat 180℃, bake for 8 min. Leave to cool at room temperature for 1 hour, then put the biscuit in an airtight bag to prevent drying.

Operating essentials of Hard biscuits

a. The dough should rest at 35 ℃-40 ℃.

b. After the dough is left to rest, knead, rub, drop and knead vigorously until the dough is smooth and cover with cling film and leave to rest for 10 min.

c. Continue to knead for 2 min, make gluten to achieve the strongest structure, soft and hard moderate, the surface has a beautiful luster.

d. Divide it into dosage forms, adjust the dough press to 3 g, roll it into dough with uniform thickness, complete shape and smooth surface, and press it into shape with biscuit mold.

Conclusions in Section 5

The processed bean dregs powder was added to the hard biscuits, and the dough and products were measured and analyzed, and the following conclusions were drawn:

1. The addition of bean dregs powder changed the gelatinization and rheological characteristics of flour, not only improve the stability of the batter, but also improve the viscosity and elasticity of the hard dough.

2. The addition of bean dregs increased the hardness of dough.

3. The color of the dough and the product have the same trend in the corresponding recipe. The addition of bean dregs powder reduced the L^* value of hard dough and biscuit, while a^* value increased greatly, b^* value changed little.

4. According to the characteristics of dough and the sensory evaluation of hard biscuits, the maximum amount of bean dregs was 10%, which gave the biscuits a better taste.

5. Through single factor and orthogonal test results the optimal formula of bean dregs hard biscuits was obtained: 90 g wheat flour, 10 g bean dreg powder (after U-M treatment), 30 mL water, 25 g sugar powder, 5 g starch, 1 g baking powder and 0.5 g salt, then add 20 g egg yolk, 5 g soybean oil, surface fire temperature at 195 ℃ for 8 min. Sensory score of bean dregs hard biscuits was 88 points, and hardness value was 4344.95 N.

CONCLUSIONS

A combined method may have greater effects than any single approach in improving the quality of bean dregs. The effects of ultrafine grinding (U), high pressure (HP), microwaves (M), high-temperature cooking (HTC) and combination technologies (U-HP, U-M, U-HTC) used in bean dregs can solve quality problems.

The results showed that both single treatments and combination treatments significantly increased the soluble dietary fiber (SDF) content and water solubility of bean dregs; however, the protein content, fat absorption capacity and swelling capacity of bean dregs were decreased compared with those of the control. The combination technologies significantly increased the contents of K, Ca, Na and Fe in bean dregs. HTC and U-HTC had prominent effects on inhibiting trypsin inhibitor activity, which were decreased from 7365 TIU/g to 1210 and 96 TIU/g, respectively. The bean dregs by ultrafine grinding and combined treatments showed honeycomb structure and small particle distribution, and their processing performances improved.

The combination treatments of U-HP, U-M and U-HTC greatly reduced the viscosity, and the slurry of bean dregs treated by U-HP combination had the best stability. After the HTC, U-HP, U-M and U-HTC treatments, the proportion of bound water of bean dregs increased and the proportion of immobile water decreased after rehydration. Different treatments could obviously affect the rheological behavior of bean dreg slurry. The HTC sample and all the combined treatments had low G', G'' and tan δ values. Different methods had great influences on the chrominance and whiteness index of bean dregs.

The addition of bean dregs greatly reduced the viscosity of paste (Mix the bean dregs with the flour). The addition of bean dregs has great influence on the texture of dough and biscuit. The hardness value increased when the bean dregs content in the hard biscuits formulation was increased. This may be the content of bean dregs increased, more fiber was able to absorb water or oil of dough, and filled in the gluten network and led to the increase of dough hardness. However, above 20% biscuits was decreased to hardness. This may be due to free fat therefore disrupts the gluten network resulting in softer doughs.

The addition of bean dregs changed the color of the dough and biscuits. On the one hand depends on the baking temperature and time, on the other hand depends on the raw material itself, the color of bean dregs after combined treatment has obvious changes.

With the increase of the proportion of bean dregs powder, the internal structure of the biscuit changes greatly, the gap gradually becomes larger, and the surface becomes rough from fine. The more bean dregs were added, the more difficult it was to form smooth dough with plasticity, thus affecting the dough shape and texture.

The addition of bean dress powder in a certain proportion can improve the structure of biscuits and increase the crispness of biscuits, when the amount of bean dress powder is too large, it may change the rheology dough and affect the quality of crisp biscuits. The results of sensory evaluation indicated that the of wheat flour up to 20% and 10% substitution level with bean dregs was possible for crisp biscuits and hard biscuits without adversely affecting the consumer acceptability of crisp biscuits.

In recent years, soybean dregs have become a hot research topic because of their rich nutrition and remarkable nutritional function and functional food has also been accepted and favored by more and more consumers. Therefore, in view of the increasing attention given to the preparation of food containing bean dregs, combined treatments are more appropriate methods for improving the physicochemical properties of bean dregs for high-quality functional dietary fiber food. Vigorously developing agricultural and sideline products is not only conducive to improving grain utilization rate and optimizing the development of grain industrial structure, but also of great significance to improving the nutritional diet structure of residents and improving people's health level. In this paper, the effects of different physical technology on compositions, characteristics and physicochemical properties of bean dregs were studied. U-M combined technology was used to process bean dregs for crisp biscuits and tough biscuits, and the technological formula was optimized.

In the next step of the experiment, U-HP and U-HTC treatments can be combined technology processing bean dregs for other products, such as: bread, noodles, steamed bread and other products in the research and analysis, so as to better guide the production of bean dregs products, improve the quality of bean dregs food.

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APPENDIX

Application Testify

Application enterprise	Henan Miduoqi Food Co., LTD
Postal address	No.1598, North of East Section of Taihang Avenue, Huixian City, Xinxiang City, Henan Province, China.
Starting and ending time	July,1, 2021 — Now
Contact Person	Zhang Xing (+086 13353671794)

Our enterprise have utilized the technology of ultrafine grinding and microwaves combined to increase the SDF (soluble dietary fiber) of bean dregs content in crisp biscuits and hard biscuits, the technology can increase the SDF contents of bean dregs from 1.63% to 19.23%, reduce anti-nutrition factors in bean dregs, and it improves the roughness of the bean dregs, enhances the texture and flavor of the biscuits. In our factory, the type of bean dregs biscuits products were produced 10 tons per day.

Henan Miduoqi Food Co., LTD.

Dec, 25, 2021

Socio-economic effectiveness of scientific and technical developments and implement the results of work in practical production

As a kind of fast-consumption snack food, biscuits are of various kinds, which are usually eaten as snacks. Besides its good taste, biscuits can also supplement the energy needed by the human body.

In recent years, with the improvement of people's income level and the change of consumption concept, the requirements for diet gradually tend to be healthy and diversified, the rapid development of the biscuit food market, the market scale continues to expand.

The direction of use is the application of U-M technology in bean dregs biscuits. A series of measures were implemented to implement the results of the practical study. The U-M processing technique is implemented in the following ways: ”Henan Miduoqi Food Co., LTD” production facilities. The calculation of indicators introduced into the results of the socio-economic efficiency of the study confirmed the feasibility of its practical implementation.

Results obtained after implementation and socio-economic effectiveness of the programme:

1. Our enterprise have utilized the technology of ultrafine grinding and microwaves combined to increase the SDF (soluble dietary fiber) of bean dregs content in crisp biscuits and hard biscuits, the technology can increase the SDF contents of bean dregs from 1.63% to 19.23%, reduce anti-nutrition factors in bean dregs, and it improves the roughness of the bean dregs, enhances the texture and flavor of the biscuits. In our factory, the type of bean dregs biscuits products were produced 10 tons per day.

2. In this program, the production of bean dregs crisp biscuits and hard biscuits is implemented, which not only enriches the types of biscuits, but also improves the nutritional value.

3. The original production line progress is slow, food enterprises increase microwave, ultrafine grinding machine and other machinery after the production progress is significantly accelerated.

4. Reduced the time required to produce one ton of products by 6%~9%, increased productivity, increased plant and equipment utilization, and reduced depreciation by $1.00~ 2.00 per ton of plant and equipment. On this basis, the labor cost is reduced by $5 ~ $7 per ton.