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THE USE OF CHINESE HERBS IN WHEAT BREAD TECHNOLOGY

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Abstract: For decades, researchers have sought ways to reduce or eliminate type 2 diabetes, for which the exact cause is not known, and there is no cure. Chinese herbal medicine has a long history of successful treatment of diabetes. Long term consumption of food products containing Chinese herbs with hypoglycemic properties could be a viable treatment solution for diabetic patients. The purpose of this study was to develop a process for manufacturing a new bread product that contains Chinese herbs with hypoglycemic properties. Different fractions of the herbal formula were added into the dough to determine a maximum dosage that would produce bread that is palatable, shelf-stable, and retains desirable organoleptic properties of bread. Results demonstrated little variation in moisture between the control sample and the samples with herbs. With increasing amounts of herbs, the acidity of the bread increased and the porosity decreased. Organoleptic characteristics, such as appearance and internal structure of the baked samples with herbal formula did not demonstrate significant changes. It was concluded that the addition of the herbal formula, regardless of the dosage, improved shelf life, slowed the staling process and improved the microbiological stability of bread.

Keywords: *bread making, Chinese herbs, functional product, herbal bread product, Traditional Chinese Medicine*

INTRODUCTION

Diabetes is a chronic, debilitating and life-threatening disease that results either from insulin insufficiency or ineffective use of endogenous insulin [1]. The morbidity and mortality associated with diabetes are consequential and derives primarily from complications of longstanding hyperglycemia. Persistent hyperglycemia causes vascular problems involving both large and small blood vessels. These problems include arteriosclerosis, glomerulosclerosis, and retinopathy [2]. According to Hu [3], the dynamics of the diabetes epidemic are changing rapidly. Once called a disease "of the West", type 2 diabetes has now spread to every country in the world. What was once "a disease of wealth" is now increasingly common among the poor [3]. The optimal, and probably the only, effective strategy to reduce the increased burden of type 2 diabetes is primary prevention at the world population level [4].

Even though Western medicine is effective in treating diabetes and its precursor disorders, it also causes some adverse effects and potential disharmony among the internal organs [5]. The conventional Western medicine approach of using insulin or oral drugs to treat diabetes is incomplete and consequently, the person relying on them to prevent long-term complications remains at risk [6].

Hypoglycemic herbal remedies have been used to treat diabetes for many years. Herbal therapy works by several modes of action to influence multiple biological pathways of the body and provides multifunctional benefits. The efficacy of hypoglycemic herbs is achieved by increasing insulin secretion, enhancing glucose uptake by adipose and muscle tissues, inhibiting glucose absorption from the intestines and inhibiting glucose production by hepatocytes [7].

Studies of Chinese herbal substances used to treat diabetes demonstrate their mechanisms of action to be multi-factorial. It has been suggested that herbs containing polysaccharides restore the function of pancreatic tissues, causing increased insulin output by the beta-cells [8]. Some polysaccharide-containing herbs are found to stimulate the immune system and liver functions, including RNA and DNA synthesis. They also promote red and white blood cell production, increase cerebral circulation, strengthen the heart muscle and reduce cardiovascular diseases [9 – 11]. Other herbs are thought to enhance the microcirculation, increase the availability of insulin and facilitate metabolism in insulin-dependent processes [8].

The purpose of this study was to develop a process for manufacturing a new bread product that contains Chinese herbs with hypoglycemic properties. The focus of this study was to apply the available evidence regarding Chinese herbal medicines that lower and normalize high blood glucose and to introduce these medicinal herbs into food products [12 – 14]. Since bread is affordable and widely consumed panculturally, the goal was to develop a palatable, shelf-stable new bread product with hypoglycemic properties.

MATERIALS AND METHODS

For this study, Traditional Chinese Medicine (TCM) guidelines [15 – 17] regarding herbal characteristics and traditional uses were followed to develop a formula containing multiple herbal substances such as, but not limited to, Huang Qi (Astragali Radix), Sheng Di Huang (Rehmanniae Radix), Ren Shen (Ginseng Radix), Ge Gen

(Puerariae Radix), and Wu Wei Zi (Fructus Schisandrae Chinensis). The characteristics and traditional uses of individual herbs included in the custom designed formula for this study are indicated in Table 1 [15 – 17].

Table 1. *Characteristics and traditional use of hypoglycemic Chinese herbs*

Chinese herb	Latin name	Characteristics & traditional uses
Huang Qi	Radix Astragali	Sweet, neutral. Influences the spleen, lung, and heart; strengthens the spleen and benefits qi; tonifies the lung and stabilizes the exterior. Used for deficient spleen and stomach with fatigue and lack of appetite. Combined with Shan Yao and Sheng Di Huang (Radix Rehmanniae Glutinosae) for wasting and thirsting.
Zhi Mu	Anemarrhenae Rhizoma	Cold, bitter. Influences the lung, stomach, and kidney. It has anti-inflammatory and anti-asthma properties; reduces the sugar content in the blood and ketone bodies in the urine, normalizes diuresis.
Shan Yao	Radix Dioscoreae Oppositae	Sweet, neutral. Enters the spleen, lung, and kidneys; benefits the lung and nourishes the kidneys (yin and yang). Combined with Tian Hua Fen (Radix Trichosanthis) for irritability and thirst associated with injured fluids.
Ren Shen	Radix Ginseng	Sweet, slightly bitter, slightly warm. Benefits yin and generates fluids; tonifies the lung and benefits qi; strengthens the spleen and stomach; benefits the heart and calms the spirit. Some patients can lower their insulin requirement by taking this herb.
Mu Dan Pi	Mountan Cortex	Cool, pungent, bitter. Enters the liver, heart, kidney. Clears heat and cools blood heat. Eliminates blood stasis. Clears empty fire from yin deficiency and liver fire.
Gou Qi Zi	Fructus Lycii Chinensis	Sweet, neutral. Enters the liver and kidneys; nourishes and tonifies the liver and kidneys. Used for yin and blood deficiency.
Mai Men Dong	Tuber Ophiopogonis Japonici	Sweet, slightly bitter, slightly cold. Enters the lung, stomach, and heart; nourishes yin and clears heat. Experimentally has lowered serum glucose, speeded recovery of islets of Langerhans, and increased glycogen storage levels in rabbits with artificially induced diabetes mellitus.
Shi Gao	Gipsum Fibrosum	Very cold, sweet, pungent. Enters lungs, stomach. Clears Qi level heat and stomach fire. Clears lung heat.
Fu Shen	Sclerotium Poriae Cocos	Sweet, bland, neutral. Enters the heart, spleen, and lung; strengthens the spleen and harmonizes the middle jiao; transforms phlegm and eliminates dampness.
Ge Gen	Radix Puerariae	Sweet, acrid, cool. Enters the spleen and stomach; nourishes fluids and alleviates thirst, especially from stomach heat. Combined with Tian Hua Fen (Radix Trichosanthis) and Mai Men Dong (Tuber Ophiopogonis Japonici) for thirst.
Sheng Di Huang	Radix Rehmanniae Glutinosae	Sweet, bitter, cold. Enters the liver, kidneys, and heart; clears heat, cools blood; nourishes yin and blood and generates fluids; lowers serum glucose levels. Used for deficient yin patterns with heat signs and injury to body fluids. Combined with Xuan Shen (Radix Scrophulariae Ningpoensis) for excessive thirst, irritability and a scarlet tongue.
Wu Wei Zi	Fructus Schisandrae Chinensis	Sour, warm. Enters the lung and kidneys; restrains essence; calms the spirit. Used for deficient lung and kidney patterns. Recent reports state this herb increases usage of both liver glycogen stores and serum glucose. Combined with Dang Shen (Radix Codonopsis Pilosulae) and Mai Men Dong (Tuber Ophiopogonis Japonici) for symptoms associated with exhaustion from qi and yin.

The herbal formula was designed to achieve a hypoglycemic effect that would include negating the blood glucose-increasing properties of the white wheat flour contained in the bread product into which the formula was incorporated.
The methodology of the experiments included preparing the dough from wheat flour type "45", splitting the dough and baking dough samples. Different fractions of the herbal formula were added into the dough. The herbal formula consists of the following components, by weight %: Fu Shen 8-10; Ge Gen 8-10; Huang Qi 13-15; Gou Qi Zi 4-5; Mai Dong 6-8; Mu Dan Pi 6-8; Ren Shen 4-5; Shen Di Huang 13-15; Shi Gao 3-5; Shan Yao 8-10; Wu Wei Zi 5-6; Zhi Mu 2-3 [9, 18]. In the course of experiments, the stages and condition of the technological process, and the quality of semi-finished and finished products were controlled.
For this study, several different recipes for wheat bread were tried, and their physical-chemical properties compared [19]. First, a "standard" white loaf recipe was used, and this became the control against which loaves with varying proportions of the herbal formula were compared. The recipe of the control sample (wheat bread) is presented in the Table 2.

Table 2. *The recipe of the control sample (wheat bread)*

Name of raw materials	Total consumption of raw materials per 100 kg of flour, kg
Wheat flour	100.0
Pressed baker's yeast	2.5
Salt	1.5

Next, a "grooved" loaf recipe was prepared. This type of bread, as opposed to a white loaf recipe, uses sugar as an ingredient. The sugar was a desired ingredient because, based on an analysis of the properties of individual herbs in the formula, the overall taste of the formula was predicted to be bitter, and therefore could impart a bitter taste to the bread product. It was assumed that consumers would not desire bread with a bitter taste. Thus, a "grooved" loaf recipe was tested, using a control loaf without herbs and an experimental loaf, which contained herbs.
Because diabetes is the main concern of the study, and the desire was to develop a bread product with hypoglycemic properties, a modified "grooved" loaf recipe was then tested. This recipe used Maltit, a sugar substitute, to counteract the expected bitter taste while avoiding the negative effects on blood sugar caused by the use of sugar [20].
In order to be incorporated into the dough without damaging the dough, the moisture content of the herbal formula had to be managed. Food chemists accomplished this by controlling the mass fraction (ratio or percentage of a substance to the whole) of ingredients added to a recipe. For this study, the mass fraction of the herbal formula was managed using the "express method" (reducing moisture at 160 °C, over 3 minutes) as opposed to the "standard method", which takes 40-50 minutes. The moisture level was measured using a "MOC-120H" hydrometer (SHIMADZU, Japan). The dough for all samples was mixed in a "SIGMA TAURO 30 2V" dough mixer (SIGMA, Italy). The "Sigma" mixer has a corkscrew hook that doesn't overwork the dough. It also has a mechanism that tilts the bowl for gentle dough removal. Proofing of the dough pieces took place in a "Miwe Aero" proofer (MIWE, Germany), and baking was conducted in a "Revent 726" rotary oven (REVENT, Sweden) [21, 22].

Physical-chemical properties of the finished products were analyzed beginning at 16 hours after baking. Tests included analyses of color, texture, microbial growth and staling. For the staling analysis, samples were packaged in plastic wrap and stored for 3 days. In order to assess the influence of the herbal formula on staling of bread, the compressibility of the crumb was analyzed and compared to the control sample.
Bread firmness assessed using a structure meter device Structometer "ST-2" (Quality Laboratory, Russia).
The acidity of the dough and finished products was determined by the titration-based method and expressed as number of milliliters of a single-normal solution of alkali consumed for neutralizing acids and acid-reactive compounds contained in 100 g of flour / finished product [22].
Elevated acidity in bread inhibits proliferation of bacterial pathogens. In order to study the effect of the herbal formula on bacterial pathogen growth, prepared bread samples were held at 37 °C (a temperature that favors pathogen growth), and were evaluated after 24, 36 and 48 hours of incubation [23, 24].

Bread making

Technological mode preparation of both white bread and "grooved" loaf is presented in Table 3.

Table 3. *Parameters of the bread making process [21]*

Parameters	**Values**
Dough development	
Water temperature [°C]	37
Dough mixing time, minutes at low then high speed	4+4 (4+5)
Dough temperature [°C]	28-30
Fermentation time [minutes]	90
Fermentation temperature [°C]	35
Relevant air humidity [%]	80
Splitting, proofing, baking	
Mass of dough pieces, г - formed - unformed/on the sheet	 600 280
Air temperature in the proofing chamber [°C]	35
Relative air humidity in the proofing chamber [%]	80
Bread baking time [min] - formed - unformed/on the sheet	 35 25
Baking temperature [°C]	210

RESULTS AND DISCUSSIONS

Effect of formula on the physicochemical and sensory characteristics of the dough

The physicochemical and organoleptic parameters of the dough made per white loaf and "grooved" loaf recipe are presented in Table 4 and Table 5.

Table 4. *Physicochemical and organoleptic indicators of white loaf dough*

Indicator	**Mass fraction [%]**			
	Control sample	**Sample №1 5.0 % herbs**	**Sample №2 7.5 % herbs**	**Sample №3 10.0 % herbs**
Moisture content [%]	45.0	44.0	45.0	45.5
Initial acidity of dough [mL 1.0 N NaOH / 100 g]	1.2	2.8	3.8	4.0
Final acidity of dough [mL 1.0 N NaOH / 100 g]	2.0	3.6	4.6	4.8
Organoleptic characteristic	Dough is light color, porous with a mesh structure and has an alcoholic aroma	Dough is viscous, dark in color, porous with mesh structure, has herbal aroma		

Table 5. *Physicochemical and organoleptic indicators of "grooved" loaf dough*

Indicator	**Mass fraction [%]**	
	Control sample "grooved" loaf	**Experimental sample "grooved" loaf with 10.0 % herbs**
Moisture content [%]	41.0	41.5
Initial acidity of dough [mL 1.0 N NaOH / 100 g]	1.2	4.2
Final acidity of dough [mL 1.0 N NaOH / 100 g]	2.0	4.6
Organoleptic characteristic	Dough is a light color, porous with a mesh structure and has an alcoholic aroma	Dough is viscous, dark in color, porous with a mesh structure and has an herbal aroma

Bread baked per "grooved" loaf recipe (it was preferred because its sugar content was counteracted the predicted bitter taste of the herbal formula) demonstrated acceptable acidity, good organoleptic characteristics. So, it was chosen for further study and sugar was replaced by Maltit sugar substitute. The physicochemical indicators of the sample with Maltit are represented in Table 6.

Table 6. *Physicochemical and organoleptic indicators of "grooved" loaf with Maltit dough*

Indicator	**Mass fraction [%]**	
	Control sample "grooved" loaf with 10.0 % herbs	**Experimental sample - "grooved" loaf with Maltit and 10.0 % herbs**
Moisture content [%]	40.0	40.0
Initial acidity of dough [mL 1.0 N NaOH / 100 g]	4.2	4.0
Final acidity of dough [mL 1.0 N NaOH / 100 g]	4.8	4.6
Organoleptic characteristic	Dough is viscous, dark, with more pronounced herbal aroma than experimental sample	Dough is more viscous, dark, with herbal aroma

Effect of formula on the physicochemical and sensory characteristics of bread

The physiochemical characteristics of white loaf samples with different fractions of Chinese herbal formula in white bread are presented in Table 7.

Table 7. *Physicochemical indicators of baked samples of white loaf recipe with differing fractions of the herbal formula*

Physicochemical indicators	**Control**	**Sample №1 5.0 % herbs**	**Sample №2 7.5 % herbs**	**Sample №3 10.0 % herbs**
Moisture [%]	44.0	43.5	44.0	45.0
Acidity [mL 1.0 N NaOH / 100 g]	6.0	8.0	9.5	11.0
Porosity [%]	82.0	75.5	71.5	71.0
Bread volume [mL]	2000.0	1510.0	1250.0	1400.0
Specific volume [$mL \cdot g^{-1}$]	3.7	2.8	2.3	2.6

Results from baked samples, illustrated in Table 7, show little variation in moisture between the control sample and the samples with herbs. With increasing amounts of herbs, the acidity of the bread increased and the porosity decreased. Organoleptic characteristics, such as appearance and internal structure of the baked samples with herbal formula did not demonstrate significant changes. The control sample demonstrated desirable loaf shape, with a convex crust, while samples with herbs had a flat surface. With increasing dosages of herbs, the crumb color became darker. Crumb color was uniform throughout the loaf in all samples. The porosity was also uniform and dominated by large and medium-sized pores in all samples. With an increase in herbal formula dosage, the softness of the crumb was diminished.

The study results showed that the addition of either 5.0 %, 7.5 % or 10.0 % herbal formula was feasible to make a white loaf recipe bread with consumer properties comparable to the control sample. For further research, the 10.0 % sample was selected because this dosage meets the daily requirement of herbs to lower blood sugar and cholesterol levels for people with diabetes. Although the 10.0 % sample was the most desirable for future study from a dosage point of view, it was the most likely to demonstrate a bitter taste, due to the addition of the herbal formula. The “grooved” loaf recipe was tested in order to determine if a recipe containing sugar could also demonstrate properties comparable to the control sample when the herbal formula was added. The physiochemical characteristics of “grooved” loaf recipe sample with 10.0 % of Chinese herbal formula are presented in Table 8.

Table 8. *Physicochemical indicators of baked “grooved” loaf sample*

Physicochemical indicators	**Results**	
	Control sample “grooved” loaf	**Experimental sample “grooved” loaf - with 10.0 % herbs**
Moisture [%]	40.0	40.5
Acidity [mL 1.0 N NaOH / 100 g]	4.0	8.0
Porosity [%]	78.0	73.5
Bread volume [mL]	1970.0	1710.0
Specific volume [$mL \cdot g^{-1}$]	3.6	3.1
Dimensional stability	0.5	0.4

Comparison of the baked per "grooved loaf recipe" and the control samples in Table 8 illustrate that the moisture of the sample with herbs did not differ much from the control sample. The porosity of the sample with herbs was decreased compared with the control sample. The experimental sample demonstrated elevated acidity, which is known to suppress longevity of yeast and to cause decreased porosity level.
The porosity level of the "grooved loaf" sample was better than the "grooved" loaf with herbs recipe sample. The sample with the herbal formula had diminished softness of the crumb.
The physiochemical characteristics of "grooved" loaf sample with 10.0 % of Chinese herbal formula and Maltit – sugar substitute are presented in Table 9.

Table 9. *Physicochemical indicators of baked "grooved" loaf sample with Maltit*

Physicochemical indicators	Results	
	Control sample - "grooved" loaf with 10.0 % herbs	**Experimental sample - "grooved" loaf with Maltit and 10.0 % herbs**
Moisture [%]	38.0	38.5
Acidity [mL 1.0 N NaOH / 100 g]	6.0	6.0
Porosity [%]	69.0	67.0
Bread volume [mL]	750.0	710.0
Specific volume [$mL \cdot g^{-1}$]	2.90	2.7
Dimensional stability	0.5	0.5

The porosity level of the sample with herbs and Maltit slightly changes; it remained within the acceptable range.

Influence of the herbal formula on bread staling

There is gradually decreasing consumer acceptance of bread due to the chemical and physical changes (staling) that occur in the crumb during storage. Changes in organoleptic properties such as texture, taste, and aroma define the staling process. The herbal formula contains organic acids, which are known to extend the freshness of bread products. Bread firmness is an indicator of freshness vs. staling, and this study assessed bread firmness using a structure meter device (ST-2), which measures crumb compressibility. The test is based on the theory that peak load increases and compressibility decreases as the bread ages. The study revealed that after 48 hours of storage the crumb compressibility of the samples with herbal formula decreased by 9 % and of the control sample by 14 %. After 72 hours of storage, there was no significant difference in compressibility among all bread samples. The results of this study are presented in Figure 1.

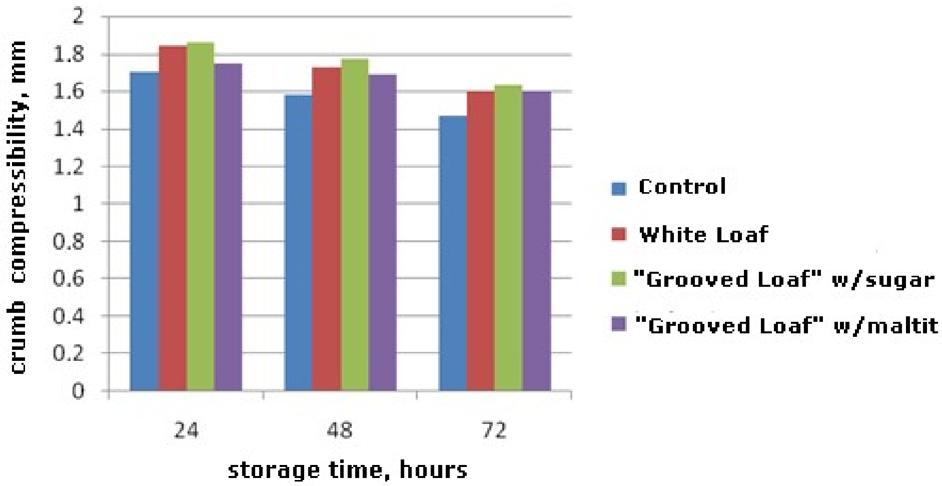

Figure 1. *Crumb compressibility of bread samples during storage*

Influence of Chinese herbal formula on the microbiological stability of bread

The most common source of microbial spoilage of bread is mold growth. Less common, but still causing problems in warm weather, is the bacterial spoilage condition caused by the growth of *Bacillus species*. The Chinese herbal formula contains organic acids, which are known to be natural mold inhibitors that act by reducing *p*H to retard the initial growth of mold.

Usually, bread becomes contaminated after baking due to mold spores present in the atmosphere surrounding bread during cooling and storage. For this study, the bread was properly cooled after baking and placed in an environment favorable for microbial growth at a temperature of 37 °C. The sample crumbs were analyzed after 24, 36 and 48 hours of incubation. Samples with Chinese herbal formula demonstrated a slightly longer shelf life. The results are shown in Table 10.

Table 10. *Influence of Chinese herbal formula on the microbiological stability of bread*

Time [hours]	Control sample - white bread loaf, no herbs	Experimental sample - white bread loaf, 10.0 % formula
24	Unpleasant smell, sticky crumb	No signs of disease
36	Increased unpleasant smell and stickiness of crumb. Change of the color of crumb, dark spots start appearing.	Light specific odor and discoloration of crumb start appearing
48	Very harsh unpleasant smell, the crumb is more sticky, the crumb gets darker, the formation of stretching mucous threads present	Unpleasant smell, the crumb is slightly sticky, the color of crumb starts changing, stretching mucous threads are absent

The organic acids present in the herbal formula increased the acidity level of the dough developed per “grooved” loaf recipe. Moisture content change in the sample with herbs was unremarkable, as it was within the standard deviation for acceptability. Dough consistency of the sample with the herbal formula was more viscous and darker in color compared to the control sample.

CONCLUSIONS

The "grooved loaf" bread sample with hypoglycemic herbs had better organoleptic properties, such as more bread volume, compared to the white loaf sample. Although the "grooved loaf" was the more desirable recipe for the future product it had the disadvantage of containing sugar, which is an undesirable ingredient in a product designed to be consumed by diabetics. Therefore, the sugar in the "grooved loaf" recipe was replaced by a sugar substitute (Maltit) in a ratio of 1:1.1. Even though substituting Maltit slightly decreased the dough acidity level, it remained within the acceptable range. Maltit also made the dough viscous and stickier. Some of the organoleptic characteristics such as dimensional parameters, color, and porosity changed unremarkably. It was found that the sweetener Maltit can be used as a sugar substitute without significant changes in the physicochemical or organoleptic properties of the bread.

This study also investigated the influence on bread staling resulting from adding an herbal formula. It was concluded that the addition of the herbal formula, regardless of the dosage, improved shelf life and slowed the staling process.

Improved microbiological stability of bread with added hypoglycemic Chinese herbs was demonstrated. It is known that the presence of the organic acids in the herbal formula increased the acidity level in bread. Consequently, the bread would have offered a less supportive environment for bacteria such as *Bacillus subtilis*. It was concluded that adding an herbal formula with hypoglycemic Chinese herbs improved the microbiological stability of bread.

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