Summary of Doctoral Thesis

Enrollment year: 2013 y 4 m
UGAS Specialty: Bioresources Science
Name: Santiago Dennis Marvin Opeña

Title	Utilization of Colored Non-cereal Energy Crops in Food Processing

Introduction and purpose

Sweet potato is the sixth most important food crop in the world. About 95% of its total production is from developing countries, with Asia as the largest producing region (Lu and Gao, 2011). It is of significant socio-economic importance because of its high nutrient, and superior carotenoid and anthocyanin contents (Antonio *et al.* 2011), which are responsible for the stable yellow, orange and purple colors of sweet potato varieties, making them a better alternative for synthetic food colorants (Bovell-Benjamin, 2007). Furthermore, the stability of anthocyanin in purple-fleshed sweet potato has been confirmed at steaming and baking temperatures (Kim *et al.* 2012). Thus, purple sweet potato can be used as a natural colorant in bakery, and noodle products (Hathorn *et al.* 2008). In this study, the effect of purple sweet potato powder (PSPP) supplementation; and α-amylase (AM) and hemicellulase (HC) treatments on bread making quality were examined. Moreover, the effect of PSPP- supplementation on the quality of fresh pasta was also determined.

Materials and methods

Bread treatments and evaluation

Bread making tests were performed following the no-time method using a standard wheat (Camellia) bread formulation as the control according to Yamauchi *et al.* (2001). For the PSPP-supplemented treatments, 4% of the original wheat flour content of the control was replaced. While for the enzyme treatment, optimum amounts of 0.025 g AM and 0.05 g HC were added to the formulation. The dough was mixed to just beyond peak development, weighed, rounded, and incubated for 20 min at 30^{o}C and 75 % relative humidity (RH) in a fermentation cabinet, panned and proofed for 70 min at 38^{o}C and 85 % RH. Gas retention of dough (GRD) and gassing power (GP) of proofed dough were evaluated by measuring the maximum expansion volume at 0 to 100kPa, and gas production at 30^{o}C for 3 h using a Fermograph II, respectively. Meanwhile, the 100 g proofed dough was baked at 180^{o}C for 25 min and the specific loaf volume (SLV) of the bread was measured by the rapeseed displacement method in accordance with Yamauchi *et al.* (2001). Photographs of bread and images of bread crumbs were recorded using a digital camera and scanner, respectively. Color of the bread crust and crumb were determined using a colorimeter. Moreover, fiber and damaged starch contents of bread were analyzed using the AOAC official method and Megazyme assay kit based on method of Gibson *et al.* (1991), respectively.

Physico-chemical evaluation of bread and doughs

Texture properties of 3x3 cm bread crumbs were measured by compressing twice at a speed of 1 mm/s using a special cube plunger up to 50% strain rate with a creep meter as presented by Yamauchi *et al.* (2001). Firming rate of bread was calculated based on the change in hardness during storage. Amylose content of bread crumbs was analyzed using a Megazyme assay kit based on the method of Gibson *et al.* (1996). On the other hand, the enthalpy of retrogradation was determined using a differential scanning calorimeter. Changes in moisture content of bread were determined using the AOAC official method (AOAC, 2000). Dough and bread structures just after mixing proofing and baking were evaluated using scanning electron microscope (Santiago *et al.* 2015). Ultimately, sensory properties of PSPP-supplemented bread were analyzed using quantitative descriptive analysis.

Fresh pasta treatments

Raw pasta was prepared using the following formulation as control: 200g Yumehiryu wheat flour, 3g salt, 3g olive oil and 65g water. For the supplemented treatments, 2.5, 5.0, 7.5, 10% of the original wheat flour was replaced with purple sweet potato powder (PSPP). All ingredients were mixed using a food processor and extruded though dice no.15 using a pasta machine (SIRIOMATIC TR-5, Imperia Corporation, Sant'Ambrogio di Torino, Italy). The extruded noodles were cut into approximately 20cm strips and stored for 2 hours at 20 ℃ in a polyethylene bag. Raw noodle strips were boiled for 3 and 7 min, and cooled in a water bath at 20 ℃ for 3min.

Physico-chemical evaluation of fresh pasta

Moisture content of the raw and boiled noodles was determined based on the AOAC official method (AOAC, 2000). After removing the excess water, boiled noodles were weighed to determine the cooking weight gain (CWG) expressed as percentage of initial dry matter. The boiled noodles were collected and dried in an air oven at 135ºC. The remaining dry matter was weighed to determine the cooking dry matter loss (CDML) which was also expressed as percentage of the initial dry matter. Texture properties of raw and boiled fresh pasta were measured by compressing twice at a speed of 0.5 mm/s using a wedge plunger, up to 50% strain rate with a creep meter. Sensory properties of PSPP-supplemented fresh pasta were evaluated and then compared with the control using quantitative descriptive analysis.

Statistical analysis

All data were statistically analyzed using SPSS for Windows (ver. 17.0). ANOVA and Tukey's multiple range test were performed to compare means at a 5% significance level. Pearson's bivariate test was used to evaluate the correlation of parameters.

Results and Discussion

Bread and dough qualities

Results showed that the PSPP dough had significantly lower GRD than the control and PSPP+AM+HC which can be attributed to the absence of gluten protein, and high fiber and damaged starch content, resulting in a weaker gluten network (Hathorn *et al.* 2008). On the other hand, GP of PSPP+AM+HC dough was significantly higher than the doughs of PSPP and control ($p<0.05$). Moreover, PSPP+AM+HC bread had a significantly higher SLV than the control and PSPP bread ($p<0.05$). These improvements in GRD, GP, and SLV of PSPP+AM+HC bread can be attributed to the activities of AM and HC, which resulted in the decomposition of damaged starch, including the gelatinized starch of PSPP and hemicellulose into fermentable sugars that were used by the yeast for increased gas production (Goesaert *et al*. 2009). These activities were evidenced by the significantly lower damaged starch and hemicellulose content of PSPP+AM+HC dough than the PSPP and control doughs.

In addition, PSPP supplementation and enzyme treatments resulted in darker crust as evidenced by the significantly lower L*, a* and b* values of PSPP+AM+HC ($p<0.05$) Darker crust can be attributed to the increased concentration of reducing sugars, which promote the Maillard reaction, resulting in the intensification of bread flavor and browning (Goesaert *et al*. 2009). On the other hand, the L* and b* values of the control bread crumb were significantly higher than the PSPP and PSPP+AM+HC breads ($p<0.05$), while the a*value of the control crumb was significantly lower than the bread crumb of other treatments ($p<0.05$). These results indicate a darker and purple crumb color of PSPP supplemented bread which can be attributed to the natural dark purple color of the anthocyanin pigments.

Physico-chemical properties of bread and doughs

The PSPP bread had significantly higher hardness, gumminess and chewiness than the control and PSPP+AM+HC breads ($p<0.05$), which can be credited to the 54% damaged starch content of PSPP that forms cross-links with the protein network during baking and increases in the number and strength during storage, causing crumb hardening (Martin *et al.* 1991). Furthermore, PSPP bread had a significantly higher firming rate than the control whereas the PSPP+AM+HC bread had the lowest. The significantly lower firming rate of PSPP+AM+HC bread agrees with its significantly lower amylose content and enthalpy of retrogradation and can be related with the anti-staling property of AM and HC ($p<0.05$). On the other hand, cohesiveness of PSPP+AM+HC bread was significantly lower than the control and PSPP bread ($p<0.05$). The activity of AM results in the degradation of mainly damaged starch of wheat flour and gelatinized starch of PSPP into simple sugars, decreasing the amount of available starch retarding the retrogradation of gelatinized starch gel in bread (Goesaert *et al.* 2009). Moreover, these saccharide products of AM hydrolysis interfere with starch-protein interactions, resulting in fewer crosslinks as shown in the structure PSPP+AM+HC dough and bread just after proofing and baking respectively, thus reducing the firming rate (Martin *et al.* 1991; Martin and Hoseney, 1991). Ultimately, enzyme treatment of PSPP supplemented bread resulted in softer bread which is liked very much by the judges. The enhanced textural properties, enthalpy of amylopectin retrogradation and bread structure indicate a more acceptable bread that may lead to an increased utilization of purple sweet potato in the baking industry.

Moisture content and cooking properties of fresh pasta

The higher amount of PSSP supplementation resulted in higher moisture content of raw fresh pasta which can be attributed to the water holding capacity of the inherent sugar content and damaged starch content of PSPP. Similarly, all boiled PSPP supplemented fresh pasta had significantly higher moisture content than the control ($p<0.05$) related to the water absorbing capacity of sugar and damaged starch present in PSPP. In terms of cooking properties, results showed that the cooking weight gain (CWG) of all the PSPP supplemented fresh pasta after boiling for 3 and 7 min were significantly lower than the control ($p<0.05$). Decrease in CWG can be can be attributed to the loss of dry matter during cooking as corroborated by the significant inverse correlation of the CWG of PSPP-supplemented fresh pasta with their CDML. In this regard, CDML of all PSPP supplemented fresh pasta were all significantly higher than the control

(p<0.05). These observations indicate the solubility of the high sugar, damaged starch and anthocyanin content of PSPP in the fresh pasta into the water during boiling.

Physico-chemical properties of raw and boiled of fresh pasta

Results showed that the hardness, gumminess, chewiness and cohesiveness of raw and boiled fresh pasta decreased with the increased concentration of supplemented PSPP which can be attributed to their significantly higher moisture content caused by the higher water holding and absorbing capacity of PSPP. On the other hand, springiness of raw fresh pasta increased with the higher amount of PSPP supplemented, related to the elasticity of gelatinized PSPP.

In terms of the color properties of raw and boiled fresh pastas, results showed that L* and b* value of raw and boiled fresh pasta decreased whereas a*value increased with higher amount of PSPP supplemented which can be attributed to the intrinsic dark purple anthocyanin content of PSPP. On the other hand, an increase in L* value decrease in a* and b* value were observed as effect of boiling indicating loss of anthocyanin related to its solubility in water.

Sensory properties of PSPP-supplemented fresh pasta

Fresh pastas were perceived to have no purple color for the control to extremely strong purple color for the 10% PSPP-supplemented fresh pasta. The sweet potato aroma was not perceived in the control, whereas, it was barely perceivable in the 2.5 and 5.0% PSPP fresh pasta, and slightly perceivable 7.5 and 10% PSPP fresh pastas. On the other hand, the judges evaluated that the sweet potato flavor of the fresh pastas ranged from not perceivable for the control to moderately perceivable for the 10% PSPP.

The hardness of the control fresh pasta was rated to be slightly hard, whereas, the 2.5, 5.0 and 7.5 % PSPP were evaluated as slightly soft, and 10% PSPP was judged as soft. All fresh pastas were perceived to have moderate elasticity and cohesiveness. The judges' perception of the hardness to show much difference among all samples considerably correlates with the hardness on texture properties measured using the creep meter.

The judges slightly disliked the 2.5% PSPP, whereas the control, 5.0%, and 10.0% PSPP were neither liked nor disliked. Ultimately, the 7.5% PSPP was liked slightly and perceived as the most acceptable among all fresh pasta treatments.

Conclusion and consideration

Substitution with PSPP in bread results in acceptable light purple color, attributable to the intrinsic anthocyanin content. This also results in low GRD and SLV, and high firming rate related to the lack of gluten protein as well as high damaged starch and fiber contents of PSPP. Moreover, high damaged starch content of PSPP caused greater starch-gluten interaction, as shown by its dough structure. In terms of sensory properties, PSPP supplementation resulted in slightly hard bread perceived to have moderate purple color, sweet potato aroma and flavor.

On the other hand, the addition of AM and HC to the PSPP dough improved the GRD, GP, and SLV of the resultant bread. Moreover, treatment with AM and HC resulted in bread with lower firming rate, enthalpy change for retrogradation, amylose content, rupture force and energy, and moisture loss during storage related to the anti-staling properties of AM and HC. Enzyme treatments also resulted in lower starch-gluten interaction, as shown by the dough and bread structures. Ultimately, enzyme treatment resulted in softer bread than the control and PSPP which was very much liked by the judges. The enhanced bread making qualities, textural properties, enthalpy change for retrogradation and structure indicate a more acceptable bread, potentially leading to the increased utilization of purple sweet potato in the baking industry.

PSPP-supplementation improved the water holding and absorbing capacities of fresh pasta resulting in softer texture as evidenced by the inverse correlation of their moisture content with hardness, rupture force and rupture energy. Moreover, PSPP provides higher amount of gelatinized starch resulting in softer and more elastic raw fresh pasta. Ultimately, PSPP provides dark purple color attributable to the intrinsic anthocyanin content. Sensory evaluation shows that PSPP-supplementation results in fresh pasta with a slight to extremely strong purple color, barely to slightly perceivable sweet potato flavor, barely to moderately perceivable sweet potato taste, slightly soft to soft firmness, and moderate elasticity and cohesiveness. Furthermore, the overall acceptability of the 5% and 10% PSPP were neither liked nor disliked along with the control, whereas the 7.5% PSPP has a slightly higher acceptability. These results indicate that PSPP-supplementation gives rise to acceptable fresh pasta that may potentially lead to the increased utilization of PSPP in noodle processing.

This study proved that purple sweet potato is a stable natural colorant that imparts acceptable color to bread and fresh pasta. Further utilization of purple sweet potato powder in other baked products like cake, confectioneries, steamed bread can be done. In addition, the determination of the effects of purple potato and purple yam substitution in baking and noodle processing should be explored and compared with purple sweet potato powder. Ultimately, the antioxidant and other functional property analysis of colored non-cereal energy crops-supplemented bread and noodle products should be done to establish the potential health benefits of the products to consumers.

References

Antonio, G.C., Takeiti, C.Y., de Oliveira, R.A. and **Park, K.J.** (2011). Sweet Potato: Production, morphological and physicochemical characteristics and technological process. *Fruit, Veg. Cereal Sci. Biotech.*, **5**, 1-18.

AOAC. (2000). “Official methods of analysis”, 17th ed. AOAC International, Gaithersburg, MD.

Bovell-Benjamin, A.C. (2007). Sweet Potato: A review of its past, present, and future role in human nutrition. *Adv. Food Nutr. Res.*, **52**, 1–59.

Gibson, T.S., Al Qalla, H. and **McCleary, B.V.** (1991). An improved enzymatic method for the measurement of starch damage in wheat flour. *J. Cereal Sci.*, **15**, 15-27.

Gibson, T.S., Solah, V.A. and **McCleary, B.V.** (1996). A procedure to measure amylose in cereal starches and flours with Con A. *J. Cereal Sci.*, **25**, 111-119.

Goesaert, H., Slade, L., Levine, H. and **Delcour, J.A.** (2009). Amylases and bread firming – an integrated view. *J. Cereal Sci.*, **50**, 345-352.

Hathorn, C.S., Biswas, M.A., Gichuhi, P.N. and **Bovell-Benjamin, A.C.** (2008). Comparison of chemical, physical, micro-structural, and microbial properties of breads supplemented with sweet potato flour and high-gluten dough enhancers. *LWT- Food Sci. Technol.*, **41**, 803-815.

Kim, H.W., Kim, J.B., Cho, S.M., Chung, M.N., Lee, Y.M., Chu, S.M., Che, J.H., Kim, S.N., Kim, S.Y., Cho, Y.S., Kim, J.H., Park, H.J. and **Lee, D.J.** (2012). Anthocyanin changes in the Korean purple-fleshed sweet potato, Shinzami, as affected by steaming and baking. *Food Chem.*, **130**, 966–972.

Lu, G. and **Gao, Q.** (2011) Use of sweet potato in bread and flour fortification. In "Flour and breads and their fortification in health and disease prevention," ed. by V.R. Preedy, R.R. Watson and V.B. Patel. Academic Press, Elsevier, pp. 407-416.

Martin, M.L., Zeleznak, K.J. and **Hoseney, R.C.** (1991). A mechanism of bread firming. I. Role of starch swelling. *Cereal Chem.*, **68**, 498-502.

Martin, M.L. and **Hoseney, R.C.** (1991). A mechanism of bread firming. II. Role of starch hydrolyzing enzymes. *Cereal Chem.*, **68**, 503-507.

Santiago, D.M., Matsushita, K., Noda, T., Tsuboi, K., Yamada, D., Murayama, D., Koaze, H. and **Yamauchi, H.** (2015). Effect of purple sweet potato powder substitution and enzymatic treatments on bread making quality. *Food Sci. Technol. Res.*, **21**, 159-165.

Yamauchi, H., Nishio, Z., Takata, K., Oda, Y., Yamaki, K., Ishida, N. and **Miura, H.** (2001). The bread-making quality of a domestic flour blended with an extra strong flour and staling of the bread made from the blended flour. *Food Sci. Technol. Res.*, **7**, 120-125.