Color, cooking properties and texture of yellow alkaline noodles enriched with millet and corn flour


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Abstract
The objective of this study was to investigate the effect of corn flour and millet flour on color, cooking properties and texture of yellow alkaline noodle (YAN). Corn flour and millet flour were added to wheat flour at different level viz. 0, 5, 10, 20, 30% (w/w), respectively. The color, cooking properties, texture and sensory value of these sample noodles were tested. The results showed that corn flour and millet flour almost had same effect on qualities of YAN. The L* value of fresh noodle declined slightly as the addition level of corn and millet flour were increased. The yellow index b* value increased with addition level of corn or millet flour, maximal at 30%. The ratio of broken-down noodle, water uptake and cooking lose increased with increase in the addition level of corn and millet flour. The ratio of broken-down noodle exceeds 10% when the addition level was beyond 10% (w/w). Total sensory score and noodle adhesiveness, firmness and tensile declined as the addition level was increased. On the basis of color, textural and sensory characteristics, the addition level at 5-10% (w/w) was found to be acceptance for the preparation of corn or millet blending flour YAN.

Keywords
Yellow alkaline noodle
Color
Cooking property
Texture
Corn flour
Millet flour

Introduction
Flour noodles are the most widely consumed common wheat (Triticum aestivum L.) product in China, representing about 40 % of national wheat consumption. Chinese or cantonese style yellow alkaline noodles (YAN) dominate the Asian market and are made using simple ingredients; flour, water, a combination of alkaline salts and sodium chloride. Bright yellow color and medium to high viscoelasticity are desirable for YAN (Morris et al., 2000). Color is a key quality trait (Mares and Campbell, 2001) because of the visual impact at the point of sale. The yellow color of alkaline noodles is attributed to the presence of naturally occurring flavones in flour (Fortmann and Joiner, 1978). These compounds are colorless at acidic or neutral PH, but appeared yellow under alkaline ambient (Miskelly 1996; Wang et al., 1995). Asenstorfer et al. (2006) further identified four flavone-C-diglycosides that contribute to the yellow color. Some yellow pigments, such as carotenoids, also contributed to the yellowness of YAN. Hu et al. (2006) reported that the yellow value of YAN was significant positively correlated to flour carotenoid content. In order to achieve bright yellow color, noodle manufacturers often add pigments such as tartrazine, sunset yellow and b-carotene because there is insufficient natural pigmentation to meet customer expectations (Asenstorfer et al., 2006).

However, customers prefer natural flour noodle.
Corn and millet are widely planted in China and its flours are very popular in human food. It was reported that corn had much higher content of phenolics, ferulic acid, and flavonoid, which have a significant antioxidant (Adom and Liu, 2002; Plate and Gallaher, 2005). Millet grains are a highly nutritious staple crop and rich in carotenoid, vitamin E, and mineral elements. Corn and millet are also rich in dietary fiber, and diets rich in fiber could reduce the risk from coronary heart disease, cancer, obesity and diabetes (Bultriss, 2008). Since corn and millet are gluten-free, its use has been primarily centered on corn batter or millet porridge. However, interest in developing alternative uses for this nutrient-rich commodity is underway. Quality characteristics of bread, steamed bread and pasta made with corn blending flour have been studied (Ugarčić-Hardi et al., 2006; Dimitrios and Constantina, 2009; Feng and Sun, 2013). However, to our knowledge, there are no reports about YAN made with corn or millet blending flour. As we all know, apart from the health benefit, the carotenoid pigment is yellow color and has significant positive correlation with yellowness of YAN. It is reported that millet and corn had a higher carotenoid concentrations than wheat (Xue and Michael, 2007; Liu and Lu, 2013). Hatcher et al. (2005) investigated the quality characteristics of YAN enriched with hull-less barley flour and reported
that addition of durum flour, rich naturally occurring yellow pigments, at even the 25% level would improve color characteristics (Hatcher et al., 2009). The yellow $b^*$ value of pasta has been increased by adding corn flour to common wheat flour (Ugarčić-Hardi et al., 2006). The objectives of this paper were to investigate the influence of blending corn and millet flour on color and cooking properties of YAN, and provide useful information for bright yellowness and nutrient-rich noodle making.

**Materials and Methods**

**Grain preparation and characterization of grain and flour properties**

The wheat variety ‘Yumai49-198’ was harvested from experimental stations of Henan Agricultural University in the year 2012, and it was used as a regular raw material for the yellow alkaline noodle production. The sample was cleaned and tempered to 14.5% moisture content overnight. Milling was performed on a Brabender Junior laboratory mill based on Approved Method 26-21A (AACC, 1995). Commercial millet flour and corn flour were purchased on the local market. Wheat ‘Yumai49-198’ was served as both the control and as the base wheat flour to which millet and corn flours was added. Grain hardness was measured on 300-kernel samples with a Perten SKCS 4100 (Perten Instruments, Springfield, IL), following the manufacturer’s instructions. Grain and flour protein contents were determined with a Kjeltec 2300 analyzer unit (Kjeltec2300, Foss, Switzerland). Dough development time (DT) and stability time (ST) were evaluated using an E-Farinograph (Brabender, Duisburg, Germany), following Approved Method AACC 54–21 (AACC, 1995). Corn flour and millet flour were added to the wheat flour at the level of 5%, 10%, 20% and 30% (w/w), respectively. Sample marks are as follow: CK (100% wheat flour), CM5 (5% corn flour : 95% wheat flour), CM10 (10% corn flour : 90% wheat flour), CM20 (20% corn flour : 80% wheat flour), CM30 (30% corn flour : 70% wheat flour), MM5 (5% millet flour : 95% wheat flour), MM10 (10% millet flour : 90% wheat flour), MM20 (20% millet flour: 80% wheat flour), MM30 (30% millet flour : 70% wheat flour).

**Color measurement**

Noodle sheet color was measured with a chromometer (model410, Minolta Camera Co., Ltd., Osaka, Japan) with a 50 mm (diameter) measuring tube, using a white tile background. $L^*$, $a^*$, and $b^*$ values denote lightness (white-black), red-green, and yellow-blue scales, respectively. Three color readings per noodle sheet were made at 0, 2, 4 hr. Measurements were made three times, each at a different location on the consistent (same) side of the surface of the noodle sheet. Noodle sheets were stored in plastic bags at 25°C between color readings. There were two replicate noodle sheets for each treatment.

**Preparation of yellow alkaline noodle**

Yellow alkaline noodles were prepared using a method similar to that of Morris et al. (2000), with modifications. Dough was made from 200 g of flour (14% moisture basis) by adding 0.5% (w/v) sodium carbonate, 2% sodium chloride solution, at the absorption rate of 37% in a pin mixer 4 min. Dough was rested for 1 hr in a plastic bag before sheeting, then folded and sheeted three times with a 5 mm gap at 25°C. Five sheeting reductions were applied until a 1.2 mm sheet was obtained. When the reduction sheeting was completed, the color of the noodle sheet was measured with a chromometer.

**Cooking properties**

The properties of the cooked yellow alkaline noodle were examined. The following parameters were determined: broken rate of cooked noodles, cooking loss (%), water uptake, noodle texture and noodle sensory value. Water uptake was calculated by subtracting the initial sample weight (20 g) from the cooked sample weight and dividing by the initial sample weight. Cooking loss is defined as the mass of solids lost into the cooking water during boiling. Broken rate of cooked noodles was calculated using the number of broken noodle strand dividing by the initial sample noodle strand number.

**Noodle texture**

Cooked noodle texture was evaluated by texture profile analysis (TPA) using a TA-XT2 texture analyzer (Stable Micro Systems, UK) within 5 min after cooking. A set of five strands of cooked noodles was placed parallel on a flat metal plate and measured using HDP/PFS metal blade. The settings used were: Pre-Test Speed: 1.0 mm/s, Test Speed: 2.0 mm/s; Post-Test Speed: 1.0 mm/s. From the TPA force–time curve, we determined cohesiveness.

**Noodle firmness**

The firmness of cooked noodles was measured by using a Texture Analyzer, TA. XT2 Plus (Stable Micro Systems, UK) with a 5 kg load cell attached with a 1 mm flat Perspex knife blade. The distance between the blade and the heavy duty platform was set at 30 mm. The settings used were: Pre-Test Speed:
1.0 mm/s, Test Speed: 2.0 mm/s; Post-Test Speed: 1.0 mm/s. The cooked noodles were cut into 70 mm in length and five noodle strands were placed straight and flat adjacent to one another on the centre of heavy duty platform, with the samples positioned at right angles to the blade. The firmness value was taken from the peak of a force-time graph. Eight repeat measures were taken for each noodle formulation.  

**Tensile test for noodles**  
Tensile strength and elasticity of noodles were assessed using a Texture analyser, TA.XT2 model (Stable Micro Systems, UK) fitted with a 5 kg load cell. The distance of the probe to move apart was set at 15 mm. The settings used were: Pre-test speed: 1.0 mm/s; Test speed: 3.0 mm/s; Post-test speed: 10.0 mm/s. Ten repeat measures were taken for each noodle formulation.  

**Noodle score**  
Noodle score included colour score (weighting 10), appearance (10), firmness (20), elasticity (25), viscosity (25), smoothness (5) and taste/flavour (5). The experiment was performed at room temperature 20–25°C and relative humidity 50–60%.

**Statistical analysis**  
Data were subjected to analysis of variance (ANOVA) using SPSS (Statistical Program for Social Science) software.  

**Results and Discussion**  
**Dough properties of blending flours**  
As shown in Table 1, dough water absorption rate decreased with increase in the addition level of corn flour, while the significant difference was only observed between CM30 and CK. As corn flour addition level was increased, dough development time decreased and the significant difference was only observed between CM30 and CK. Compared to CK, corn blending flour decreased dough stability time, but the significant difference was only observed between CM30 and CK. As corn flour addition level increasing, the reason maybe is that noodle darkening became weaken with corn flour addition level increasing. The reason maybe is due to the PPO activity in wheat flour. It is reported that PPO activity was considered the mainly factor affecting the rate of development of undesirable dull brown and gray colors (Davies et al., 2003; Jukanti et al., 2003). All samples noodle sheets were slightly green (negative a' value) and all samples exhibited fairly smooth change in a' value between 0 and 4 hr. Regardless of no obvious regular change among theses treatments, corn blending flour had a lower a' value than CK (apart from CM30 at 4 hr). This results also indicated that noodle darkening became weaken with corn flour addition level increasing. High yellow value was desirable for consumer. As presented in Table 2, the highest b' value was observed in CM30 treatment regardless of the resting time, which indicated that adding corn flour to wheat flour would increase the yellowness of AYN. This was due to the higher carotene content of corn flour as reported by Ugarčić-Hardi et al. (2006) also reported that adding corn flour to wheat flour would increase pasta yellowness. The similar results were also appeared in millet blending flour. The b' value increased dramatically with increase in no gluten. So, blending millet flour with wheat flour could decrease the strength of dough.  

### Yellow alkaline noodle color  
Color is an important quality parameter of YAN. It results from the desirable yellow component and the undesirable brown component. The L', a', b' value of the YAN samples with different level of corn and millet flour are presented in Table 2. The L' is the measure of the bright from black to white. Compared to CK, corn blending flour decreased slightly noodle L' at 0 resting time, while the significant difference was only observed between CM30 and CK. Lightness decreased dramatically between 0 and 2 hr and then continued to decline at a relative slower rate from 2 hr to 4 hr. We also noticed that the difference of L' value between 0 and 4 hr declined with the increase of corn adding level. For example, the difference of L' in CK and CM30 treatment between 0 and 4 hr was 4.41 and 2.84, respectively. The results indicated that noodle darkening became weaken with corn flour addition level increasing. The reason maybe is due to the PPO activity in wheat flour. It is reported that PPO activity was considered the mainly factor affecting the rate of development of undesirable dull brown and gray colors (Davies et al., 2003; Jukanti et al., 2003). All samples noodle sheets were slightly green (negative a' value) and all samples exhibited fairly smooth change in a' value between 0 and 4 hr. Regardless of no obvious regular change among theses treatments, corn blending flour had a lower a' value than CK (apart from CM30 at 4 hr). This results also indicated that noodle darkening became weaken with corn flour addition level increasing. High yellow value was desirable for consumer. As presented in Table 2, the highest b' value was observed in CM30 treatment regardless of the resting time, which indicated that adding corn flour to wheat flour would increase the yellowness of AYN. This was due to the higher carotene content of corn flour as compared to that of wheat flour. Ugarčić-Hardi et al. (2006) also reported that adding corn flour to wheat flour would increase pasta yellowness. The similar results were also appeared in millet blending flour. The b' value increased dramatically with increase in

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**Table 1. Dough properties of wheat flour with corn flour and millet flour supplements**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Water absorption (%)</th>
<th>Development time (min)</th>
<th>Stability time (min)</th>
<th>Degree of softness (FU)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>53.2a</td>
<td>2.4b</td>
<td>14.2b</td>
<td>59b</td>
<td></td>
</tr>
<tr>
<td>CM5</td>
<td>53.2a</td>
<td>1.4b</td>
<td>2.4b</td>
<td>52a</td>
<td></td>
</tr>
<tr>
<td>CM10</td>
<td>52.6b</td>
<td>1.4b</td>
<td>2.4b</td>
<td>52a</td>
<td></td>
</tr>
<tr>
<td>CM20</td>
<td>53.6b</td>
<td>1.2b</td>
<td>1.9b</td>
<td>55a</td>
<td></td>
</tr>
<tr>
<td>CM30</td>
<td>53.2b</td>
<td>1.3b</td>
<td>2.1b</td>
<td>62a</td>
<td></td>
</tr>
<tr>
<td>CK</td>
<td>53.2a</td>
<td>2.5a</td>
<td>2.7a</td>
<td>59a</td>
<td></td>
</tr>
<tr>
<td>MM5</td>
<td>53.5a</td>
<td>1.4b</td>
<td>2.4b</td>
<td>159a</td>
<td></td>
</tr>
<tr>
<td>MM10</td>
<td>53.5a</td>
<td>1.4b</td>
<td>2.1b</td>
<td>144a</td>
<td>234a</td>
</tr>
<tr>
<td>MM20</td>
<td>53.1a</td>
<td>1.4b</td>
<td>2.1b</td>
<td>104a</td>
<td>25a</td>
</tr>
<tr>
<td>MM30</td>
<td>53.1b</td>
<td>1.4b</td>
<td>1.7b</td>
<td>139a</td>
<td></td>
</tr>
</tbody>
</table>

* Mean value ± standard deviation (n = 2)
the addition level of millet flour and the highest b' was observed in MM30.

**Cooking properties of YAN**

Ratio of broken-down noodle after boiling, water uptake and cooking lose are the main indexes of cooking properties of YAN. As shown in Table 3, Ratio of broken-down noodle increased significantly with the addition level of corn flour or millet flour increasing, and the highest ratio was showed in treatment CM30 and MM30. It is generally accepted that ratio of broken-down noodle should not exceed 10%. In this study, only when corn flour or millet flour was below 10:100, ratio of broken-down noodle was not exceed 10%. With addition level of corn flour or millet flour increasing, water uptake increased and the highest value was showed in treatment CM30 and MM30, respectively. However, the significant difference was only observed between CK and CM30, CK and MM30. Cooking loss exhibited the same trend as water uptake with increasing corn and millet flour level. Cooking loss is undesirable and according to Wu et al. (1987), it should not exceed 10% of the dry weight. In this study, cooking loss of treatment MM30 is 12.27%. The CK had a low cooking loss and the blend flour had a high cooking loss. The type of ingredients in the noodle mix influences the loss of solubles and solids during cooking, and it has been reported that a compact texture of the pasta often results in less cooking loss than the loose textured pasta (Del Nobile et al., 2005). Fortification with non-traditional ingredients tends to weaken the gluten, which otherwise forms a strong protein-starch network (Petitot et al., 2010).

**Sensory scores of YAN samples**

Mean scores of the sensory parameters and the total quality scores are shown in Table 4. The scores of color, palate, taste and flavor had an increasing trend with the addition level of corn flour increasing. Regardless of no significant difference among all the treatment for taste & flavor, the panel members commented that the noodle with high level corn flour addition had a pleasant odor and flavor. This taste and flavor are due to the corn flour flavor. The values of appearance, elasticity, stickiness, smoothness and total score declined with the ratio of corn flour addition increasing and the lowest value was observed on treatment CM30. There was no significant difference among all the treatments for appearance and elasticity. The low elasticity was due to that corn flour free gluten could hinder the formation of gluten network. The same trend was also observed on the treatment with millet flour addition, apart from the taste and flavor parameter. Regardless of no significant difference among all the treatments for taste & flavor, the panel members commented that the noodle with millet flour addition did not have a pleasant odor and flavor as corn flour.

**Texture parameters of YAN samples**

Adhesiveness, a measure of the stickiness of the noodle while eating was found to be the maximum (103.0) for the control YAN. The various treatments lowered the stickiness levels, and the treatment CM30 and MM30 had the lowest value, 69.8 and 71.6, respectively. It was reported that noodle firmness was decided by the internal structures of the cooked product (Edwards et al., 1993). Firmness, a measure of the toughness of cooked noodle, showed the highest value on CM5 and MM5, respectively. The value of firmness declined as the percentage of corn flour or millet flour addition had a pleasant odor and flavor. This taste and flavor were due to the corn flour flavor. The values of appearance, elasticity, stickiness, smoothness and total score declined with the ratio of corn flour addition increasing and the lowest value was observed on treatment CM30. There was no significant difference among all the treatments for appearance and elasticity. The low elasticity was due to that corn flour free gluten could hinder the formation of gluten network. The same trend was also observed on the treatment with millet flour addition, apart from the taste and flavor parameter. Regardless of no significant difference among all the treatments for taste & flavor, the panel members commented that the noodle with millet flour addition did not have a pleasant odor and flavor as corn flour.

**Table 2. Color parameters of YAN with corn flour and millet flour supplements**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Rest time 0 h</th>
<th>Rest time 2 h</th>
<th>Rest time 4 h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L*</td>
<td>a*</td>
<td>b*</td>
</tr>
<tr>
<td>CK</td>
<td>85.22a</td>
<td>-1.96a</td>
<td>15.97e</td>
</tr>
<tr>
<td>CM5</td>
<td>83.93b</td>
<td>-2.45c</td>
<td>19.03c</td>
</tr>
<tr>
<td>CM10</td>
<td>85.09a</td>
<td>-2.02a</td>
<td>19.81c</td>
</tr>
<tr>
<td>CM20</td>
<td>84.57ab</td>
<td>-2.58c</td>
<td>24.17b</td>
</tr>
<tr>
<td>CM30</td>
<td>84.36b</td>
<td>-2.26b</td>
<td>25.71a</td>
</tr>
<tr>
<td>CK</td>
<td>85.22a</td>
<td>-1.96a</td>
<td>15.97e</td>
</tr>
<tr>
<td>MM5</td>
<td>83.39b</td>
<td>-2.17b</td>
<td>20.93c</td>
</tr>
<tr>
<td>MM10</td>
<td>85.19a</td>
<td>-2.03b</td>
<td>20.70c</td>
</tr>
<tr>
<td>MM20</td>
<td>86.01a</td>
<td>-2.56c</td>
<td>21.65b</td>
</tr>
<tr>
<td>MM30</td>
<td>85.26b</td>
<td>-2.34c</td>
<td>23.33a</td>
</tr>
</tbody>
</table>

* Mean value ± standard deviation (n = 6)

**Table 3. Cooking properties of YAN with corn flour and millet flour supplements**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Ratio of broken-down noodle (%)</th>
<th>Water uptake (g/g)</th>
<th>Cooking lose (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>0</td>
<td>1.44b</td>
<td>8.09d</td>
</tr>
<tr>
<td>CM5</td>
<td>5</td>
<td>1.45ab</td>
<td>8.45cd</td>
</tr>
<tr>
<td>CM10</td>
<td>10</td>
<td>1.50ab</td>
<td>8.93bc</td>
</tr>
<tr>
<td>CM20</td>
<td>20</td>
<td>1.55ab</td>
<td>9.45ab</td>
</tr>
<tr>
<td>CM30</td>
<td>27.5</td>
<td>1.58a</td>
<td>9.78a</td>
</tr>
<tr>
<td>CK</td>
<td>0</td>
<td>1.44b</td>
<td>8.09a</td>
</tr>
<tr>
<td>MM5</td>
<td>3</td>
<td>1.47ab</td>
<td>9.32b</td>
</tr>
<tr>
<td>MM10</td>
<td>10</td>
<td>1.51ab</td>
<td>9.56b</td>
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<td>MM20</td>
<td>22.5</td>
<td>1.59ab</td>
<td>9.63b</td>
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<tr>
<td>MM30</td>
<td>30</td>
<td>1.61a</td>
<td>12.27a</td>
</tr>
</tbody>
</table>

* Mean value ± standard deviation (n = 2)
elasticiy. As shown in Table 5, tensile and distance declined with the level of corn flour or millet flour increasing, and the maximum value was observed for the control.

Conclusion

Fortification of wheat flour with corn flour and millet flour can increase the $b^*$ value of YAN. The yellowness $b^*$ value increased with the percentage of corn or millet flour increasing and the highest value was obtained at 30% corn flour or 30% millet flour addition. The cooking properties, such as ratio of broken-down noodle, water uptake and cooking lose increased as the addition level was increased. At the same time, total sensory score and noodle adhesiveness, firmness and tensile declined with addition of supplement increasing. The addition of corn flour and millet flour in the noodle also improves the nutritional quality, since corn flour and millet flour are rich in carotenoids and other nutrient element. Based on these results, the ratio of corn flour or millet flour at less than 10% can be used in the yellow alkaline noodle formulation to produce higher yellowness noodle, without obvious lower noodle texture and sensory value.

References


