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ORIGINAL ARTICLE

# Effect of incorporation of corn byproducts on quality of baked and extruded products from wheat flour and semolina

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**Abstract** The effect of blending level (0, 5, 10, 15 and 20%) of corn bran, defatted germ and gluten with wheat flour on the physico-chemical properties (protein, crude fiber, phosphorus, iron and calcium), baking properties of bread, muffins and cookies, and extrusion properties of noodles and extruded snacks prepared from semolina were examined. Blending of wheat flour and corn byproducts significantly increased the protein, crude fiber, phosphorus, iron and calcium contents. Breads from gluten blends had higher loaf volume as compared to bran and germ breads. Among corn byproducts, gluten cookies were rated superior with respect to top grain. Muffins from germ blends and gluten blends had higher acceptability scores than the bran muffins. Blending of corn bran, defatted germ and gluten at 5 and 10% with wheat flour resulted in satisfactory bread, cookie, and muffin score. Quality of noodles was significantly influenced by addition of corn byproducts and their levels. Corn byproducts blending had significant influence on cooking time, however, gruel solid loss affected non-significantly in case of noodles. Expansion ratio and density of extruded snacks was affected non significantly by blending source and blending level. However, significant effect was observed on amperage, pressure, yield and overall acceptability of extruded snacks. Acceptable extruded products (noodles and extruded snacks) could be produced by blending corn byproducts with semolina upto 10% level.

**Keywords** Corn bran · Defatted germ · Gluten · Wheat flour · Semolina · Bread · Muffins · Cookies · Noodles · Extruded snacks

In India, corn is emerging as third most important crop after rice and wheat. Corn has its significance as a source of a large number of industrial products besides its uses as human food and animal feed. Diversified uses of corn starch industry, corn oil production, baby corns, popcorns, etc., and potential for exports has added to the demand of corn all over world. Corn does possess tremendous potential in terms of feed for dairy, poultry and piggery agro-industries. It has continued to be the leading crop in terms of production and area of land on which it has been produced during the last decade.

The production of corn is constantly increasing due to rising demand from the industries where corn is used as raw material. It is grown as a commercial crop in over 25 countries worldwide. Worldwide production of corn is about 600 million tons a year (Pingali 2001). In India, it was grown on an area of 7.58 mha with 14.70 m ton production and 1,938 Kg/ ha productivity during 2005–06 (Anon 2006). India consumes almost all the corn that it produces. About 50% of the total Indian produce is consumed as poultry feed and about 8% is consumed by the starch industry. Indian corn exports fluctuates around 5 lakh tons annually.

Corn is processed either by wet or dry milling to separate the fractions. Most of the products obtained after milling are used for agricultural and industrial sectors. But the byproducts like bran, germ and gluten are used for animal feed only. The utilization of these byproducts for human consumption is an additional nutritional source and is profitable. Neuman and Wall (1984) and Springsteen et al. (1977) reported that these byproducts have substantial

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amount of fiber, protein and minerals. Polizotto et al. (1983) studied that corn bran had 5.0% protein, 0.5% fat, 17.7% non fiber carbohydrate, 0.5% ash and 76.3% ENDF (Enzymatic neutral detergent fiber) and 86.4% EIR (Enzymatic Indigestible residue) and 7.7% moisture. Blessin et al. (1973) reported that defatted germ flour has possibilities of serving as protein and mineral supplement in a variety of foods as it is rich in minerals and protein with lysine content more than twice than that of normal wheat flour. He also reported that defatted corn germ contained 25% protein, 0.5% fat, 4% fiber, 10% ash. Corn gluten is the concentrated protein co-product (70% protein, db) obtained from wet milling of corn after the germ, oil, bran and starch are extracted. It had 69.4% protein, 4.3% fat, 17.5% starch, 0.6% fiber, 1.9% ash and 7.3% carbohydrate (Neuman and Wall 1984). Purich et al. (1989) also reported a high level of phosphorus, iron and calcium in corn germ.

## Materials and methods

Corn bran, defatted germ and gluten were procured immediately after wet milling from starch industry (Sukhjit Industries, Phagwara, Punjab) and dried at 38 °C for 24 h followed by grinding in hand operated grinder and sifting was done to obtain fine particles of products. Yellow colour and typical flavour of corn gluten was removed by stirring corn gluten in 1:2 ratio with ethyl acetate for 1 h at room temperature. The slurry was filtered through Whatman No. 1 filter paper. The retentate was suspended in distilled water (2:1, water-corn gluten), stirred at 40 °C for 15 min and filtered. Ethyl acetate extraction followed by washing with distilled water was repeated and refiltered (Phillips 1977). The retentate was dried at 35 °C for 24 h and is made into powder and stored in airtight jars.

For noodle making, laboratory extruder (Brabender Co. USA) at 125 °C temperature using die of 4 mm was used. Single Screw laboratory extruder (Brabender Co. USA) at 65, 160 and 160 °C for 1st, 2nd and 3rd zone respectively was used for extruded snacks. The screw speed of 100 rpm was kept constant.

*Blending of samples* Baking properties of blends were assessed by preparing bread, muffins & cookies. Extruded products (noodles and extruded snacks) were processed from wheat semolina blends. Wheat flour and semolina was supplemented with corn bran, defatted corn germ and gluten at different levels ranged from 0% to 20% (0,5,10, 15 and 20%). Physico-chemical characteristics of corn byproducts, blended wheat flour and semolina were determined.

*Physico-chemical characteristics* Protein was determined as per the method described in AACC (2000) and crude fiber as per method in AOAC (1980). Mineral content like calcium, iron were estimated on the basis of atomic absorption and phosphorus were determined as per procedure given in AOAC (1980).

### Baking preparations

a) Bread: Straight dough method (AACC, 2000) with remixing procedure (Irvine and McMullan, 1960) was followed for determining properties of bread.
b) Cookies: For baking cookies from different flour blends, AACC (2000) method was followed.
c) Muffins: For baking muffins, AACC (2000) method for cake preparation was used.

### Extruded products

a) Noodles: Cooking time (minutes), Water absorption ratio, Gruel solid loss (%) and Overall acceptability of noodles was determined (AACC 2000).
b) Extruded snacks: Expansion ratio, density, amperage, pressure, yield and overall acceptability of extruded snacks was determined.

*Evaluation of products* Bread, muffins, noodles and extruded snacks were evaluated organoleptically using 9 point Hedonic scale (Larmond 1970) and cookies using 6 point Hedonic scale.

*Statistical analysis* Experiments were carried out in triplicate and the data was analysed using factorial design (Steel Robert and Torrie 1960).

## Results and discussion

### Physico-chemical characteristics

*Protein* Blending of different levels of corn bran, defatted corn germ and corn gluten significantly affected the protein content of wheat flour. Blending of corn bran with wheat flour resulted in increase in protein content of wheat flour from 10.07% at 0% bran level to 10.54% at 5% bran level. Further protein content decreased as the level of corn bran increased from 10% to 20%. Increasing trend in protein content of wheat flour was observed as the level of defatted corn germ and corn gluten increased from 0% to 20% (Fig. 1). Polizotto et al. (1983) reported 5% protein in corn bran, Yamaguchi and Yamaguchi (1990) reported 20% protein in corn germ and Neuman and Wall (1984) reported 69.4% protein in corn gluten.

*Crude fiber* Wheat flour blends showed a significant variation in crude fiber content. Figure 1 shows that the

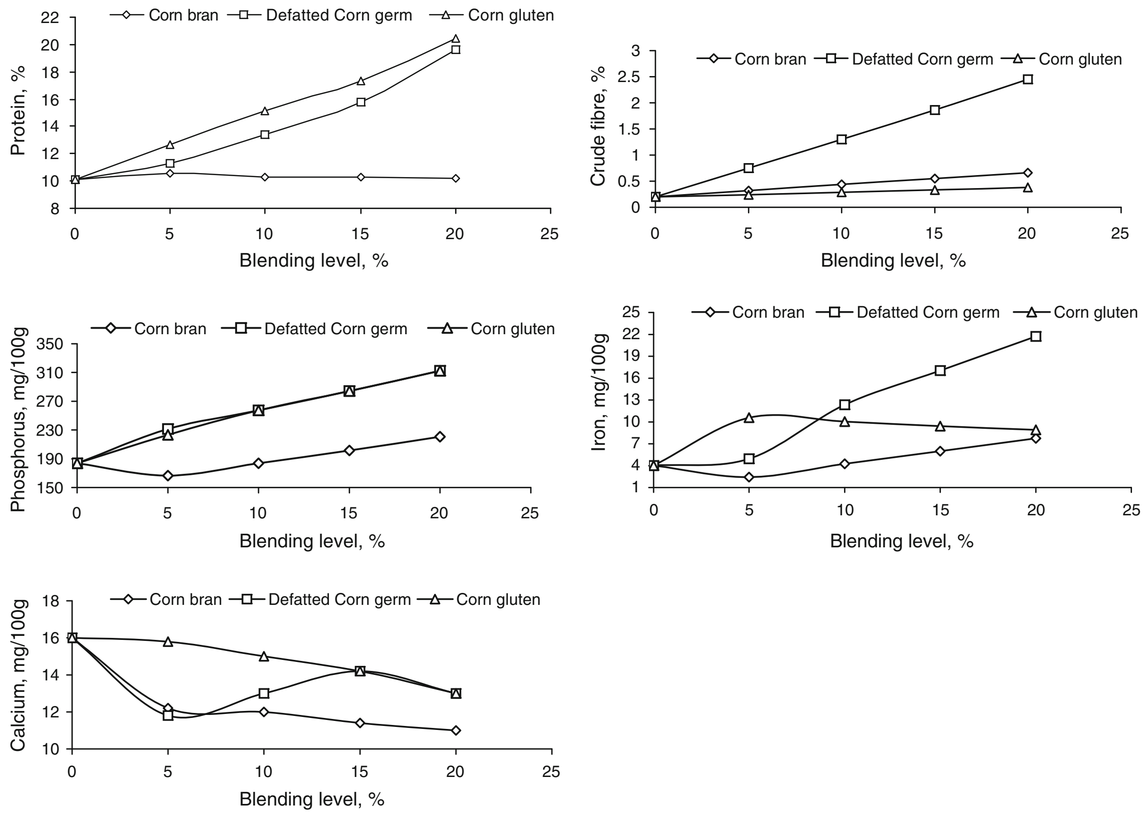


**Fig. 1** Effect of blending varying levels of corn byproducts with wheat flour on change in protein (%), Crude fibre (%), phosphorus(mg/100 g), iron(mg/100 g) and calcium (mg/100 g). * Values are mean of 3 replications

crude fiber in germ blended wheat flour was varied from 0.20% to 2.45% followed by bran blended wheat flour (0.20 to 0.66%) and gluten blended wheat flour (0.20 to 0.38%) as the blending level varied from 0% to 20%.Gupta et al. (1984) also observed that corn germ was the richest source of crude fibre among the corn byproducts.

*Mineral composition* The effect of blending of corn byproducts on phosphorus and iron showed significant increase in their concentration with increase in blending level of corn byproducts from 0% to 20% in wheat flour (Fig. 1). Phosphorus content increased from 183.8 to 312.5 mg/100 g (70.2%) each in defatted corn germ and

**Table 1** Mean values of effect of blending sources and level of corn byproducts with wheat flour on bread making properties

| | Bake absorption, % | Loaf weight, % | Loaf volume, CC | Overall acceptability* |
|---|---|---|---|---|
| Blending source | | | | |
| Corn bran | 68.0$^{a}$ | 147.1$^{a}$ | 510$^{ab}$ | 6.86$^{a}$ |
| Corn germ | 79.8$^{b}$ | 162.0$^{a}$ | 479$^{a}$ | 6.58$^{a}$ |
| Corn gluten | 76.7$^{b}$ | 152.7$^{a}$ | 532$^{b}$ | 6.72$^{a}$ |
| Blending levels (%) | | | | |
| 0 | 62.0$^{a}$ | 139.3$^{a}$ | 560.0$^{a}$ | 8.20$^{a}$ |
| 5 | 77.2$^{b}$ | 153.0$^{a}$ | 561.7$^{a}$ | 7.46$^{b}$ |
| 10 | 77.5$^{b}$ | 156.0$^{a}$ | 511.7$^{bc}$ | 6.83$^{b}$ |
| 15 | 78.8$^{b}$ | 159.1$^{a}$ | 486.7$^{c}$ | 6.10$^{d}$ |
| 20 | 78.6$^{b}$ | 162.3$^{a}$ | 415.0$^{d}$ | 5.00$^{e}$ |
| CD (0.05) | | | | |
| Blending source | 5.21 | NS | 36.9 | NS |
| Blending levels | 6.73 | NS | 47.7 | 0.83 |

Values are mean of 3 replications

* Score out of 9.0

Values having same superscript do not vary significantly from each other

*NS* Non-significant

**Table 2** Mean values of effect of blending sources and level of corn byproducts with wheat flour on cookies and muffins making properties

| | Cookies | | | Muffins | |
|---|---|---|---|---|---|
| | Spread ratio | Top grain* | Overall acceptability** | Specific volume | Overall acceptability*** |
| Blending source | | | | | |
| Corn bran | 4.91[a] | 2.82[a] | 4.16[a] | 1.52[a] | 6.56[a] |
| Corn germ | 4.94[a] | 2.80[a] | 4.44[ab] | 1.53[a] | 7.30[b] |
| Corn gluten | 5.17[a] | 3.00[a] | 4.34[a] | 1.53[a] | 7.12[b] |
| Blending levels (%) | | | | | |
| 0 | 4.90[a] | 4.00[a] | 4.90[a] | 1.52[a] | 8.3[a] |
| 5 | 5.26[a] | 2.66[a] | 4.80[a] | 1.52[a] | 7.2[b] |
| 10 | 5.13[a] | 2.33[c] | 4.46[b] | 1.51[a] | 6.86[b] |
| 15 | 4.19[a] | 3.00[d] | 4.06[c] | 1.53[a] | 6.36[c] |
| 20 | 4.66[a] | 2.33[c] | 3.66[d] | 1.56[a] | 6.23[c] |
| CD (0.05) | | | | | |
| Blending source | NS | NS | 0.23 | NS | 0.35 |
| Blending levels | NS | 0.26 | 0.31 | NS | 0.46 |

Values are mean of 3 replications

* Score out of 4.0 **Score out of 6.0 *** Score out of 9.0

Values having same superscript do not vary significantly from each other

*NS* Non-significant

corn gluten while in case of corn bran blending it increased from 183.6 to 220.6 mg/100 g (20.2%). Maximum increase in iron content was 440.29% (from 4.02 to 21.72 mg/100 g) in case of defatted corn germ while in case of corn gluten it increased from 4.02 to 8.9 mg/100 g (121.39%) and in corn bran blending it increased by 93.03% (from 4.02 to 7.76 mg/100 g). Significant decrease in calcium was observed at higher levels of blending. The calcium content followed a decreasing trend registering decrease of 18.75% each in defatted corn germ and corn gluten blending and 31.25% in corn bran blending (Fig. 1). This may be due to the

**Table 3** Mean values of effect of blending sources and level of corn byproducts with wheat semolina on noodle making properties

| | Cooking time, minutes | Water absorption ratio | Gruel solid loss, % | Overall acceptability* |
|---|---|---|---|---|
| Blending source | | | | |
| Corn bran | 10.2[a] | 3.4[a] | 22.1[a] | 6.9[a] |
| Corn germ | 9.7[ab] | 2.3[b] | 21.6[a] | 6.5[ab] |
| Corn gluten | 8.9[b] | 3.2[a] | 18.6[a] | 6.2[b] |
| Blending levels (%) | | | | |
| 0 | 8.10[a] | 3.04[a] | 18.9[a] | 8.5[a] |
| 5 | 9.40[ab] | 2.83[a] | 18.5[a] | 7.5[b] |
| 10 | 9.82[b] | 2.94[a] | 21.0[a] | 6.6[c] |
| 15 | 10.2[b] | 2.99[a] | 22.7[a] | 5.6[d] |
| 20 | 10.6[b] | 3.04[a] | 23.3[a] | 4.3[e] |
| CD (0.05) | | | | |
| Blending source | 1.13 | 0.44 | NS | 0.45 |
| Blending levels | 1.46 | NS | NS | 0.58 |

Values are mean of 3 replications

* Score out of 9.0

Values having same superscript do not vary significantly from each other

*NS* Non-significant

**Table 4** Mean values of effect of blending sources and level of corn byproducts with wheat semolina on extruded snacks making properties

| | Expansion ratio | Density, g/cm$^3$ | Amperage, Amp | Pressure, Psi | Yield, g/30 s | Overall acceptability* |
|---|---|---|---|---|---|---|
| Blending source | | | | | | |
| Corn bran | 2.13$^a$ | 0.30$^a$ | 5.16$^a$ | 7.61$^a$ | 47.34$^a$ | 6.75$^a$ |
| Corn gluten | 2.00$^a$ | 0.32$^a$ | 4.16$^b$ | 5.06$^b$ | 44.0$^b$ | 7.05$^b$ |
| Blending levels, % | | | | | | |
| 0 | 2.13$^a$ | 0.38$^a$ | 3.0$^a$ | 230$^a$ | 40$^a$ | 8.0$^a$ |
| 5 | 2.14$^a$ | 0.30$^a$ | 5.95$^b$ | 885$^b$ | 49$^{bc}$ | 7.62$^{ab}$ |
| 10 | 2.15$^a$ | 0.29$^a$ | 5.4$^b$ | 795$^{bc}$ | 46.8$^b$ | 7.25$^b$ |
| 15 | 1.95$^a$ | 0.29$^a$ | 4.7$^{bc}$ | 630$^c$ | 44.7$^c$ | 6.55$^c$ |
| 20 | 1.93$^a$ | 0.30$^a$ | 4.25$^c$ | 577.5$^c$ | 42.7$^{ac}$ | 5.07$^d$ |
| CD (0.05) | | | | | | |
| Blending source | NS | NS | 0.75 | 179.7 | 3.28 | 0.28 |
| Blending levels | NS | NS | 1.18 | 284.2 | 3.67 | 0.44 |

Values are mean of 3 replications

* Score out of 9.0

Values having same superscript do not vary significantly from each other

*NS* Non-significant

fixation of minerals by fiber at higher levels of fiber supplementation.

## Baking properties

*Bread* The effect of blending of corn byproducts at varying levels with wheat flour on bread making properties are given in Table 1. Increase in bake absorption (Water absorbed by flour during mixing of flour) was noticed at higher blending level. Among the corn byproducts, defatted corn germ blends had higher bake absorption (79.8%) followed by corn gluten (76.7%) and corn bran (68.0%). Blending source and blending level have significant effect on bake absorption. High fiber and protein content in corn byproducts may be the contributing factor for high water absorption. Loaf weight was found to be increased from 139.3% to 162.3% as the corn byproducts blending increased from 0% to 20%. Maximum loaf weight of 162.04% was observed in defatted corn germ and minimum (147.12%) in corn bran blending. Blending source and blending level had non significant effect on loaf weight. Loaf volume decreased with increase in blending level. Blending source as well as blending level had significant effect on loaf volume. Higher loaf volume was observed in corn gluten blended loaves as compared to loaves containing corn bran and corn defatted germ. Shogren et al. (1981) also reported a decrease in loaf volume with increase in level of fiber and concluded that possible reason for this is the dilution of gluten protein by addition of fiber.

Table 1 reveals that wheat flour bread had higher acceptability than the breads from corn byproducts blends. The overall acceptability score was 8.2 for wheat flour bread while it decreased to 5.0 as the blending level increased to 20%. Overall acceptability score for corn bran, defatted germ and gluten breads were 6.86, 6.58 and 6.72. Blending source had non significant and blending level had significant effect on overall acceptability. The decrease in acceptability score was due to change in colour and reduced loaf volume by incorporation of corn byproducts.

*Cookies* Cookies characteristics of blended samples are depicted in Table 2. Corn gluten cookies had maximum spread ratio among the corn byproducts followed by corn germ cookies and corn bran cookies. With the incorporation of these corn byproducts at varying levels to wheat flour, there was non-significant variation in the spread ratio of cookies. A slight increase in spread ratio of cookies was observed at 5 and 10% level. Diane and Zabik (1978) reported that increasing the level of red and white bran decreased the cookie spread ratio. Among the corn byproducts blended cookies, gluten blended cookies observed to be superior with regard to top grain score. The level of blending had significant effect in decreasing the top grain score of cookies while blending source had non significant effect on top grain score. Kissell et al. (1979) had reported a significant decrease in top grain when brewer's spent grain was used as a source of fiber in cookies. Both blending source and blending level had significant effect on overall acceptability of cookies prepared from wheat flour and corn byproducts.

*Muffins* The effect of corn byproducts blending on muffin making properties (specific volume and overall accept-

ability) are given in Table 2. Levels of blending and blending source had non-significant effect on specific volume whereas significant effect was observed on overall acceptability of cookies. Corn germ muffins (7.30) and gluten muffins (7.12) had higher acceptability scores than the corn bran muffins (6.56). Polizotto et al. (1983) observed that muffins with corn and wheat brans were the only acceptable products in comparison to muffins with oat, rice and soy bran. Upto 10% blending level, the product remained highly acceptable. Thereafter, a significant decrease in score was noted.

Extruded products

*Noodles* The properties of noodles prepared from semolina and corn byproducts are illustrated in Table 3. Corn byproducts and their level had significant influence on cooking time. Mean cooking time for corn bran, germ and gluten blended noodles was 10.2, 9.7 and 8.9 min, respectively. The cooking time increased as the blending level increased from 0% to 20%. Water absorption ratio was more in noodles from bran blends (3.4) in comparison to germ noodles (2.3) and gluten noodles (3.2) while non significant effect was observed in case of blending level. Purich et al. (1989) also reported an increase in water absorption on addition of corn germ in pasta products. Noodles from corn bran blends resulted in high solid loss (22.1%) than that of corn germ noodles (21.6%) and corn gluten noodles (18.6%). Gruel solid loss increased with increase in blending level. At 5% level of significance, blending source and blending level had non significant effect on gruel solid loss. Mean acceptability scores for cooked noodles were affected significantly with blending source and blending level.

*Extruded snacks* The extrusion behaviour of extruded snacks prepared from semolina and corn byproducts (corn bran and gluten) at varying blending levels are given in Table 4. The expansion ratio was more in bran extrudate (2.13) than gluten (2.0). With the incorporation of corn bran and gluten to wheat semolina, overall mean values of expansion ratio showed an increase in expansion of product upto 10% blending level and after that decreasing trend was observed upto 20% blending level. Both the corn byproducts and their blending levels had non significant difference in expansion ratio.

Density of extrudates was affected non significantly by blending source and blending level. Average amperage, average pressure requirements and yield were higher for bran blended snacks than the snacks from gluten blends. Amperage, pressure and yield showed a significant increase upto 10% blending level and then decreased upto 20%. Both blending source and blending level had significant effect on amperage, pressure and yield.

Significant effect was observed on overall acceptability of extruded snacks. Gluten blended snacks had more acceptability than those of bran blended snacks. Mean acceptability score decreased from 8.0 to 5.07 as the blending level increased from 0% to 20%.

## Conclusion

It can be concluded that corn byproducts (corn bran, defatted germ and gluten) as a source of dietary fiber and protein can be added upto 10% level without adversely affecting the physico-chemical & baking properties of wheat flour and extruded products (prepared from semolina) making properties. These types of baked and extruded products can go a long way in supplying the required quantities of dietary fiber and protein to various segments of population and also results in profitable utilization of corn byproducts of corn milling industry.

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