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# Effect of Irradiation and Germination on Selected Nutrients of Corn

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*ABSTRACT*

*The effect of germination on potential nutrients (mineral matter, protein, lipids, fibre, carbohydrates and total energy) and an antinutrient (phytate) of corn, was studied. The influence of irradiation (5–20 krad) and germination on the vitamin contents (ascorbic acid, riboflavin) was also investigated. Comparison of the coefficients of variability revealed striking differences in the contents of these nutrients as a result of germination. Total mineral matter increased from 1·15% to 1·40%, protein from 9·6% to 14·0%, lipids from 4·36% to 4·60% and fibre from 0·71% to 0·82% whereas phytate decreased from 200 to 105 mg/100 g and carbohydrates from 85·5% to 70·0%. Radiation and germination significantly affected the ascorbic acid and riboflavin contents of corn* ($p < 0.05$)*. A maximum value of ascorbic acid (19·4 mg/100 g) was observed in the 10 krad treated seeds as compared with 14·3 mg/100 g in the control after 120 h of germination. Similarly, riboflavin increased from an initial value of 1·5 μg/g to 13·1 μg/g in the 20 krad sample as compared with 6·0 μg/g in the unirradiated control.*

## INTRODUCTION

It is well established that a majority of people in the developing countries depend mainly on cereal grains as their staple food. Corn is a major agricultural product, which contributes to the human food supply



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directly, or indirectly as a livestock feed. Like other cereals, the nutritive value of corn is not complete and its storage proteins are of poor nutritional quality for man and monogastric animals. Corn contains little or no ascorbic acid and is deficient in niacin, riboflavin and some essential amino acids but contains considerable amounts of phytic acid. The ability of phytate to complex and reduce the availability of certain essential metals in diets containing plant proteins is a problem of concern to nutritionists (El-Mahdy & El-Sebaiy, 1982).

In addition to the approaches for improving the nutritional value of corn through supplementation and mutant genes (Nelson *et al.*, 1965), other techniques, including soaking and germination, have been successfully attempted by several workers (Gi-Lay & Field, 1981; Rahman, 1984) with a concomitant decrease in phytate (El-Mahdy & El-Sebaiy, 1982; Alexander, 1983). Irradiation is known to adversely affect the vitamins (Sattar *et al.*, 1971) and stimulate sprouting and plant growth at low doses (Sax, 1963) but its effect on sensitive nutrients during the germination of seeds has not been studied.

This study was conducted to determine the influence of soaking and subsequent germination on the potential nutrients and an antinutrient (phytic acid). A second objective was to study the influence of irradiation and germination on the vitamin contents of corn.

## MATERIALS AND METHODS

Corn (variety, Sarahad-white) was obtained from the Cereal Crops Research Institute, Pirsabaq, Nowshera. The seeds were dried under sunlight to a moisture level of about 10%.

### Germination

The cleaned seeds were soaked in 4–5 volumes of water at $55{\cdot}0 \pm 0{\cdot}1\,°C$ (optimum temperature for phytase activity) for 6 h. The water was then removed and batches of seed were placed in plastic trays (30 × 45 cm) containing filter papers with embryo down and seed-base towards the centre of the tray. Germination was carried out for 144 h in the laboratory at ambient temperatures (30–45 °C) under prevailing light and dark conditions during the day and night, respectively. The seeds were washed every 24 h with tap-water.

### Irradiation

The seeds were irradiated with gamma rays at doses of 5, 10, 15 and 20 krad in a ISSLEDOVATEL (USSR) irradiator with a dose rate of 0·96 Mrad/h.

### Sample preparation

The germinated seeds, along with roots and shoots, were taken every 24 h, dried at about 75 °C in an air oven, ground in a Wiley mill to pass through a 40 mesh screen and stored in plastic bottles in a deep freeze until analysed for different nutrients except the ascorbic acid, which was determined in the fresh samples.

### Chemical analysis

Moisture was determined directly using a drying method at 105 °C. Proximate analysis was performed in duplicate in accordance with AOAC (1975) procedures. Crude fat was determined by Soxhlet extraction using petroleum ether (boiling point, 40–60 °C). Crude protein (%NX 6·25) was determined by the microKjeldahl method, ash by heating at 550 °C and crude fibre by digestion with acid and alkali. The food energy was calculated from the proximate analysis data by multiplying the fat by 9·0 and protein and carbohydrates by 4·0 kcal/g.

Total phosphorus was analysed after digesting the samples in a mixture of $HNO_3$ and $HClO_4$ by spectrophotometry using ammonium molybdate and ammonium vanadate. Extraction, precipitation and determination of phytate phosphorus were carried out according to the method of Wheeler & Ferrel (1971) assuming an iron–phosphorus ratio of 4:6 in the ferric phytate.

Vitamin assays were performed according to the methods of the Association of Vitamin Chemists (1966). Ascorbic acid was determined by titration with 2,6-dichlorophenolindophenol and riboflavin by fluorimetry using a Turner model 111 fluorometer with 2A and 47B as primary filters and 2A 12 as a secondary filter.

### Statistical analysis

An estimate of relative variation in potential nutrients in relation to germination time was made by determining the coefficient of variation

(CV) which is a ratio of standard deviation to the mean. Statistical significance of the influence of germination and irradiation was tested by analysis of variance and the means were separated by the Duncan's multiple range test (Little & Hills, 1972).

## RESULTS AND DISCUSSION

The effect of soaking and subsequent germination on potential nutrients of corn is shown in Table 1. These treatments resulted in profound changes in the chemical constituents of corn and generally a conspicuous increasing trend in the values occurred except for the carbohydrates, which markedly decreased during germination for 144 h. Total mineral matter increased from 1·15% to 1·40%, protein from 9·6% to 14·0%, total lipids from 4·36% to 4·60% and crude fibre from 0·71% to 0·82% whereas total carbohydrates decreased from 85·5% to 70·0%. Energy values remained about the same (422–426 kcal/100 g) except at 72 h germination where they were a few units higher than the remainder; the reason for this net gain in energy value is not clear. Minerals, fat, protein and fibre values all increased with germination. The substantial increase in crude protein (45%) and crude fibre (15·5%), and the decrease in carbohydrates (19%) is of value in counteracting malnutrition and the negative effects of our frequently excessive intake of refined foods.

**TABLE 1**
Effect of Soaking and Germination on Potential Nutrients of Corn[a]

| *Germination time (h)* | *Mineral matter (%)* | *Protein (%)* | *Total lipids (%)* | *Crude fibre (%)* | *Carbo-hydrates (%)* | *Energy value (kcal/100 g)* |
|---|---|---|---|---|---|---|
| Ungerminated control | 1·15 | 9·6 | 4·36 | 0·71 | 85·5 | 422 |
| 24 | 1·18 | 13·1 | 4·36 | 0·71 | 82·6 | 422 |
| 48 | 1·20 | 13·5 | 4·40 | 0·76 | 80·1 | 423 |
| 72 | 1·30 | 13·5 | 5·20 | 0·75 | 77·6 | 426 |
| 96 | 1·27 | 14·0 | 5·80 | 0·78 | 74·6 | 422 |
| 120 | 1·27 | 14·0 | 5·70 | 0·71 | 73·1 | 419 |
| 144 | 1·40 | 13·1 | 4·60 | 0·82 | 70·0 | 424 |
| AV | 1·25 | 12·9 | 4·92 | 0·76 | 77·6 | 423 |
| CV | 6·78 | 11·8 | 13·0 | 5·14 | 7·1 | 0·5 |

[a] Moisture-free basis; averages of at least two separate determinations.

In order to make an estimate of dispersion of the amount of individual nutrient in relation to the time of germination, the coefficient of variation (CV) was measured. This revealed striking differences in the contents of these nutrients. Determination of the CV is especially appropriate under conditions where there are extreme values or when it is desired to express variation as a percentage of the average around which the deviations are taken. Obviously, the carbohydrates were mobilised in the formation of non-nitrogenous nutrients. An increase in the total protein content was interesting. The nitrogenous compounds in the water used for soaking and germination could be the source of nitrogen build up in the germinated seeds. Accumulation of total mineral matter (ash), proteins, lipids, free amino acids and reducing sugars and degradation of starch in cereals has been reported by various workers (Chavan *et al.*, 1981; Tsai *et al.*, 1975). However, Rahman (1984) found little effect of germination on protein, ether extract, crude fibre and ash whereas a substantial increase in sucrose, reducing sugars and free fatty acids was observed. In his studies, the negligible influence of germination on total minerals and protein contents could primarily be due to the use of distilled water during germination, which is considered to be free of nitrates.

The effect of soaking and germination on phytic acid phosphorus, total phosphorus and non-phytate phosphorus is shown in Table 2. Phytic acid phosphorus content exhibited a decreasing trend (from 200 to 105 mg/100 g) up to 120 h of germination and thereafter the value increased to 120 mg/100 g. Total phosphorus increased from 300 to almost 493 mg/100 g which could be due to the absorption of phosphorus or phosphates from the water employed for soaking and germination. Obviously, the non-phytate phosphorus increased as well. Again, the coefficients of variation revealed large differences in the contents of total phosphorus and phytic acid phosphorus in relation to the germination time. In most cases, the phytic acid phosphorus level diminished, which could help make a number of important mineral nutrients more available in the human diet. The decreasing trend of phytic acid or phytate phosphorus as a result of soaking/germination and cooking of several food grains has been reported by various workers (El-Mahdy & El-Sebaiy, 1982; Alexander, 1983; Haug & Lantzsch, 1983). Eskin & Wiebe (1983) found a marked increase in phytase activity, accompanied by a concomitant decrease in phytate, of Fababeans during germination. El-Mahdy & El-Sebaiy (1982) observed a significant decrease in phytate phosphorus during germination (from 88·4 to 28·2 mg/100 g) and cooking

**TABLE 2**
Effect of Soaking and Germination on Phytate and Phosphorus of Corn[a]

| *Germination time (h)* | *Total phosphorus (mg/100 g)* | *Phytate phosphorus* | | *Non-phytate phosphorus (mg/100 g)* |
|---|---|---|---|---|
| | | *(mg/100 g)* | *(Per cent of total)* | |
| Ungerminated control | 300 | 200 | 66·7 | 100 |
| 24 | 330 | 175 | 53·0 | 155 |
| 48 | 340 | 125 | 36·8 | 215 |
| 72 | 399 | 120 | 30·0 | 280 |
| 96 | 466 | 113 | 24·1 | 354 |
| 120 | 532 | 105 | 19·7 | 427 |
| 144 | 493 | 120 | 24·3 | 373 |
| AV | 409 | 137 | 36·4 | 272 |
| CV | 21·9 | 26·3 | 47·7 | 44·4 |

[a] Moisture-free basis; averages of at least two separate determinations.

(from 88·4 to 64·9 mg/100 g) while the phytase and phosphatase activities increased.

Since irradiation of food grains/tubers at low doses with gamma or other ionizing rays is known to enhance sprouting, it was considered worth while to study the effect of radiation on selected vitamins of corn. Although radiation is expected to slightly affect other nutrients as well, vitamins are generally considered radio-labile (Sattar *et al.*, 1971). As ascorbic acid is important in fresh food materials, germinated corn was analysed for this vitamin and the influence of soaking and subsequent germination of irradiated (5–20 krad) and unirradiated seeds is shown in Fig. 1. The ascorbic acid was not detectable in the seeds and the data revealed that this vitamin increased significantly during germination, depending on the dose level ($p < 0{\cdot}05$). It is evident that the highest increase in the content of this vitamin was observed in the 10 krad treated—and the lowest in the 20 krad-treated—samples. Ascorbic acid contents were at a maximum at 120 h of germination in the 5 krad, 10 krad and unirradiated control and then decreased, whereas these values continued to increase up to 144 h in the 15 krad and 20 krad samples. A maximum amount (19·4 mg/100 g) of this vitamin was found in the samples irradiated with 10 krad after 120 h of germination as compared with 14·3 mg/100 g in the unirradiated control. The effect of soaking and

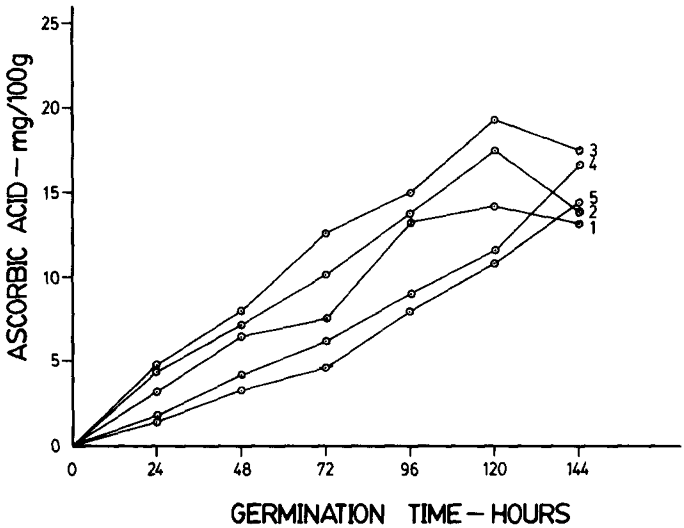


**Fig. 1.** Effect of irradiation and germination on ascorbic acid content of corn (1, control; 2, 5 krad; 3, 10 krad; 4, 15 krad; 5, 20 krad).

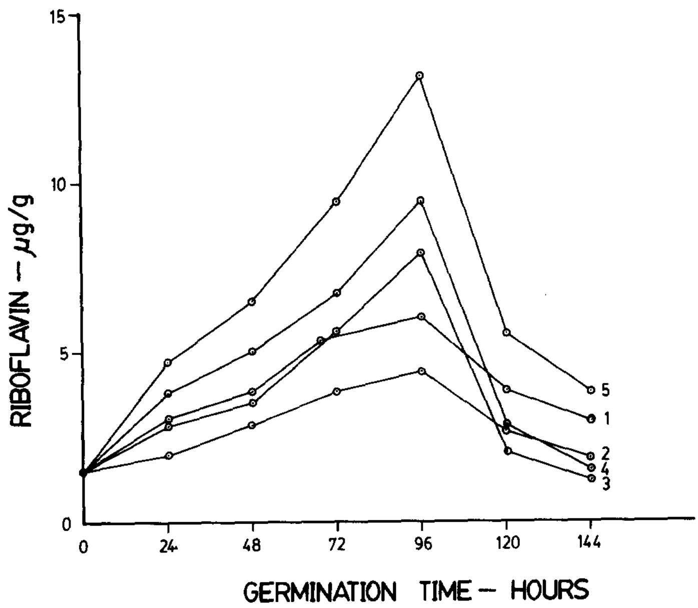


**Fig. 2.** Effect of irradiation and germination on riboflavin content of corn (1, control; 2, 5 krad; 3, 10 krad; 4, 15 krad; 5, 20 krad).

subsequent germination on riboflavin content of irradiated (5–20 krad) and unirradiated seeds is shown in Fig. 2. In each case, the riboflavin contents increased, depending on the dose level, up to 96 h of germination, and then decreased. The greatest increase was in the 20 krad sample, followed by the 15 krad, 10 krad and control samples. From an initial riboflavin value of 1·5 μg/g, the content increased to a range of 6·0–13·1 μg/g in unirradiated and irradiated samples over a period of 144 h.

Statistical analysis of the data revealed significant effect of germination and irradiation on these vitamins ($p < 0{\cdot}05$). Although the individual values have been shown in Figs 1 and 2, the influence of germination alone on the overall means of irradiated and unirradiated samples is presented in Table 3, which clearly indicates significantly higher amounts of ascorbic acid and riboflavin contents of germinated seeds than in the ungerminated originals. Increases in the content of ascorbic acid and riboflavin as a result of germination have been reported by other workers (Alexander, 1983; Rahman, 1984).

It has been proved through nutritional assays (Khan & Ghafoor, 1978) that soaking and germination improve the nutritional quality of food grain. This is mainly because these processes increase the essential nutrients and decrease the potential antinutrients. The present and some other studies (Hassim & Fields, 1979; Alexander, 1983; Rahman, 1984)

**TABLE 3**
Ascorbic Acid and Riboflavin Contents of Corn During Soaking and Germination*

| *Germination time (h)* | *Ascorbic acid (mg/100 g)* | *Riboflavin (μg/g)* |
|---|---|---|
| Ungerminated control | — | 1·50[a] |
| 24 | 3·10[a] | 3·25[b] |
| 48 | 5·85[b] | 4·31[c] |
| 72 | 8·27[c] | 6·15[d] |
| 96 | 11·8[d] | 8·15[e] |
| 120 | 14·8[e] | 3·30[b] |
| 144 | 15·0[e] | 2·23[f] |

* Values are means of irradiated and unirradiated samples.
[abcdef] in each column, values sharing a common letter are not significantly different ($p < 0{\cdot}05$).

suggest that germinated grains contain significantly larger amounts of important nutrients and fibre than do their ungerminated originals and that they can be used to make acceptable food products. While such information could be put to use on a practical level, further research will widen the possibilities. Successful development of ways to use sprouted cereals in conventional foods would not only improve people's diets; it would also have the potential to expand consumer demand for cereal products.

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