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The Effect of Corn Bran as a Fiber Source on the Utilization of Thiamin, Niacin and Pantothenic Acid in Humans

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ABSTRACT

The study was performed to investigate the effect of corn bran as a fiber source on the utilization of thiamin, niacin, and pantothenic acid in human subjects for 8 weeks. Four different corn bran diets were fed : dry milled, fine(DF), dry milled, coarse(DC), wet milled, fine(WF), and wet milled, coarse(WC). Basal diet, no corn bran bread added, was employed as a control. Apparent recovery of each B complex vitamin in urine was estimated to evaluate the vitamin utilization. Percentage of neutral detergent fiber(NDF) recovered in feces was also measured and compared. The utilization of three B vitamins was affected by the corn bran treatment. Dry milled corn bran had a higher recovery rate of thiamin(dry milled : 2.33%, wet milled : 1.70%) than those receiving wet milled corn bran. Similar recovery pattern of niacin(dry milled : 1.94%, wet milled : 1.50%) to that of thiamin was also observed. Particle size seemed to affect the vitamin utilization regardless of type of corn bran. Coarse bran gave a lower recovery value than fine corn bran in general. For pantothenic acid, the recovery of the vitamin was affected to a greater extent by particle size of corn bran than by type of corn bran milling(fine : 60.22%, coarse : 51.51%). Groups consuming wet milled corn bran(51.57%) excreted more NDF than those fed dry milled corn bran(42.29%). Dry milled corn bran showed little or no water holding capacity, poor fecal bulking properties, and increased fecal transit time. The results suggest that corn bran supplementation exerts an negative effect on three B vitamin utilization.

KEY WORDS : corn bran · thiamin · niacin · pantothenic acid · bioavailability.

Introduction

Recent studies indicate that increasing fiber in the diet might offer people benefits including lowering incidence of constipation, colon cancer, diverticulitis, diabetes mellitus and atherosclerosis[1-5]. Various reports have encouraged the use of whole grain cereals and bran supplements for the prevention and treatment for such diseases mentioned the above[6-8]. In contrast, the negative effects of diet-

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ary fiber also have been shown in terms of nutrient availability[9-11].

Whole grain cereals are good sources of vitamins and minerals as well as dietary fiber[12)13]. Cereal brans once used almost solely as animal feeds, are currently being used as ingredients in foods for humans. Pellagra, a niacin deficiency disease is associated with corn eating populations often times although corn contains appreciable amounts of niacin[14)15]. This might be partly due to unavailable bound form of niacin in corn. Traditionally, the method of preparing corn by soaking it in a lime solution, as practiced by Mexican Indian groups from ancient times to the present, increases the bioavailability of niacin just like roasting of sweet corn prepared by the Hopi Indians who are free from pellagra[16)17]. Corn bran also contains appreciable amounts of niacin. In the past, most marked corn bran was produced from a dry milling process. Currently, in the United States, most corn is ground in a wet milling process as part of the ethanol/corn sweetener industry. This latter process is relatively severe, resembling the treatment used by Indians and may enhance the bioavailability of niacin and of other B complex vitamins found in corn bran[18)19].

The purpose of the study was to compare the thiamin, niacin, and pantothenic acid status of human adults as affected by corn bran supplements produced by the wet milling and dry milling processes. Since grind size of bran also may affect the physiological responses of animals and humans, this respect was also investigated[20].

Materials and Methods

1. Experimental design

This human study consisted of a 5-day pre-period and 6 experimental periods of 7 days each involving 9 healthy adult men and women. Periods were arranged according to a double, randomized cross-over design(Table 1). The study was composed of two parts with each section having an introductory 7-day adjustment period and three experimental periods of 7 days each. Individual subject assignments to experimental periods are given in Table 2. All subjects received all experimental treatments. Five kinds of extracted wheat flour bread were prepared. These were as follows.

1) Bread with no bran supplement.

2) Bread with fine ground, wet-milled corn bran to supply 20g fiber/subject/day.

3) Bread with coarse ground, wet-milled corn bran to supply 20g fiber/subject/day.

Table 1. Experimental plan

Period¹	# days	Diet type	Corn bran addition
Pre-period	5	Self-selected	—
Part A			
Adj. A	7	Lab-controlled	None
Expt. 1	7	Lab-controlled	Wet milled, fine
Expt. 2	7	Lab-controlled	Dry milled, fine
Expt. 3	7	Lab-controlled	None
Part B			
Adj. B	7	Lab-controlled	None
Expt. 4	7	Lab-controlled	Wet milled, coarse
Expt. 5	7	Lab-controlled	Dry milled, coarse
Expt. 6	7	Lab-controlled	None

¹ Periods arranged according to randomized cross-over design for each subject. See Table 2.

Table 2. Diet arrangement

Subject Number	Period I	II	III	IV	V	VI	VII	VIII
3420	B[1]	B	DF	WF	B	B	DC	WC
3422	B	WF	DF	B	B	WC	DC	B
3424	B	DF	B	WF	B	DC	B	WC
3426	B	WF	B	DF	B	WC	B	DC
3428	B	DF	WF	B	B	DC	WC	B
3421	B	DC	B	WC	B	DF	B	WF
3423	B	B	WC	DC	B	B	WF	DF
3425	B	WC	DC	B	B	WF	DF	B
3427	B	DC	WC	B	B	DF	WF	B

[1] Diet code :

B : Basal alone DF : Dry milled, fine WF : Wet milled, fine
DC : Dry milled, coarse WC : Wet milled, coarse

Table 3. Batter bread recipe(serving for 1 person/2 .days)

Ingredients	1 loaf[1]
Yeast	7 g
Oil	20 g
Sugar	24 g
Salt	6 g
Flour, unenriched white	300 g
Water for bran breads	240 g
Water for "O" bran breads	200 g
Bran	43 g

[1] Amount for one subject for two days

4) Bread with fine ground, dry-milled corn bran to supply 20g fiber/subject/day.

5) Bread with coarse ground, dry-milled corn bran to supply 20g fiber/subject/day.

Procedures for preparation of the wheat-corn bran breads are given in the Table 3. Each subject received one bread type throughout one experimental period. During the adjustment and experimental periods, subjects consumed a low fiber(10g/subject/day), laboratory controlled, measured constant diet(Table 4). This diet met NRC Recommended Dietary Allowances for nutrient intakes, 1980[21)]. Some alterations in amounts of a few high calorie foods fed to the different subjects were made in order to adjust energy intakes to those needed for

Table 4. [1] Basal diet for controlled diet period

Food item	Amount/day
Breakfast	
Orange juice	170.4 g
Whole milk	227.2 g
Sucrose	3.2 g
Margarine	24.2 g
Wheat flour bread	113.6 g
Cheerios	21.0 g
Lunch	
Peanut butter	42.6 g
Potato chips	56.8 g
Peaches	142.0 g
Apple juice	170.4 g
Wheat flour bread	113.6 g
Dinner	
Wheat flour bread	113.6 g
Frankfurters(or eggs)	92.6 g (56.8g)
Margarine	24.2 g
Tomato juice cocktail	170.4 g
Sweet pickle relish	7.7 g
Mustard	5.0 g
Lorna doone cookies	56.8 g
Green beans	227.2 g
Fruit cup	142.0 g

[1] Food items of diets varied between subjects to maintain body weight during the study.

[2] Subjects were allowed to choose to have either frankfurters or eggs for dinner depending on their preference usually based on religious considerations.

weight maintenance. All the sujbects were considerred healthy on the basis of evaluation of health history forms by medical personnel of the University of Nebraska-Lincoln. Subjects resided and ate all meals in the human nutrition metaboic subject dormitory located in Ruth Leverton Hall. However, subjects were allowed to continue usual class study, work and social activities. Signing of consent forms was required from all subjects prior to the start of the study. The study was approved by the University Institutional Review Committee For Studies Involving Human Subjects.

2. **Sampling procedure and analyses**

Subjects made complete collections of feces throughout the project. Feces were divided into periods representing food eaten during each experimental period by use of orally-given, non-absorbable dyes(brilliant blue) and colored glass beads. These were given in gelatin capsules. Fecal samples were analyzed for neutral detergent fiber by the modified method of Goering and Van Soest, 1970[22]. Subjects also made complete collections of urine which were composited by time into 24-hour lots, measured, mixed, sampled and stored for later analysis of thiamin, niacin, and pantothenic acid. Thiamin was measured fluorometrically(Model 111, G. K. Turner) by the method of Haugen. Niacin and pantothenic acid were analyzed microbiologically using *Lactobacillus Plantarum*. Collections were also measured for creatinine content to ascertain completeness of collection and accuracy of division of urine composites into daily lots.

Statistical analyses of the data were completed using the Statistical Analyses System[23]. An Analysis of Variation procedure was performed to detect variation as a result of dietary treatment. Duncan's

Table 5. Recovery of thiamin in urine

Parameters	Mean value while receiving diet[1]					
	B_1	DF	WF	B_2	DC	WC
Dietary intake (μg/d)	1003	1025	1025	1003	1025	1025
Urinary thiamin (μg/d)	20.51[a] ± (15.49)	21.59[a] ± (16.98)	18.90[a] ± (14.33)	12.84[a] ± (6.56)	20.51[a] ± (9.86)	14.45[a] ± (8.92)
Recovery of thiamin (%)	2.05[a] ± (1.27)	2.10[a] ± (1.57)	1.84[a] ± (1.32)	1.28[a] ± (0.79)	2.00[a] ± (0.99)	1.41[a] ± (0.99)
Corrected urinary thiamin(μg/d)	20.36[a] ± (16.03)	21.05[a] ± (15.69)	20.38[a] ± (14.90)	12.88[a] ± (7.55)	20.59[a] ± (9.89)	15.27[a] ± (10.34)
Corrected recovery of thiamin (%)	1.98[c] ± (0.08)	2.45[a] ± (0.25)	1.89[cd] ± (0.11)	1.77[d] ± (0.16)	2.21[b] ± (0.19)	1.51[e] ± (0.10)

[1]Means with different letter superscripts are significantly different at $p<0.05$

Diet code :

B_1 : Basal 1 DF : Dry-milled fine corn bran

WF : Wet-milled fine corn bran B_2 : Basal 2

DC : Dry-milled coarse corn bran WC : Wet-milled coarse corn bran

Multiple Range test was used to determine effects among treatments.

Results and Discussion

Mean data relative to recovery of thiamin, niacin, and pantothenic acid status of subjects while receiving the corn brans processed by different milling with different particle size are shown in Table 5, 6 and 7. Urine collections were analyzed for creatinine contents in order to ascertain completeness and accuracy of urine collections. Some variations in urinary creatinine excretion existed between periods for some individuals which could not be explained by the experimental treatments. It was assumed that these differences were due to collection or processing errors which would be reflected in the excretion of all urinary constituents. Hence, urinary excretions of thiamin, niacin, and pantothenic acid were corrected to mean urinary creatinine excretion for each individual subject by ratio.

Urinary excretion of water soluble vitamins in proportion to intake is sometimes used as an index of bioavailability of those vitamins. At equal levels of intake, an increase in urinary excretion of the vitamin is assumed to be indicative of an increase in intestinal absorption of that vitamin which would, in turn, indicate an increase in bioavailability of that vitamin. This approach assumes that tissue saturation of the vitamin exists, that active vitamers of the vitamin that are absorbed in excess of need are excreted in the urine, and that no metabolic processes are occurring which lower need for the vitamin in question[24]. Because of bacteria in the large colon, analysis of fecal vitamin loss is not useful in determining whether or not a vitamin

Table 6. Recovery of niacin in urine

Parameters	Mean value while receiving diet[1]					
	B_1	DF	WF	B_2	DC	WC
Dietary intake (mg/d)	14.803	15.271	15.271	14.803	15.271	15.271
Urinary niacin (mg/d)	0.296[a] ± (0.030)	0.318[a] ± (0.026)	0.232[b] ± (0.029)	0.317[a] ± (0.025)	0.259[a] ± (0.044)	0.201[c] ± (0.016)
Recovery of niacin (%)	2.00[a] ± (0.20)	2.09[a] ± (0.17)	1.51[c] ± (1.19)	2.13[a] ± (0.16)	1.70[b] ± (0.29)	1.32[c] ± (0.11)
Corrected urinary niacin(mg/d)	0.292[ab] ± (0.054)	0.323[a] ± (0.041)	0.249[c] ± (0.035)	0.316[a] ± (0.043)	0.264[bc] ± (0.060)	0.209[d] ± (0.017)
Corrected recovery of niacin (%)	1.98[ab] ± (0.36)	2.13[a] ± (0.26)	1.62[cd] ± (0.23)	2.14[a] ± (0.29)	1.74[bc] ± (0.39)	1.37[d] ± (0.12)

[1]Means with different letter superscripts are significantly different at $p<0.05$
Diet code :
B_1 : Basal 1 DF : Dry-milled fine corn bran
WF : Wet-milled fine corn bran B_2 : Basal 2
DC : Dry-milled coarse corn bran WC : Wet-milled coarse corn bran

Table 7. Recovery of pantothenic acid in urine

Parameters	Mean value while receiving diet[1]					
	B_1	DF	WF	B_2	DC	WC
Dietary intake (mg/d)	3.236	3.279	3.279	3.236	3.279	3.279
Urinary pantothenic acid(mg/d)	1.95^{b} ± (0.06)	2.03^{a} ± (0.04)	1.78^{c} ± (0.05)	1.97^{ab} ± (0.03)	1.76^{c} ± (0.16)	1.54^{d} ± (0.03)
Recovery of pantothenic acid(%)	60.44^{a} ± (1.85)	61.77^{a} ± (1.06)	54.18^{b} ± (1.45)	60.81^{a} ± (1.00)	53.71^{b} ± (4.91)	46.87^{c} ± (0.88)
Corrected urinary pantothenic acid(mg/d)	1.92^{ab} ± (0.21)	2.06^{ab} ± (0.14)	1.90^{ab} ± (0.09)	1.96^{ab} ± (0.12)	1.78^{bc} ± (0.17)	1.60^{c} ± (0.09)
Corrected recovery of pantothenic acid(%)	59.37^{a} ± (6.20)	62.41^{a} ± (5.11)	58.03^{ab} ± (2.99)	60.66^{a} ± (3.62)	54.33^{b} ± (5.19)	48.69^{c} ± (8.69)

[1]Means with different letter superscripts are significantly different at $p<0.05$

Diet code :

B_1 : Basal 1 DF : Dry-milled fine corn bran

WF : Wet-milled fine corn bran B_2 : Basal 2

DC : Dry-milled coarse corn bran WC : Wet-milled coarse corn bran

from a food is absorbed.

In the present study, corrected urinary thiamin excretion values were affected by the experimental treatments. Apparent recoveries of dietary thiamin were affected by corn bran treatment when examined by contrast analysis. Groups receiving dry-milled corn bran tended to have higher bioavailability(DF : 2.45%, DC : 2.21%, mean : 2.33%) than those receiving wet-milled corn bran(WF : 1.89%, WC : 1.51%, mean : 1.70%) or the basal diet(1.88 %). When effect of particle size was compared regardless of type of milling, coarse bran(DF : 2.45%, DC : 2.21%, mean : 1.86%) gave significantly lower utilization of this vitamin than fine corn bran(DF : 2.45%, WF : 1.89%, mean : 2.17%). The degree to which particle size affected bioavailability was much greater in wet-milled corn bran than in dry-milled corn bran.

Mean urinary excretion of niacin was lower in wet-milled corn bran, in both uncorrected(wet-milled : 0.217mg/day, dry-milled : 0.318mg/day) and corrected(wet-milled : 0.229mg/day, dry-milled : 0.294mg/day). Recovery of niacin in urine when expressed as a percentage of dietary intake showed a trend similar to that of mean urinary niacin excretion whether corrected or uncorrected. While wet milling of the corn bran negatively affected the utilization of the vitamin, particle size also appeared to be a factor that affected the bioavailability of the vitamin. Values on recovery of the vitamin in urine when it was corrected to the mean creatinine were 2.06%, 1.94%, and 1.50% for the basal diet, dry-milled corn bran and wet-milled corn bran, respectively.

Table 8. Neurtal detergent fiber(NDF) excretions, fecal wet weights, fecal dry weights, and fecal transit times of humans fed corn bran supplemented bread

Parameter	Mean values while receiving diet[1]			
	DF	WF	DC	WC
NDF (% of dry feces)	39.31[e] ± (1.19)	48.04[b] ± (1.25)	45.27[c] ± (0.71)	55.10[a] ± (0.64)
Fecal wet weights (g/5 days)	516[b] ± (218)	788[a] ± (217)	684[ab] ± (238)	842[a] ± (240)
Fecal dry weights (g/5 days)	128[a] ± (47)	161[a] ± (64)	151[a] ± (44)	171[a] ± (42)
Fecal Moisture(%)	72.3[b] ± (9.3)	79.3[a] ± (6.0)	75.2[ab] ± (4.2)	80.5[a] ± (3.5)
Fecal transit time (hours)	39.7[a] ± (8.1)	27.2[ab] ± (3.4)	39.3[a] ± (8.2)	23.7[b] ± (4.5)

[1] Means with different letter superscripts are significantly different at $p<0.05$

Diet code :

DF : Dry-milled fine corn bran WF : Wet-milled fine corn bran

DC : Dry-milled coarse corn bran WC : Wet-milled coarse corn bran

Effect of wet or dry milling on niacin availability from corn bran has not been reported. However, Laguna and Carpenter(1951) reported that niacin in reconstituted corn from wet-milled corn fraction was no more available to the rat than was that from raw corn[25).

The utilization of pantothenic acid was also affected by corn bran supplementation compared to the basal diet when no corn bran was added. The corrected urinary pantothenic acid excretion was not demonstrated to be affected by corn bran supplementation. There was a tendency for the wet-milled corn bran fed subjects to have reduced excretion of pantothenic acid. The same pattern in percentage recovery of pantothenic acid in urine was shown when the urinary pantothenic acid values were corrected to mean creatinine values. There were no significant differences in percentage recovery of the vitamin between groups receiving the dry-milled, fine-ground corn bran and the wet-milled, fine-ground corn bran. Values were 59.37%, 62.41%, and 58.03% for basal, dry-milled, fine-ground corn bran and wet-milled, fine ground corn gran, respectively. However, the coarse corn bran treatment appeared to affect the utilization of pantothenic acid. Wet-milled coarse corn bran fed subjects showed a lower recovery of pantothenic acid(48.69%) than did dry-milled coarse corn bran(54.33%) fed subjects. Therefore, utilization of pantothenic acid seemed to be affected to a greater extent by particle size of corn bran than by type of corn bran milling.

Neutral detergent fiber(NDF) excretions were also estimated for the different treatments. Table 9 shows the NDF excretion of subjects. Those consuming wet-milled corn bran(coarse : 55.10%, fine : 48.04%, mean : 51.57%) excreted more neutral detergent fiber than those fed dry-milled corn bran (coarse : 45.27%, fine : 39.31%, mean : 42.29%).

Dry-milled corn bran showed little or no water holding capacity, poor fecal bulking properties, and increased fecal transit time.

Due to the beneficial effects of dietary fiber on human nutrition the researchers have recommended the consumption of high dietary fiber foods at a level of 30g to 35g daily[26)27)]. The use of whole grain cereals or brans is also encouraged. Currently, wheat bran, cellulose, soy fiber and oat bran are the forms of fiber most frequently used as food ingredients. Corn brans, once used almost solely as animal feeds, are being used as ingredients in foods for humans[27)]. Interest in manufacturing corn sweeteners and alcohol has stimulated growth of the wet corn milling industry. Wet-milled corn bran may have different physicochemical properties and produce different physiological responses than that produced by the dry milling process since wet milling involves the prolonged water soaking and sulfur dioxide treatment. In this study, neutral detergent fiber excretion was significantly higher($p<0.05$) with the feeding of wet-milled corn bran than with dry-milled corn bran and produced higher wet and dry fecal weights than did dry-milled corn bran. The increase in fecal weight was due to increased fecal moisture content rather than increased solid material in feces.

In earlier studies conducted at the University of Nebraska and at other sites, corn bran when fed to humans was found to have little effect on fecal transit time or on fecal bulking[29)]. Most of nutrients and fiber contained in the corn bran could be recovered in feces. Radiographic examination of feces indicated that the bran passed through the gastrointestinal tract without change. Even starch granules remained trapped within the corn bran particles recovered from the feces. The pericarp of the mature corn kernel(the bran layer) is very hard, and very tough in comparison to the bran layer of wheat, oats, and rice. More recently, Ip, et al.[30)] reported that corn bran had positive effects on decreasing fecal transit time and increasing fecal bulk. The earlier mentioned studies probably involved the use of corn bran from the dry milling process while the latter was involved with corn bran obtained from the wet milling process.

In the wet milling of corn, the corn initially undergoes a steeping process. The steeping process involves the soaking of corn in water under controlled conditions of temperature(usually 52℃), time(22 to 50 hours), sulfur dioxide concentration and lactic acid content[31)]. This process softens the kernels and allows them to be more easily separated into its component parts : the germ, the pericarp(bran, fiber), gluten(protein), and starch. Following separation by the steeping washings, the separate component parts may be dried or may be processed in the slurry form. Although larger in scale, the wet milling process is somewhat similar to the wet-lime treatment of corn used traditionally by Indians in Mexico, Central, and South America. In 1985, principal products of wet milling by use were high fructose corn syrups, glucose and corn syrup solids, starch, ethanol, corn gluten meal, feeds, and corn oil.

The dry milling of corn has been practiced for thousands of years. In its simplist form, the corn was ground between a hand held stone and a concave hedstone[19)].

Most large dry corn mills employ tempering-degerming systems. In this process the corn is wet cleaned and moisture is adjusted to 20%. The kernels are then placed in tempering bins following germ and pericarp(bran) are physically stripped away leaving an intact endosperm. These fractions can then be ground in flour mills. Products of dry use were reported to be as followed : animal feeds 34%, brewing 23.5%, breakfast cereals 15%, industrial use 6%[32)].

Bioavailability of three water soluble vitamins seemed to be affected differently by particle size and kind of corn bran processing. Thiamin did not appear to be influenced by corn bran as severely as were the other vitamins, although corrected percentage recovery of vitamins showed impaired utilization of thiamin in the wet-milled corn bran. Niacin and pantothenic acid were influenced by corn bran supplementation more clearly.

Little research on dietary fiber and vitamin utilization has been conducted. However, in the present study, results indicated that people who have low or marginal vitamin nutriture may be adversely affected by increased consumption of dietary fiber even though the mechanism by which dietary fiber acts on the vitamin utilization is unknown.

Conclusion

Dietary fiber apparently exerts an adverse effect on vitamin utilization. Particle size of dietary fiber also was found to be a factor influencing the vitamin absorption. Wet-milled corn bran seemed to have a greater impact on vitamin utilization than did dry-milled corn bran.

It should be noted that the wet milled corn brans also had a greater positive effect on increasing fecal bulk and in decreasing fecal transit times than did the dry milled brans.

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=국 문 초 록=

옥수수겨가 티아민, 나이아신, 판토텐산의 생체이용율에 미치는 영향

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본 연구는 사람을 대상으로하여 8주간 종류가 서로 다른 옥수수겨를 식이섬유질의 급원으로 기본식이에 첨가하여 먹였을 때 티아민, 나이아신 및 판토텐산의 체내 이용율을 살펴보고자 실시되었다. 실험식이의 종류의 옥수수겨를 첨가하지 않은 기본식이(Basal diet : B)와 이에 wet-milled fine(WF)/coarse(WC) corn bran이나 dry-milled fine(DF)/coarse(DC) corn bran을 첨가한 식이들로서 무작위법에 의하여 첫 4주간동안 일부의 피실험자는 B, WF, WC 식이를 급여받았으며, 나머지 피실험자는 B, DF, DC를 급여받았다. 따라서, 각각의 피실험자들은 8주간의 실험기간동안 모든 실험식이를 섭취하였다. 비타민의 이용율을 측정하기 위하여 24시간 뇨를 채집하였으며 이들을 주별로 나누어 이들 비타민의 뇨중함량을 측정하였고 변을 채집, 건조하여 neutral detergent fiber (NDF)량을 측정하였다. 또한 매일 뇨중의 creatinine치를 측정하여 뇨의 완전한 채집을 도모하였으며 불완전한 채집으로 인한 실험오차를 줄여주기 위하여 비타민의 이용을 계산시 각 주별의 평균 creatinine치에 대하여 비타민 이용율을 보정하여 주었다. 실험분석 결과에 따르면 옥수수겨를 첨가한 식이를 먹는 경우 티아민, 나이아신 및 판토텐산의 생체 이용율이 저하되는 것으로 나타났으며 옥수수겨를 wet-milling 방법으로 처리한 식이의 경우 저하의 효과가 더욱 현저한 것으로 보여졌다. 또한 옥수수겨의 처리방법을 막론하고 옥수수겨의 입자가 거친 것이 비타민 이용율의 저하효과가 더욱 큰것으로 나타났다. 한편 wet-milled corn bran 식이군이 dry-milled corn bran 식이군보다 NDF의 배설량이 많았으며, 변건량과 변량에 있어서도 이와 유사한 양상을 보였고 특히 fecal transit time이 wet-milled corn bran 식이군과 입자가 거친 옥수수군에서 빨랐다. 따라서 본 연구는 옥수수겨가 이들 세가지 B 비타민의 이용율을 저하시키는 것이 식이 섬유질의 종류에 따라서 영향을 받을 수 있음을 시사하고 있다.