THE EFFECT OF RYE IN RATIONS FOR GROWING PIGS

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ABSTRACT

Five experiments were conducted feeding pigs rye, in all stages of growth, as a replacement for wheat or barley. In two experiments with young growing pigs (13-30 kg), rye replaced wheat and the use of different milling fractions (i.e. flour and bran), different protein sources, level of protein, amino acid availabilities and digestibility of protein and energy were studied. With growing pigs (30-65 kg), different levels of rye were fed and performance evaluated, whereas with finishing pigs (65-100 kg), performance, amino acid availabilities, digestible protein and digestible energy values as well as carcass quality were evaluated. In the case of all growing-finishing experiments, rye was used as a replacement for barley.

The addition of rye flour and or rye bran to rations for young growing pigs did not result in any significant differences in pig performance. Similarly, casein and soybean meal as a supplement to rye or wheat - based rations showed no significant difference.

Feeding low (15%) protein rations (both rye and wheat) resulted in lower gains ($p \leq 0.05$) and poorer feed efficiency when compared with the high (18%) protein rations. In comparing rye and wheat as the sole source of grain in rations for young growing pigs at low (15%) and high levels (18%) of protein, no significant differences in pig performance were noted at either level. Pelleting of the low protein rye and wheat rations improved pig performance only slightly over the same rations in mash form.

As a replacement for barley, rye at a level of 84% fed to growing pigs, resulted in decreased feed intake and significantly

lower gains ($P \leq 0.10$). However, the inclusion of rye in rations resulted in improved feed efficiency. When rye replaced barley in finisher rations, superior pig performance was obtained with barrows but slightly lower gains were obtained for gilts,although differences in both cases were not significant. In the case of the grower and finisher experiments, an adaptation period was indicated, as pigs showed better utilization of rye-based rations in the second half of all three growing - finishing experiments. Carcass traits were not affected by inclusion of rye in finishing rations.

Essential amino acid availabilities, digestible protein and digestible energy values were slightly lower for rye - based rations in comparison to wheat based rations fed to young growing pigs. However, these values were higher when compared to the barley-based rations fed to older (65-100 kg) finishing pigs.

DEDICATION

This thesis is dedicated to my wife and children for their encouragement, help, and understanding during the course of my work.

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INTRODUCTION

Although the nutritive value of rye is quite good when compared with other cereals, it has never been extensively used in animal feeding. This may be attributed to the fact that early reports from researchers indicated that rye was not as palatable as other grains in livestock rations. This poort reputation of rye was probably due to the presence of ergot which has been known to lower feed intake and decrease performance.

Over the past fifteen years, research results have continued to be variable. Many authors report rye to be superior to barley and equal to wheat in feeding value and could be used at levels of 50-60% in rations. Others strongly believe that rye should not constitute more than 30% of the ration and sometimes less, whether it be for swine, poultry or cattle.

The contradictory results justify further research on the feeding value of rye. In the study reported here, five experiments were conducted which covered the feeding of rye in all stages for growing and finishing pigs. With the older pigs, crietria used to measure performance were average daily feed, average daily gain, and feed efficiency. Carcass traits were also evaluated in the finishing experiments. Apparent amino acid availabilities were obtained to determine if essential amino acids were utilized to a lesser degree when rye was a major component of the ration.

In reports that have dealt with the feeding of rye grain, usually pigs 30 kg of weight and heavier were used. Therefore, two experiments were conducted where weanling pigs with initial weights of approximately 15 kg were used to determine their performance when rye or rye fractions (i.e. from milling) constituted the major portion of their diet.

In one experiment rye flour and rye bran were compared with wheat flour and wheat bran and their effect upon performance of young growing pigs. In the second experiment, rye and wheat were used as the basal grain and fed at high and low protein levels and in mash and pellet form.

LITERATURE REVIEW

A. Classification

Rye belongs to the grass family, Gramineae. It is a member of the genus, Secale and is species S. cereale. The genus Secale L. which includes cultivated rye, consists of only four to twelve species (depending upon the criteria used for species definition) so detailed comparative studies are not too difficult (Stutz, 1972). Intercrossing is normally rare, but can result in at least partially fertile hybrids. Secale consists of both annual and perennial species. Cultivated rye is of the spring or fall sown annual. In Canada, about 85% of the rye grown is fall rye (Carmichael and Norman, 1970).

Considerably less effort has been expended in the improvement and development of rye varieties than of most other cereal grains (Bushuk, 1976). As a result there are relatively lower numbers of rye varieties when compared to wheat or most other cereals.

B. Origin and Geographic Distribution of Rye

To determine or hypothesize the origin of evolution of a plant species can be a long, tedious process. Secale cereale L. has been no exception, but there is now general agreement with the hypothesis of Vavilov (1917, 1926) that cultivated varieties of rye originated from weedy forms and that these weedy forms were carried to the northern regions and higher altitudes with the main crops of wheat and barley (Khush, 1963). Wheat and barley were weakened by the lower temperatures and higher precipitation but rye, once a weed, gained the upper hand and through mutation and human selection was further improved.

Rye entered northern Europe probably between 2,000 to 2,500 B.C. so that its first domestication must have occurred somewhat earlier; that is between 2,500 to 3,000 B.C. (Khush, 1963). Northern European rye gradually spread throughout most of Europe and was eventually brought to North America and western South America with the settling of these areas by Europeans in the 16th and 17th centuries (Bushuk, 1976).

C. Production Trends

The area of rye production in the world has declined from an average of 27.8 million hectares from 1961-65 to 13.9 million in 1977 (F.A.O., 1977). This represents a 50% decline of land area used for the production of rye. Although there has been a substantial decrease in land under rye cultivation, production has dropped by merely 30% from 33.8 metric tonnes to 23.3 metric tonnes.

The marked decline in area under rye cultivation has been offset to a limited degree by yield increases. From a period of 1963 yields increased annually through to 1973 where the highest yield figure of approximately 1,874 kg/HA was recorded which represents a 62% increase during this time span. This substantial increase was achieved through improvement of agronomic practices, especially in the use of chemical fertilizers and crop rotation and through improvement of varieties and elimination of the use of low fertility land (Bushuk, 1976). Since 1973, a slight decrease in average yield has occurred, most likely due to climatic conditions.

Rye ranks eighth in production relative to other major cereal crops (F.A.O., 1977). Its production is about one-twelfth that of wheat. The ten leading rye producing countries in 1977 are given in Table 1. Poland, the second largest producer of rye, most of which is fall rye, is one of the few countries where the rye acreage still exceeds that of

TABLE 1

Rye Production by Countries

Country	1000 MT	% of Total
U.S.S.R.	8,471	36.5
Poland	6,200	26.7
West Germany	2,538	10.9
East Germany	1,500	6.5
Czechoslovakia	870	3.7
Turkey	715	3.1
U.S.A.	432	1.9
Canada	392	1.7
France	376	1.6

Source: (F.A.O., 1977)

wheat (Carmicheal and Norman, 1970).

D. Uses of Rye and International Trade

The major use of rye has always been that of bread making, and it ranks second to wheat for this purpose (Schaben, 1948; Hunter, 1950; Bushuk, 1976). However, in Canada, only one quarter of the rye crop is used for bread making, while approximately one-third is used by distillers for the production of rye whiskey. The remainder of the rye grain is used for livestock feed or exported.

Unlike wheat, which enters international trade in large quantities, the movement of rye in trade between nations is relatively small, being only approximately 2% of the total production and is limited chiefly to the quantities needed to cover occasional deficits in countries which are themselves large producers (F.A.O., 1977). This was the case in 1977 when the U.S.S.R. and Poland, the two largest producers, were the largest importers of rye. Many European countries frequently import and export rye at the same time, either importing high quality rye for bread making and exporting lower quality grain for feed, or occasionally importing feed rye and exporting bread rye (Schaben, 1948).

Canada, the eighth largest producer in 1977 was the largest exporter of rye.

E. Canadian Situation

In Western Canada, rye ranks sixth and seventh nationally, among major cereals in areas under production (Table 2), making up only 2% of that of the wheat production in Western Canada.

Of the 392,000,000 kg of rye produced in Canada in 1977, over 81% was grown in the Prairie Provinces (Table 3). Saskatchewan, Alberta, and Manitoba were the largest producers of rye in 1977 making up 35,29

Table 2

Crop Production of Western Canada

	Wheat	Barley	Oats	Rapeseed	Flax	Rye
Hectares	9,794,000	4,411,000	1,680,000	1,315,000	575,000	219,000
Yield (kg/HA)	1,780	2,890	3,450	1,490	1,060	1,590
Production (1000 kg)	17,399,000	12,751,000	5,791,000	1,953,000	610,000	349,000

Source: Quarterly Bull. of Agric. Stats. (1978).

Table 3

Provincial Production of Rye
in Canada from 1972 and 1977

	1972	1977
SASKATCHEWAN		
Area (HA)	105,000	91,000
Yield (kg/HA)	1,140	1,520
Production (1000 kg)	119,000	138,000
ALBERTA		
Area (HA)	81,000	71,000
Yield (kg/HA)	1,480	1,610
Production (1000 kg)	119,000	114,000
MANITOBA		
Area (HA)	32,000	36,000
Yield (kg/HA)	1,410	1,880
Production (1000 kg)	46,000	69,000
ONTARIO		
Area (HA)	20,000	16,593
Yield (kg/HA)	1,900	1,950
Production (1000 kg)	38,000	32,000
QUEBEC		
Area (HA)	800	4,000
Yield (kg/HA)	1,380	1,560
Production (1000 kg)	1,000	6,000
BRITISH COLUMBIA		
Area (HA)	400	2,400
Yield (kg/HA)	1,880	1,880
Production (1000 kg)	760	4,600

Source: F.A.O. (1977).

and 17% of the Canadian total, respectively. The only other provinces reporting rye production were Quebec, Ontario, and British Columbia, supplying approximately 11% of the total Canadian production.

F. Adaptations

Rye usually stands stronger and taller than oats and barley. On fertile soils it can grow five feet tall or more. The stem terminates with a head or spike. Its roots branch in many directions and can go as deep as six feet.

Currently, intensive rye cultivation is usually confined between the 18^{o} and 20^{o} C isotherms of the northern hemisphere. Rye is cultivated intensively where the annual rainfall is 500-1000 mm. but has been grown in areas between a rainfall range of 100 to 1200 mm./yr. (Szasz, 1962). It is a cool weather plant, not as well adapted to either dry or moist heat as oats and barley.

One of the major advantages of fall rye is that it can be grown in areas of Western Canada where the prospect of growing winter wheat is too great a risk due to severe winters. Since it can be sown in the fall, it takes advantage of the early spring moisture and can be harvested earlier than spring sown crops, helping to distribute farm work more evenly.

Rye can also be grown on poorer soils than any other grain crop. Soils too poor for rye are generally not used for crop production. It can also be grown successfully under distinctly acid soil conditions, but on the other hand, a fairly high degree of alkalinity is not harmful to the crop (Schaben, 1948; Hunter, 1950). Rye produces better on light loams and sandy soil when compared to barley, wheat, or oats. It is more tolerant of dry soils than of wet, poorly drained soils (Briggle,1959).

Fewer diseases and insects attack rye than attack other cereals

(Schaben, 1948; Briggle, 1959).

G. Nutritive Value of Rye

The chemical analysis of rye in comparison to other cereals is given in Table 4. Langborg Hansen et al. (1976) also compared the apparent digestibilities of protein, carbohydrate, and fat of these five grains using pigs as the test animal (Table 4). Based on these results, the metabolizable energy values of rye compare well with those of wheat, maize, and sorghum.

The coefficients of apparent digestibility of dry matter wer higher for rye than for barley (Friend and MacIntyre, 1969; Smith, 1978). Smith (1978) also found that rye had a greater energy digestibility than barley --85.0 versus 80.2%. Friend and MacIntyre (1969) noted that the crude protein of rye was slightly more digestible than that of barley (84.5 versus 82.1%).

Eggum (1973) found the protein quality of barley, oats, and rye to be very much the same when fed to pigs. He found wheat, maize, and sorghum to have a lower biological value since they were lower in lysine, the most limiting amino acid. Biological value (B.V.) for barley was calculated at 80.8, 79.7 for rye, 76.4 for oats, and only 71.2 for wheat. Friend and MacIntyre (1969) and Smith (1978) found little difference in percentage nitrogen retention when pigs were fed rye or barley.

Knipel (1969) indicated that rye when fed to rats had a higher protein efficiency ratio (P.E.R.) that wheat. Zhmakina et al. (1977) obtained similar results with rats reporting P.E.R. values of 1.67 for rye and 0.99 for wheat.

Therefore, these digestibility and utilization studies comparing rye, barley and wheat, clearly demonstrate that lowered digestibility

Table 4

Chemical Composition (% of dry matter) of five cereal grains and apparent digestibility determined in experiments with pigs.

	Protein	Fat	Crude Fiber	NFE	Starch	G.E.
Oats	14.0	5.0	9.2	69.1	55.2	4.52
Wheat	14.8	2.7	2.6	78.0	64.1	4.39
Maize	10.7	4.9	2.7	80.1	72.6	4.46
Sorghum	11.0	3.8	2.6	80.3	71.7	4.40
Rye	11.2	2.7	2.6	81.4	64.2	4.36
			Digestibility			M.E.
Oats	79	67	18	82	100	3.17
Wheat	78	37	27	94	100	3.73
Maize	76	59	53	94	100	3.78
Sorghum	70	51	91	95	100	3.73
Rye	80	33	33	93	100	3.61

G.E.= Gross Energy

M.E.= Metabolizable energy

NFE= Nitrogen free extract

Source: Langborg Hansen et al., (1976)

is not the limiting factor since the apparent digestibility of dry matter and crude protein was highest for rye while nitrogen-retention was similar for rye and barley.

It is well known that genetic as well as environmental factors influence amino acid composition and protein quality of grain. Protein contents ranging between 6.5 and 14.5% have been reported for rye, the higher values usually being obtained under North American conditions of cultivation where nitrogen fertilizer applications are generally higher (Kent-Jones and Amos, 1967). Although, in many cases the level of crude protein in rye equals that of wheat, rye protein contains little gluten, the elastic and distensible substance, important in making bread from wheat, which is formed as a complex of the two proteins, gliadin and glutenin in the presence of water (Hunter, 1950). The protein of rye contains gliadin but little glutenin and therefore, its ability to retain gases is more limited. Even though the nutritive quality of rye bread may equal of exceed that of wheat, it has a distinct sour taste, is flatter and is not as porous as wheat bread.

Rye differs from wheat, barley, and most other cereals in having a comparatively higher proportion of water and salt soluble proteins, both of which have an improved content of the essential amino acid, lysine. In a review, Sauer (1976) indicates lysine and theronine to be the first and second limiting amino acids respectively for barley, oats, rice, rye, triticale and wheat when these cereals were fed to pigs and rats. The amino acid composition of rye protein is claimed to be nutritionally superior to that of most cereals (Bushuk, 1976). This is due, in part, to the higher proportion of lysine and threonine which is found in rye (Table 5).

The mineral and vitamin composition of rye compares favourably

Table 5

Average essential amino acid content of rye, triticale, and wheat as determined by ion-exchange chromatography[a] (gm. of amino acid per 100gm. of total nitrogen; ranges encountered in the literature in parentheses).

Amino Acid	Rye	Triticale[b] (1972-73)	Wheat
Lysine	21.2 (15.1-28.1)	19.6	17.9 (13.1-24.9)
Threonine	20.9 (19.1-23.1)	19.6	18.3 (14.8-22.2)
Arginine	28.6 (18.4-34.4)	38.2	28.8 (23.4-34.4)
Histidine	13.8 (12.5-16.5)	13.3	14.3 (12.5-16.3)
Isoleucine	21.9 (20.0-24.2)	18.7	20.4 (18.8-21.4)
Leucine	38.5 (36.1-40.6)	45.0	41.7 (37.1-45.0)
Methionine	9.1 (5.9-18.1)	6.0	9.4 (6.3-15.6)
Phenylalanine	27.6 (25.0-30.0)	28.6	28.2 (23.4-33.8)
Tryptophan	4.6 (3.4-8.8)	6.3	6.8 (5.1-13.6)
Valine	29.7 (20.6-34.3)	24.2	27.6 (22.8-32.5)

[a]Source: Food and Agriculture Organization (1970) via Hulse and Laing (1974).

[b]Average of data for three advanced triticales produced at CIMMYT, Mexico in 1972-1973.

Source: Bushuk, (1976).

with that of the other cereal grains. Levels of niacin in rye are lower than that found in other cereals. Wojtusiak (1974) reported that nicotinic acid contained in rye is assimilable by rats to a small degree, the values ranging from 11.9 to 35.0%. Since cost of mineral and vitamin supplementation is relatively small when compared to other constituents of the diet, their composition in cereal grains is not of great concern.

H. Use of Rye in Livestock and Poultry Rations

(a) General

Research done in the thirties with livestock and poultry indicated that rye was not as palatable as other grains. Feeding recommendations with the various species suggested that rye should not make up more than 30% of most rations i.e. it should be mixed with other grains. The presence of ergot in rye in varying amounts undoubtedly conditioned these recommendations, but in a number of cases, where apparently lower levels of ergot were present, palatability problems still remained. In the material reviewed here, the emphasis will be on the research data of the past 20 years.

(b) Swine

In order to reduce dustiness and to provide diets with gross energy levels equal to those of maize diets, Hale et al. (1967) added 2.5% tallow to diets where rye completely substituted maize. Pigs fed rye diets with or without added fat grew more slowly (approximately 10-15%) and required more feed to produce a kilogram of live weight gain than pigs fed maize based diets. Hale et al. (1967), therefore concluded that rye is worth only 78 to 80% as much as maize when used as the only grain in a well fortified, 16% protein diet fed to growing - finishing pigs (30-90 kg). In contrast to these results, Danielson (1972) fed rye, in

meal form, at levels up to 60% in replacement of corn for growing-finishing pigs without any decrease in growth rate or feed efficiency.

Contrary to earlier reports that rye should not make up more than 30% of the ration, Bowland (1966) indicated that the rate of gain was not affected by the addition of 25 or 50% rye, in replacement for barley and wheat, to rations fed as a mash. Rye was found to be superior to barley but inferior to wheat with regard to gain and feed efficiency and it was suggested that ergot-free rye can be utilized satisfactorily up to levels as high as 50% of the total balanced ration for market pigs above 25 kg in weight. At levels as high as 65%, Smith (1978) found ground rye to be superior to barley in performance when fed to pigs in the 28-63 kg range.

It appears the inclusion of rye in rations does not affect carcass traits (Bowland, 1966; Johnston et al. 1976). Johnston et al. (1976) compared the feeding value of six feed grains (corn, rye, wheat, triticale, barley and milo). No statistical differences were found between the six grain rations for feed conversion, rate of gain, slaughter weight, or various carcass traits associated with carcass composition.

Conversely, from a review of literature, Wieringa (1967) reported that the recommended maximum levels of rye used for pigs were 30% in diets for older pigs, 15% for pigs weighing 30-50 kg and that no rye be used for piglets or sows. Wieringa (1967) also obtained lower growth rates (12%) in mash diets containing 50% rye when compared to diets containing 50% barley when fed to pigs 16-30 kg of weight.

Friend and MacIntyre (1969) reported that the inclusion of 60% rye in growing pig rations reduced rate of gain more in gilts than in barrows. Inclusion of 30% and 60% rye in replacement for barley in rations resulted in decreased feed intake and therefore lower gains.

Very little work has been conducted with rye in diets for gestating or lactating sows. It is known that rye with high levels of ergot should not be fed to gestating sows. Although Wieringa (1967) suggested that rye should not be fed to sows, Delwiche et al. (1940) recommended that bred sow diets could include up to 40% rye. Trials done at the University of Manitoba (1978- unpublished data) found that gestating sows on restricted diets comsumed pelleted rye diets as well as pelleted barley diets. Digestibility coefficients of dry matter and crude protein were higher for rye. During lactation, research at the University of Manitoba (1978 - unpublished data) found that lactating sows fed rye as the sole cereal grain consumed slightly less feed than those on a barley - based ration. Growth of piglets on sows during a 21 day test period fed pelleted rye were slightly inferior to those fed barley suggesting a lower milk production from sows fed rye diets.

(c) Poultry

Proudfoot (1977) indicated that up to 10% ground rye as a replacement for ground wheat may lead to either an equivalent or superior performance with growing chicks. Associated with the feeding of rye in the mash form at levels of 15% or greater was the presence of feed accumulation on the beaks and "sticky feces" which tended to accumulate on the toes of the chickens (Halpin, 1936; Smith and MacIntyre, 1960; Moran et al., 1970; Finzi et al., 1971; Proudfoot, 1977; and Wagner and Thomas, 1978ab). In most cases the material had to be removed so the mobility of the chick was not hampered. Higher mortality rates were reported by Halpin (1936) but not by Proudfoot when ground rye was fed.

Mature roosters utilized pelleted rye more efficiently than chicks (7-12 days of age) according to Moran et al. (1969).

Smith and MacIntyre (1960) supported the fact that up to 60% rye

may be safely fed to growing chickens if the entire ration is pelleted. In agreement with these data, Moran et al. (1969) found that additions of 64% rye in place of corn showed a dramatic decrease in growth rate which was largely overcome by pelleting. The large improvement was almost wholly attributed to the overcoming of the problem of feed accumulation on the beaks, however, the problems of feces still existed.

Wagner and Thomas (1978[a])found that day old chicks fed 55% rye showed an adaptive response after about eight days. Since the adaptation occurred only in the chicks not supplemented with antibiotics, they suggested that the adaptation was due to changes in the gut population. It has been reported by many researchers that the growth depression in chicks fed a large percentage of rye, is largely overcome by procaine penicillin or by other antibiotics (MacAuliffe and M^{c}Ginnis, 1971; Fernandez et al., 1973 a,b; Ferndandez et al. 1974; Patel and M^{c}Ginnis, 1976; and Misir, 1977). Improvement in the growth of chicks fed 55% rye diets containing antibiotic supplements show that the depression otherwise noted, suggests a toxin in rye is not involved (Wagner and Thomas, 1978a). Misir (1977) reported that the detrimental effects of rye can be minimized by supplementing the diet with 160 mg/kg procaine penicillin and a level of good quality protein which exceeded the N.R.C. protein requirement by 3%.

Removal of water soluble fractions of rye gave a significant improvement in chick growth and feed efficiency (MacAuliffe and M^{c}Ginnis, 1971; Lucas, 1973; Misir, 1977; and Misir and Marquardt, 1978b). It has been suggested that the water soluble pentosans of rye lead to increases in penicillin sensitive, sporeforming organisms which produce large amounts of gas (CO_2 and some NH_3) and butyric acid fermentatively resulting in decreased feed intake and hence decreased gains (Wagner and Thomas, 1978b).

Halpin et al. (1936), attempted to determine the effect of feeding rye to laying hens in mash form, at levels of 15, 30, and 45% of the diet, as a replacement for corn. Egg production was similar for all groups. The fertility and hatchability of eggs from all groups were satisfactory. More recently, Fernandez et al. (1973) reported that rye replacing corn and wheat at a level of 80% in the diet caused a sharp decline in egg production, followed by a subsequent partial recovery, indicating a toxic effect rather than a nutrient deficiency (Fernandez et al., 1973c), which does not agree with the later results of Wagner and Thomas (1978) who suggest a toxic effect is not the cause of the poor performance associated with rye in chick diets.

(d) Ruminants

Baker et al. (1935) reported that finishing calves consumed and gained almost as much when fed ground rye compared to cattle fed ground corn and wheat, but the rye fed calves, lacked finish. Later results obtained by Winter (1975) indicate that up to 60% rye grain can be used in high energy rations for steer calves. There were essentially no effects on feed consumption, weight gains, or feed efficiency of the steers and the rye grain had a feeding value at least equal to that of the barley it replaced. Feeding rye to fattening lambs has produced as good results as wheat or barley (Morrison, 1969).

Cullison (1975) reported that levels of rye as high as 45% of the concentrate may be fed to dairy cows without decreasing performance.

I. Anti - Nutritional Factors in Rye

(a) Ergot

It is now generally understood that levels of ergot exceeding 0.1% in the diet may prove to be detrimental to the performance of animals.