A COMPARISON OF THE NUTRITIONAL QUALITIES OF CORN, WHOLE SORGHUM, AND PEARLED SORGHUM TORTILLAS

By

Deanna Marie Hoelscher

Department of Food Science and Technology

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Approved by:

Dr. Lloyd W. Rooney
Department of Soil & Crop Sciences

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ABSTRACT

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Deanna M. Hoelscher

Texas A & M University

Directed by: Dr. L. W. Rooney

Sorghum has been shown to produce tortillas comparable to the traditional corn tortilla. Sorghum has been found to have a lower feed efficiency than corn. This study examined, for the first time, the nutritional quality of sorghum when processed into tortillas and compared it with the corn tortilla.

Tortillas were made from corn, whole sorghum, and pearled sorghum. Fifteen percent of the outer layers of the sorghum kernel were removed during the pearling process. A longer cooking time was required for the corn tortilla. The pearled sorghum was soaked in water and alkali prior to cooking; it cooked for only 4 minutes.

Organoleptic properties of the tortillas were evaluated with a taste panel. Acceptance of the sorghum tortillas were about half of the acceptance of the corn tortillas, although none were disliked extremely in any case. The whole sorghum tortillas were dark in color. Pearling seemed to improve the color of the tortillas, but the pearled tortillas were still darker than the corn tortillas. A white sorghum, such as the one that was used in this study, does not always produce a tortilla of acceptable color. Environment can influence polyphenol content and thus, influence color of the finished product. The corn had a higher

protein content than the sorghum (8.38 compared to 6.69). Pearling removed some of the pericarp proteins to lower the protein level of the decorticated grain to 6.3. The protein content of all of the grains increased during the processing due to loss of starch. Calcium levels also increased during cooking because of addition of CaO. The pearled sorghum have slightly lower amounts of the Si, P, Mg, and K.

In vivo analysis was attempted using a modified Protein Efficiecy Ratio. Moisture and fiber contents of the diets were raised to 10 and 2 % respectively. Casein supplementation to reach a level of 9% protein in the diet was needed for both the grains and the tortillas. Modified PERs (mPERs) for the sorghum fed rats were higher than corn. Corn tortilla fed rats had slightly higher mPERs than both groups of sorghum tortilla fed rats. However, since the corn and sorghum results conflict directly with the values in the literature, these trials should not be accepted without further experimentation.

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INTRODUCTION

Sorghum is the third largest cereal crop in the United States and the first largest cereal crop in Texas. Part of the reason for its large output is due to its ability to grow under a wide range of climatic conditions. Even in years of drought, sorghum produces grain. Although sorghum is used mainly as an animal food in the United States, several other countries incorporate it into their diets. In Africa, sorghum is used to produce a porridge called to and is also fermented into a beer. In India, an unleavened bread called chapati is made from sorghum flour. Ogi, injera, roti, and kisra are other foods produced from sorghum. The incorporation of sorghum into breads, cakes, and pastas is also being studied (Rooney et al., 1980).

Sorghum can also be incorporated either alone or in combination with corn into tortillas, a unleavened bread consumed in Central America and Mexico (Khan et al., 1980). Tortillas are made by cooking corn in alkali, steeping the cooked grain (nixtamal), grinding the grain into a dough (masa), forming the masa into a pancake shape, and cooking the tortilla on a griddle (Bedolla and Rooney, 1982). Tortillas are a major part of the diets of people in these countries, especially in rural areas where people may obtain up to 70% of the total protein intake from tortillas (Bedolla, unpublished data). Substituting sorghum for corn in tortillas may provide a cheaper and more dependable food alternative. Because of rapid population increases, Mexico and other countries in Central America will not be able to produce enough corn to meet the needs of their people in the future. A partial substitution of corn with sorghum might help to ease this situation, while providing a comparable product. In Mexico alone, more than 1 million metric tons of sorghum would be incorporated into the diet at a substitution rate of 15% (Iruegas et al., 1982).

Sorghum is not always accepted in tortillas, because of its stigma as an animal food and the greenish colors produced by the reaction of polyphenols in the sorghum kernel with the alkali in the cooking process. White sorghum varieties, such as CS3541, have been shown to produce tortillas of accepatable color (Choto, 1983). Pearling, a removal of the pericarp of the sorghum kernel, can also produce a lighter colored tortilla since most of the polyphenols are located in the outer layers of the sorghum kernel. A pearling level of 15-25%, in which 15 to 25 % of the weight of the kernel is removed has been suggested (Bedolla et al., unpublished data). Weathering of the sorghum kernel can also cause production of polyphenols, leading to formation of colored tortillas. Since sorghum has exposed grain, rather than a strong outer covering as corn does, it is much more prone to insect attack, molding, and climatic changes (Lichtenwalner et al., 1979). When attacked, the kernel produces polyphenols as a protective measure. Thus, environment can stongly influence the acceptability of sorghum in tortillas.

The objectives of this study are:

1. To compare the chemical composition, yield and acceptability of corn, whole sorghum, and pearled sorghum tortillas.
2. To determine and compare the nutritional quality of corn, whole sorghum, and pearled sorghum tortillas by both *in vitro* and *in vivo* methods.

REVIEW OF LITERATURE

The nutritional quality of sorghum grain has been well studied. In composition, sorghum grain resembles corn. Starch comprises about 70-75% of the dry weight of the kernel, with an extra 5-10% composed of other carbohydrates. Protein comprises another 10-11% of the kernel (Rooney et al., 1980). Lipids, minerals, and other chemical compounds compose the remainder of the kernel.

Even though the sorghum kernel contains about one more percentage point protein than corn, feeding trials have shown that the sorghum protein seems to have a lower feed efficiency than corn (Tanksley et al., 1975; Maxson et al., 1973). Tanksley et al. have determined the protein content of sorghum to have about 90-95 % of the feed efficiency of corn. The sorghum fed swine in this experiment gained about as much weight as the corn fed swine but ate a larger amount of the sorghum. In sorghum, as in corn, lysine is the first limiting amino acid, followed by threonine and tryptophan. The percent lysine decreases in the grain as its protein content increases (Rooney et al., 1980).

During processing of the corn into tortillas, leucine content decreases which corrects the leucine to isoleucine ratio and improves the protein quality (Katz et al., 1974). With an unfavorable leucine to isoleucine ratio the conversion of tryphtophan to niacin is decreased; with the low niacin content of the corn pellegra, a niacin deficiency, will develop.

Raw corn contains niacin in bound form; when cooked with alkali, this bound niacin is released into a biologically useful form. Cooking corn with alkali to produce tortillas has prevented pellegra in Mexico and Central America. Alkali treatment also increases the amount of calcium in the tortillas since $Ca(OH)_2$ is the usual source. Calcium absorption from tortillas is as high as that from milk (Bressani, 1972).

The Protein Efficiency Ratio (PER) is one method of measuring the quality of the protein of a food. Although the procedure is an accepted one, it does have many limitations, including: non-repeatable results, use of only one kind of protein, use of proteins with 10% or more protein by composition, acceptability of diets (Robaidek, 1983).It does, however, provide a means of in vivo measurement of food value. A product that may yield good test tube results may not fare well in a living system.

MATERIALS AND METHODS

Grain

The corn used in this study was Asgrow 405, a white corn grown at Uvalde, Texas in 1982, while the white sorghum, ATx623 x Tx430, was grown at Weslaco, Texas in 1982 (Figure 1). Both grains were free of mold and disease. Clean, whole kernels were used for this study. The pearled grain was prepared by running 3 kg of grain through a barley pearler for 2 minutes and 54 seconds to remove 15% of the kernel by weight, including mostly pericarp and aleurone layers. The pearled grain was cleaned using an E. L. Erickson blower and a Clipper grain cleaner.

Preparation of Tortillas

The tortillas were prepared using the steam cooking method described by Choto (1983). Three kg of the grain was combined with the proper amount of CaO and distilled water and cooked for the appropriate time (Table 1). The CaO was obtained from Amigos Manufacturing Co., San Antonio, Texas. After washing the nixtamal with 8 l of water to remove the excess alkali and pericarp that had been loosened in the cooking process, the wash water was collected. The grain was then run through a stone grinder as described by Des Rosiers (1980). The masa was forced through a tortilla former and the resulting tortillas were cooked on a griddle at 280°C for 60 seconds on one side, 30 seconds on the other side, and another 30 seconds on the other side. Samples were taken at each step in the tortilla-making process. The cooked tortillas were then cooled, packaged in plastic bags, and frozen at 0°C until about 24 kg of each kind of tortilla were collected (approximately 6 batches).

Each group of cooked tortillas was dried in a rotating gas oven at 40°C for 24 hours or until thoroughly dried. The tortillas were then broken into smaller pieces and stored in plastic bags.

Chemical Analysis

For analysis, grain and tortillas from each group were gathered and ground in a Udy mill. Moisture and ash content (4 hour, 600°C) were determined using AACC procedures (1976). Protein was analyzed using a Technicon Auto-Analyzer as described by Khan et al. (1981). Ether extract and crude fiber were analyzed using AOAC procedures for proximate analysis. All values were converted to dry weight basis. Phenol content was analyzed using the methods of Kaluza et al. (1980). Mineral analysis was conducted at the University of Nebraska, using X-ray diffraction. A taste panel was conducted by a sampling of people who evaluated all three tortillas on the basis of color, taste, and overall acceptability.

Preparation of the Diets

The AOAC (1980) procedures for Protein Efficiency Ratios (PER) were followed for content of the diets with a few modifications: (1) fiber increased to 2%, (2) moisture increased to 10%, (3) protein content decreased to 9 %, and (4) casein supplementation to the tortilla and grain diets (Table 6). Seven diets were prepared: casein control, corn, whole sorghum, pearled sorghum, corn tortillas, whole sorghum tortilla, and pearled sorghum tortilla. The diets were mixed in a Hobart mixer and stored in plastic buckets in the freezer throughout the study.

Rat Feeding Trials

Twenty-eight day old male weanling Sprague Dawley rats ($\bar{x}$ = 85 g) obtained from Timco, Inc. were used for the feeding study. The rats were housed in individual wire bottomed cages and distributed evenly among 2 batteries. An acclimatization period of 7 days preceded the test. On the first, second, and last days, the rats were fed Wayne Lab Blox (Allied Mills, Inc., Chicago, Ill.), and the remaining days they were fed a casein control diet of 10 % protein.

Experimental Design

Ten rats were assigned to each diet according to weight. Each group had a range of 10 g, and the mean weights of each group differed by no more than 10 g from the control. After assignment to a group, the rats were placed into the batteries in a randomized placement determined by lottery. Each cage and each feed cup was individually labelled. The feed cups were stainless steel, with a cover and perforated circle that held the feed down (Figure 3). Very little spillage (<.2 g per week) occurred throughout the 28 day feeding period. Food and water were given *ad libitum*, and food was weighed daily. The feed dishes were cleaned each week, and the water bottles every other day. The rats were weighed before and after the test, and at 7 day intervals during the test. Total food intake and weight gained for each rat was recorded and a modified PER (mPER) was calculated for the group using the following formula:

PER = (weight gained)/(amount of feed consumed)(% protein of feed).

RESULTS AND DISCUSSION

Tortilla Production

Modifications were made in the formula used by Choto (1983). Cooking time for the corn increased to 105 minutes (Table 1). The corn used in this study was a different variety than that used by Choto and previous experimentation has shown that varietal differences in cooking time exist (Bedolla, 1980). The pearled sorghum tortillas required a cooking time of only 4 minutes, when coupled with a pre-cook soak of 45 minutes in the alkali and water. The pearled sorghum tortillas were not washed, but drained for 30 minutes as a continuation of the cooking process. The reduction in cooking time is significant between the sorghum and the corn. The energy savings alone are reason to pursue the incorporation of sorghum into tortillas.

The sorghum nixtamal had a dark tint which was accentuated during the grinding and cooking processes. Although the sorghum was a white variety, it evidently contained a high enough polyphenol level to react with the alkali to produce the darkening. Tortillas of light color have been produced from other varieties of sorghum (Khan et al., 1980), which proves that the color of the kernel itself is not indicative of the final color of the tortilla. Environment has an important role in the development of polyphenols, which cause the color changes in tortillas. The pearled sorghum nixtamal and resulting tortillas were significantly lighter than the whole sorghum ones (Figure 2), but not as light as the corn nixtamal and tortillas.

Both sorghums had a distinctive smell during cooking that differed from corn. The masa for the whole sorghum and pearled sorghum tortillas was as pliable as the corn masa, although the sorghum masas tended to dry very quickly. Any overcooking of the sorghums produced a sticky, unworkable masa. The finished tortillas were similar in texture, but differed markedly in color (Figure 1).

Organoleptic Evaluation

The majority of the participants in the taste panel were United States citizens, so acceptance was based on an "American" taste for tortillas. The test was based on degrees of acceptance, but for convenience the groups were analyzed for acceptance, neutrality, and non-acceptance based on color, taste, and texture. The corn tortillas were widely preferred (Table 2). Both sorghum tortillas were fairly accepted. The pearled sorghum tortilla had more neutral responses than the whole sorghum tortilla. The fact that the sorghum tortillas were acceptable, even at a lower level than the corn tortilla, demonstrates that sorghum may be used to produce a product similar to that of corn. Since this particular variety of sorghum produced dark tortillas, the color may have influenced the outcome of the taste panel.

Chemical Analysis

The sorghum contained less protein than the corn unlike the sorghum in other studies (Table 3). This variety of sorghum was weathered and grown under commercial conditions unlike most test grain which is grown under optimum conditions. Most sorghum varieties average 9 to 10 % protein (Rooney et al., 1980), while the variety of sorghum used in this project contained only 6% protein. The low protein value was one reason for supplementation of casein in the diet, in order to bring the diet up to a 9% protein level. The pearled grain and tortillas both show a lower value of protein than the whole grain samples. Some of the protein in the kernel is found in and under the pericarp, which is mostly removed during pearling.

The pearled grain has a lower percentage of phenols than does the whole grain (Table 4). However, corn shows a higher content of phenols than either of the sorghums. Possibly some other component in the corn is reacting to provide a false negative for this test. The other sorghum variety, CS3541, has a phenol content as low as that for the pearled ATx623 x Tx430. CS3541 produces an tortilla of acceptable quality, especially when pearled. Mineral analysis (Table 5) shows a significant increase in calcium levels in all three grains through the cooking process. This increase in calcium has been one of the major nutritional benefits of the alkali cooking process (Bressani et al., 1958). The pearled grain also shows a decrease in most of the minerals, which can be expected due to the fact that the pericarp and aleurone layers of the grain, which contain many of the minerals in the grain, are removed in the pearling process.

<u>In Vivo</u> Results

The modified PER (mPER) values are shown in Table 7. The actual values were converted to a 2.5 casein reference. Corn had the lowest mPER of any of the groups. This information contrasts with all other feeding trial data using sorghum and corn diets (Maxson et al., 1973; Tanksley, 1975) In the other research, corn has the highest PER of any of the grains. The corn fed rats in this study gained little weight and developed bloody noses, coarse hair, and hyperactivity. The corn diet may have become contaminated or it may not have been mixed as thoroughly as it should have. An amino acid toxicity may have caused this condition. This fact alone suggests that another trial be attempted before accepting this data as fact. The whole sorghum and pearled sorghum diets both had larger mPER values than did the casein control. This data is also contradictory to published results. These diets did have a high level of casein supplementation, so in actuality the diets were measuring the supplementary effect of the sorghum. The sorghum may have had a better amino acid ratio which naturally complemented the amino acid composition of casein.

The tortillas were close in mPER values, although the corn tortilla mPER was higher than either of the sorghum tortillas. The higher protein utilization of the corn is borne out by other experiments. Pearled sorghum tortillas had a higher mPER than the whole sorghum tortillas. The pearling process may remove some of the undigestible proteins in the outer layer of the kernel, leaving the easily digestible proteins inside the kernel.

CONCLUSION

Pearled sorghum can be used to make tortillas with only 4 minutes of cooking time if a soak precedes the cook. The energy saving implications of this finding are enormous.

Tortillas made from the whole sorghum and the pearled sorghum are dark in color compared to tortillas made from other varieties of white sorghum. Environment definitely has an impact on formation of polyphenols in sorghum grain and therefore, color. Pearling did reduce the darkness to a significant degree, although both sorghum tortillas were still less acceptable than the corn tortillas in taste panel data.

The sorghum grain had a lower protein content than the corn. The sorghum grain also had a lower protein content than the average sorghum. Protein content increased during the cooking process due to the loss of starch in the steep waters. The low protein content of both grains led to complications in the rat feeding trials.

The phenol content of the grain did not accurately indicate the color of the finished product. The corn had a higher phenol content probably due to the reaction of other components to give a false negative. Calcium level does increase significantly during cooking, in all three grains. Other mineral losses occurred in the whole sorghum when it was pearled. The minerals that were lost probably are contained within the outer layers of the kernel that were removed.

The mPER values are not consistent with values in the literature. This study showed corn with an extremely low mPER and sorghum with a high mPER. These results directly conflict with prior knowledge. Until more research on the tortillas is done, this study should be viewed caution. I recommend that this experiment be done again, possibly with a sorghum of better food quality to really determine if the nutritional value of the sorghum tortilla is similar to the corn tortilla.

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TABLE 1

COMPARISON OF TORTILLA MAKING PROCESSES

	AMT CaO (g)	AMT H_2O (l)	SOAK BEFORE COOK (min)	COOKING TIME (min)	STEEPING TIME (min)
CORN	30	9	0	105	240
WHOLE SORGHUM	24	9	0	35	0
PEARLED SORGHUM	6	4	45	4	30[1]

1 DRAINED FIRST

TABLE 2

TASTE PANEL DATA (%)

TORTILLA	ACCEPTABLE	NEUTRAL	NOT ACCEPTABLE
CORN	84.2	5.3	10.5
WHOLE SORGHUM	39.5	18.4	42.1
PEARLED SORGHUM	39.5	28.9	31.6

TOTAL	UNITED STATES	MEXICAN	LATIN AMERICAN	OTHER
100.0	81.5	7.9	5.3	5.3

SAMPLE SIZE = 38

TABLE 3

CHEMICAL ANALYSIS OF GRAIN AND TORTILLAS

	PROTEIN[1]	ASH[1]	MOISTURE	ETHER EXTRACT	CRUDE FIBER[1]
CORN	8.38	1.47	11.6	4.90	1.84
WS	6.69	1.57	10.9	2.90	1.73
PS	6.30	1.02	12.2	1.90	.69
CORN TORTILLA	8.40	1.63	6.88	4.50	1.30
WS TORTILLA	8.36	1.45	7.28	2.42	1.65
PS TORTILLA	7.55	.91	6.67	1.39	.62

[1] PRESENTED AS % ON DRY WEIGHT BASIS

WS - WHOLE SORGHUM
PS - PEARLED SORGHUM

TABLE 4

PHENOLS (%)

	WHOLE KERNELS	GROUND GRAIN	TORTILLAS
ATX62 X TX430			
WHOLE SORGHUM	.094	.070	.023
PEARLED SORGHUM	.072	.041	.011
ASGROW 405			
WHOLE CORN	.093	.086	.090
CS3541[1]			
WHOLE SORGHUM	.073	.079	-

[1] USED FOR COMPARISON PURPOSES

TABLE 5

MINERAL ANALYSIS (%)

	Ca	Si	P	Mg	K
CORN	.00446	.183	.319	.230	.418
WHOLE SORGHUM	<.00300	.107	.215	.186	.422
PEARLED SORGHUM	.01072	.102	.189	.169	.306
CORN TORTILLA	.27800	.031	.331	.235	.282
WS TORTILLA	.16200	.046	.291	.251	.310
PS TORTILLA	.08900	.057	.179	.173	.273

WS - WHOLE SORGHUM
PS - PEARLED SORGHUM

TABLE 6

DIET COMPOSITION (%)

	AOAC, 1980	TORTILLA DIETS	GRAIN DIETS
PROTEIN	10	9[1]	9[2]
FAT	8	8	8
MINERALS	5	5	5
VITAMINS	1	1	1
FIBER	1	2	2
WATER	5	10	10
CORN STARCH	70	65	65
TOTAL	100	100	100

1 94% TORTILLA, 6% CASEIN

2 92% GRAIN, 8% CASEIN

TABLE 7

PROTEIN EFFICIENCY RATIOS

	OBTAINED VALUE	ADJUSTED VALUE
CASEIN	3.57	2.50
CORN TORTILLA	3.66	2.56
WS TORTILLA	3.09	2.16
PS TORTILLA	3.43	2.40
CORN	2.22	1.55
WHOLE SORGHUM	3.93	2.75
PEARLED SORGHUM	3.90	2.73

WS - WHOLE SORGHUM
PS - PEARLED SORGHUM

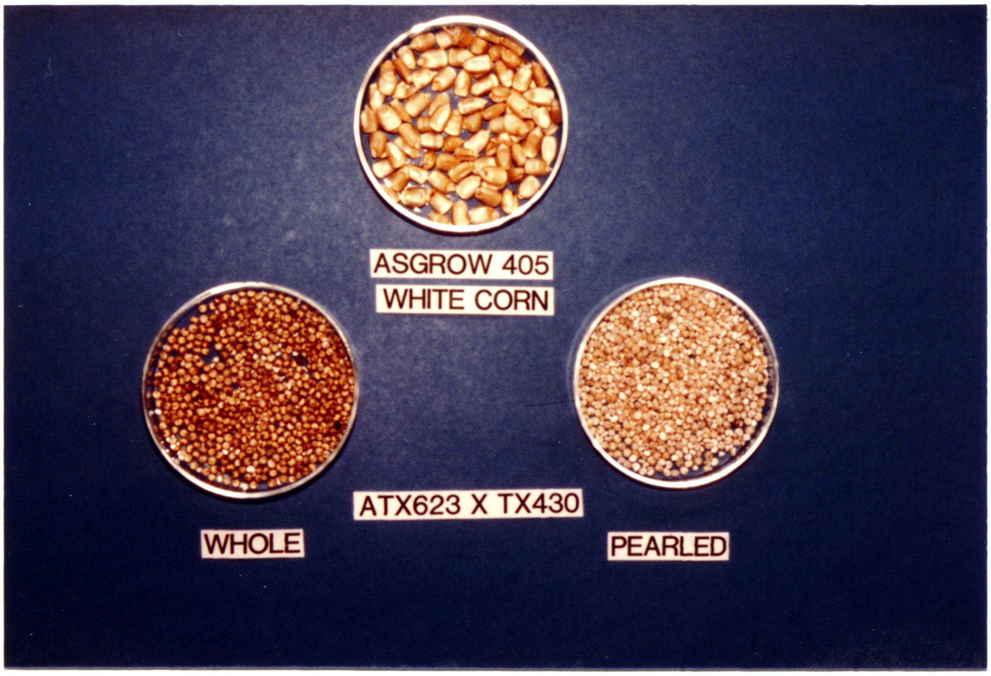

Figure 1: Grain

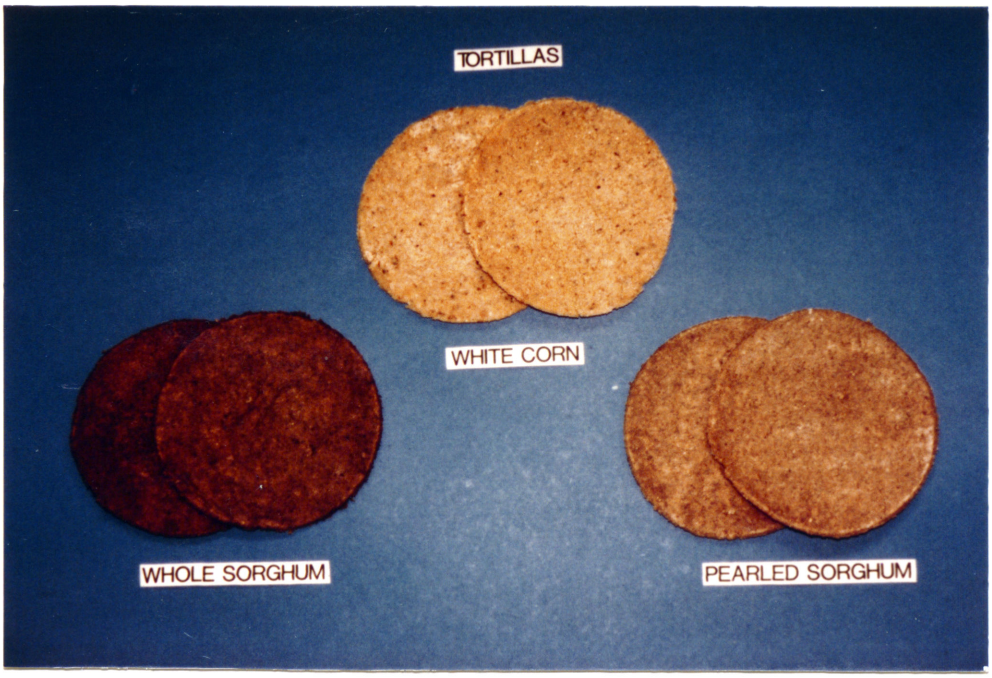

Figure 2: Tortillas

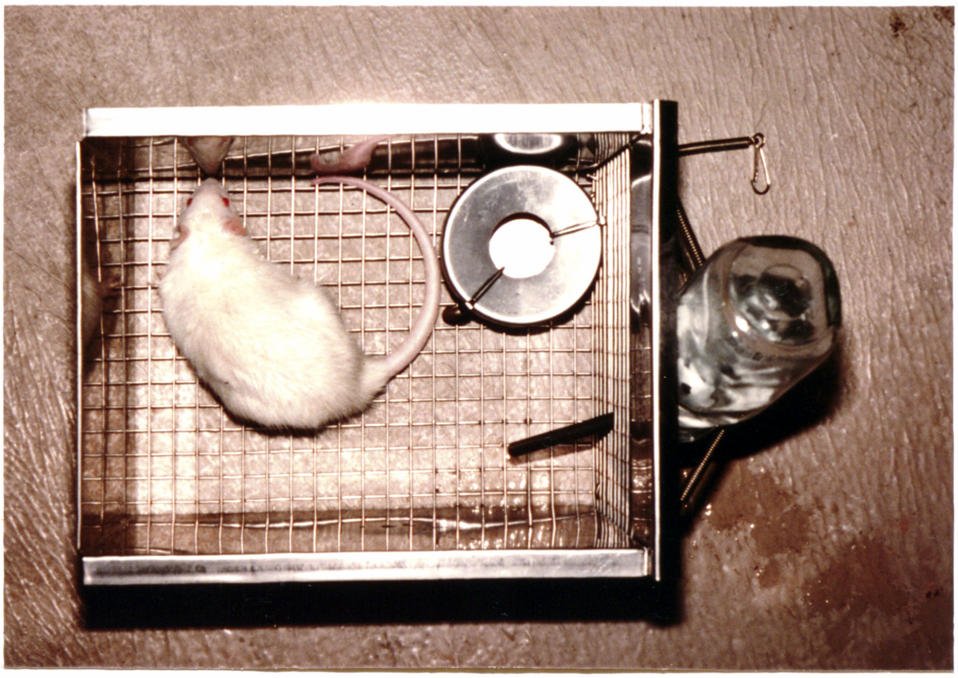

Figure 3: Individual Cage Arrangement