(Buamah and Singsen, 1976). In this study the maximum PER for peanut meal occurred with the diets containing 10% protein. The relative value for peanut protein at this concentration, compared with the value for 10% casein indicated by the curves in Figure 3, is approximately 68% at 2 weeks and 71% at 4 weeks. These values for relative PER of peanut protein would be 13% lower if the factor of 6.25 had been used to calculate protein concentration from nitrogen content as is often done (AOAC, 1975). However, a conversion factor of 5.46 is considered to be more nearly correct for the proteins in peanuts (USDA, 1957).

The data presented show that peanut meal as the sole source of protein is capable of producing maximum rate of growth in weanling rats. The meal used was carefully handled to minimize post-harvest changes in peanut protein quality. The failure (Wethli et al., 1975) to obtain maximum growth of chicks with groundnut meal may have been due to their higher dietary protein requirement or to deterioration of protein quality of the product during processing and storage.

Peanut meal, prepared and stored under conditions to minimize deterioration of protein quality, could become a significant source of protein on the world food market. In some geographical areas where the supply of protein is scarce, the peanut residue from oil mills is essentially wasted because of unsanitary conditions that prevail during storage and processing. Recognition of the value of the protein of the press cake might provide the economic incentive to improve processing conditions. The meal has potential as a human food but it might well serve as a source of feed for production of meat animals in these areas. Even if growth rate of such animals was not maximal, this would be nutritionally preferable to a lack of animal proteins in the diets of the people.

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# Lead and Other Elements in Sheep Fed Colored Magazines and Newsprint

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Colored paper from magazines and newsprint was fed as 23% of a ration to sheep for 124 days. Among 44 elements determined in the paper and selected sheep tissues, marked accumulation of lead in animal organs was found reaching 22 ppm in bone. Barium and bromine was higher in kidney and fluorine was higher in bone of sheep fed the paper vs. the control ration. Histological examination of animal tissue revealed no apparent lesions which could be attributed to consumption of the paper diet. The sheep on the paper ration consumed more and gained weight at a faster rate than the control animals. The paper rations showed a higher in vivo digestibility than the control diet.

Several investigators have incorporated waste paper in farm animal rations as a possible substitute form of cellulose in their diets. Others have studied its digestibility in vitro. Waste paper has included newsprint and magazines (Sherrod and Hansen, 1973; Rural Research, 1974; Dinius and Oltjen, 1971; Daniels et al., 1970; Dinius and Oltjen, 1972; Mertens et al., 1971; Kesler et al., 1967), office bond (Nishimuta et al., 1969), and a variety of others (Becker et al., 1975). Polychlorinated biphenyls (PCB's) (Shahied et al., 1973; Masuda and Kagawa, 1972; Villeneuve et al., 1973), polychlorinated terphenyls (Thomas and Reynolds, 1973; Villeneuve et al., 1973), and unidentified compounds (Serum, et al., 1973) have been detected in waste paper and paperboard. Lactating cows fed waste newsprint, grey or brown cardboards, or computer paper as 30% of their ration for periods up to 39 days excreted PCB's in their milk and showed tissue

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Table I. Feed Composition

| Constituent | Wt, % |
|---|---|
| Paper | 23 |
| Corn meal | 41 |
| Soybean meal | 20 |
| Alfalfa meal | 10 |
| Molasses | 4.95 |
| Minerals | 1 |
| Vitamins | 0.05 |

Table II. Elemental Content of Colored Paper

| Element | Concn, ppm, dry wt |
|---|---|
| Al | 37 700 |
| As | 0.6 |
| Au | 0.0006 |
| B | 153 |
| Ba | 333 |
| Br | 225 |
| Ca | 6 600 |
| Cd | 0.05 |
| Ce | 21 |
| Cl | 832 |
| Co | 2.3 |
| Cr | 94 |
| Cs | 0.3 |
| Cu | 20 |
| Eu | 0.5 |
| F | 29 |
| Fe | 744 |
| Hf | 0.8 |
| He | 0.02 |
| I | 9.6 |
| K | 557 |
| La | 9.1 |
| Lu | 0.05 |
| Mg | 4 100 |
| Mn | 7.8 |
| Mo | 5.3 |
| Na | 658 |
| Ni | 3.0 |
| Pb | 514 |
| Rb | 7.1 |
| Sb | 4.6 |
| Sc | 1.9 |
| Se | 0.01 |
| Sm | 8.7 |
| Sn | 240 |
| Sr | 310 |
| Ta | 0.6 |
| Th | 9.2 |
| Ti | 4 220 |
| U | 0.5 |
| V | 36 |
| W | 1.8 |
| Yb | 0.4 |
| Zn | 100 |
| | % dry wt |
| N | 0.04 |
| Ether extractable residue | 0.55 |
| Ash | 20.24 |
| Energy | 3 531.5[a] |

[a] Cal/g.

residues of PCB's (Furr et al., 1974). Others have reported concentrations of lead in magazines and colored newsprint (Heichel et al., 1974; Eaton et al., 1975; Hankin et al., 1974a), colored food wraps (Hankin et al., 1974b,c), and colored printing inks (Hankin et al., 1973) up to 10 000 ppm. In the work reported, colored magazine and newspaper was fed as 23% by weight of a ration to sheep for 124 days. Sheep tissues were analyzed for lead and other elements. Studies of tissue pathology and ration digestibility were also conducted.

## EXPERIMENTAL SECTION

**Sheep Feeding.** A variety of colored paper was collected consisting mainly of magazines but also including catalogs, brochures, and rotogravure sections of newspapers. Staples were removed and about 80 kg of the paper was pulverized in a hammer mill equipped with a 0.32-cm mesh sieve. The paper was thoroughly mixed and incorporated (23% dry weight) into a ration for sheep and pelleted (0.4 cm pellets). The feed composition is listed in Table I. Agway's Early Market Lamb Pellets comprised the control ration. Two Dorset and two Hampshire wethers, 10 months old, were obtained. Two of the animals (one of each breed) were fed the rations containing paper and the remaining two were fed the control diet. Each animal was kept in a separate stall. The animals were adapted from a hay to a pelleted diet over a period of 16 days just prior to beginning the feeding experiment. Following this an additional 9 days was used to adapt two of the animals from a diet of pellets without paper to pellets containing 23% paper. The feeding continued for 124 days beginning with their receipt of the complete pelleted 23% paper ration. Salt (without iodine or trace minerals) and water was provided ad libitum. The sheep remained in these stalls except for a 9-day period during the last 2 weeks of the experiment when the animals were placed in metabolic stalls to measure the digestibility of the rations. At the end of the feeding period the sheep were killed and tissue samples taken for necropsy, histological examination, and element analysis.

Table III. Elements Found at Elevated Concentrations in the Complete Pelleted Ration Containing 23% Paper vs. the Control Ration

| Ration | Element, ppm, dry wt Ba | Br | Cr | F | Pb |
|---|---|---|---|---|---|
| Control | 12 | 16 | 0.7 | 3.5 | 1.1 |
| 23% paper | 69 | 43 | 32 | 7.5 | 138 |

Table IV. Concentration of Lead (ppm, dry wt.) in Sheep Tissues

| Tissue | Control Dorset sheep no. 1 | Control Hampshire sheep no. 2 | Paper-fed Dorset sheep no. 1 | Paper-fed Hampshire sheep no. 2 |
|---|---|---|---|---|
| Blood[a] | 0.2 | 0.2 | 0.8 | 0.6 |
| Bone (tibia) | 2.6 | 2.7 | 22 | 17 |
| Brain | 0.4 | 0.5 | 1.2 | 1.2 |
| Heart | 0.5 | 0.3 | 0.3 | 0.2 |
| Kidney | 0.7 | 1.0 | 7.0 | 8.3 |
| Liver | 0.3 | 0.6 | 5.9 | 4.1 |
| Muscle (chuck) | 0.5 | 0.4 | 0.4 | 0.3 |
| Muscle (round) | 0.3 | 0.4 | 0.3 | 0.2 |
| Pancreas | 0.6 | 0.7 | 3.3 | 3.8 |
| Spleen | 0.5 | 0.8 | 0.7 | 0.7 |
| Feces[b] | 2.3 | 16.9 | 361 | 379 |

[a] Sampled at time of sacrifice. [b] Sampled after 110 days of feeding.

**Methods of Analysis.** Nondestructive neutron activation analysis for 33 elements was conducted by the procedure previously described (Furr et al., 1976). Other methods of analysis which were employed required preliminary ashing of the samples. Up to 1 g of the freeze-dried sample was dry ashed at 475 °C by the method of Gajan and Larry (1972). Cadmium, lead, copper, and zinc were analyzed by conventional stripping voltammetry using a Princeton Applied Research Corp. Model 174 polarographic analyzer (Gajan and Larry, 1972). Chromium and nickel were determined by furnace atomic

Table V. Other Elements Found at Elevated Concentrations in Tissues of Sheep Fed the 23% Paper Ration vs. the Control Ration

| | | Element, ppm, dry wt | | | |
|---|---|---|---|---|---|
| Element | Tissue | Control Dorset sheep no. 1 | Control Hampshire sheep no. 2 | Paper-fed Dorset sheep no. 1 | Paper-fed Hampshire sheep no. 2 |
| Barium | Kidney | 8.3 | 8.2 | 23.8 | 20.1 |
| Bromine | Kidney | 16 | 27 | 32 | 41 |
| Fluorine | Bone (tibia) | 1.1 | 1.1 | 2.0 | 1.5 |
| Fluorine | Feces | 3.2 | 3.3 | 21.7 | 23.3 |

Table VI. Digestibility Coefficients of the Pelleted Rations and Rate of Weight Gain of Sheep during the Feeding Study

| Sheep | Initial body weight,[a] g | Total feed consumed,[b] kg | Rate of weight gain, g/day | Ration digestibility, % |
|---|---|---|---|---|
| Control Dorset no. 1 | 37 200 | 146.06 | 96 | 65.04 |
| Control Hampshire no. 2 | 35 900 | 145.91 | 76 | 64.63 |
| Paper-fed Dorset no. 1 | 42 150 | 166.29 | 129 | 68.15 |
| Paper-fed Hampshire no. 2 | 40 000 | 151.35 | 107 | 67.51 |

[a] Weight of sheep on first day paper ration was fed. [b] Total feed consumed during the entire 124-day feeding period.

Table VII. Analysis of Pelleted Rations for Nutrients, Fiber, and Ash

| Ration | Ash, % | Fat, % | Fiber, % | Protein, % | Ca, % | P, % |
|---|---|---|---|---|---|---|
| Control | 8.68 | 3.24 | 9.46 | 16.4 | 1.30 | 0.63 |
| 23% paper | 7.59 | 2.45 | 14.38 | 14.8 | 0.62 | 0.40 |

absorption spectrophotometry using a Perkin-Elmer Model 303 spectrophotometer equipped with a HGA-2000 furnace. Arsenic was determined by distillation of arsine and analysis using the silver diethyldithiocarbamate spectrophotometric procedure (Evans and Bandemer, 1954; Fisher, 1960). Boron was analyzed by the curcumin spectrophotometric procedure (Greweling, 1966). Phosphorus was determined by the molybdivanadophosphoric acid spectrophotometric procedure (Greweling, 1966).

Analysis of selenium was performed by a modification of the method of Olsen (1969) employing wet digestion of the sample and measurement of the fluorescence of piazselenol resulting from reaction of selenium with 2,3-diaminonaphthalene. Mercury was determined by flameless atomic absorption analysis following combustion of the dry sample using an oxygen flask (Bache et al., 1973). Fluoride analysis involved sample combustion in a 1-L polypropylene flask filled with oxygen, absorption of combustion gases in 20 mL of distilled water contained in the flask and measurement of fluoride in this solution using a specific fluoride ion electrode.

Nitrogen was estimated by the Kjeldahl method. Protein, fat, fiber, ash, calcium, and phosphorus in the rations were determined by the procedures cited, respectively, in "Official Methods of Analysis" (AOAC, 1975).

## RESULTS AND DISCUSSION

The concentrations of the various elements determined in a subsample of the mixed colored paper (before incorporation into the ration) are shown in Table II. Those elements which were significantly higher in the complete pelleted ration containing paper compared with the control ration are listed in Table III. Lead exhibited the highest concentration among the elements in the paper ration (Table III). The concentration of lead found in sheep tissues is given in Table IV. Lead exhibited the highest concentration in bone which agrees with the findings of Fairhall and Miller (1941). Heart, muscle, and spleen did not show elevated levels of lead in the sheep fed the paper ration. Kidney tissue was analyzed for most of the elements listed in Table II.

Table V lists the concentrations of the other elements (Table II) which were found at higher levels in tissues of the sheep fed the paper ration. The concentration of fluorine was slightly higher only in bone in which the element is well known to deposit (Vostal et al., 1971). Chromium did not show elevated concentrations in kidney or bone of the sheep fed the paper ration. Soluble salts of chromium administered orally to animals have been reported to be rapidly and completely eliminated (Conn et al., 1932).

Postmortem pathologic examination of animal tissues showed no gross lesions in the no. 1 control and no. 1 paper-fed sheep. Both of these animals exhibited some liver bile duct proliferation. The no. 2 control sheep showed suppurative bronchitis and peribronchitis while the no. 2 paper-fed sheep showed evidence of chronic pleuritis. These findings were, however, considered incidental.

The in vivo digestibility coefficients, the consumed input minus the fecal output divided by the consumed input, were determined and are given in Table VI. The rate of weight gain by the sheep on the control and paper-containing rations were followed and are also listed in Table VI. Analysis of the pelleted rations for nutrients, fiber, and ash were made and are listed in Table VII. The animals fed the paper ration consumed more feed and gained weight more rapidly. The ration was also somewhat more digestible.

As cited earlier, a significant amount of research has been conducted on animal acceptance and performance when waste paper or paper products are included in their rations. This study indicates that lead and certain other elements present in waste paper may concentrate in specific animal organs and bone. The possibility of organic compounds such as dyes used in the production of colored newsprint accumulating in animal tissues has not been investigated. In this regard gas chromatographic analysis of organic solvent extracts of the ground colored paper fed in this study showed the presence of a number of compounds which responded to electron affinity detection but these were not identified. It is recommended that further studies on the feasibility of including paper in farm animal rations be conducted with tissue analysis for such constituents.

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