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# EFFECTS OF DIETS CONTAINING SODIUM FLUORIDE ON MINK

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ABSTRACT: Mink (*Mustela vison*) kits still nursing, and adult male mink were fed diets containing various levels of fluorine (as NaF) to determine the effects on health, growth and pelt quality. Different groups were fed diets containing 25.5 (control), 46.0, 111.5 or 287.0 ppm fluorine (on a wet basis) for 7–8 mo. Gross, radiographic and microscopic changes were seen in bones from some animals ingesting the higher levels of fluorine. Chemical analyses for fluorine generally reflected levels ingested. Fluorine caused no detectable differences in pelt quality. After data were evaluated, tolerance levels in the feed of not more than 50 ppm fluorine for breeding stock and 100 ppm fluorine for animals being raised only for pelts are recommended.

*Key words:* Mink, *Mustela vison*, chronic fluoride toxicosis, dietary ingestion, sodium fluoride.

## INTRODUCTION

Historically, most reports of suspected or actual cases of chronic fluoride toxicosis in animals have involved herbivores. Only a few of the extensive controlled experiments and field studies involving domestic livestock species and large noncaptive wild ungulates are cited here (Roholm, 1937; Hobbs and Merriman, 1962; Shupe and Alther, 1966; Singer et al., 1967; Shupe and Olson, 1971; Suttie and Faltin, 1973; National Academy of Sciences, 1974; Shupe et al., 1984). Laboratory animals have been used also in fluoride studies, especially to evaluate biological responses resulting from ingestion of different levels of various fluoride compounds (Smith, 1934; Greenwood et al., 1946; Bunce et al., 1962; Messer et al., 1972).

This report concerns the effects of feeding different levels of sodium fluoride (NaF) to mink (*Mustela vison*). Fluoride tolerance levels for different ages of mink needed to be determined. Based on information obtained about similar species, excessive intake of NaF may have a deleterious effect on the quality of mink pelts, reproductive ability and health (Smith, 1934; Roholm, 1937; Greenwood et al., 1946; Bunce et al., 1962; Chiemchaisri and Phillips, 1963; Messer et al., 1972).

Desirable animal growth and production of top quality pelts require that mink are fed consistently a strict diet. An animal's nutritional status can be related to the effects of a known dietary fluoride level (Harris et al., 1964; Suttie and Faltin, 1973). Portions of animal carcasses, including bones, frequently comprise a large percentage of the carefully calculated total diet of captive mink. Fluorides normally do not accumulate in muscle and it usually contains <1.0 ppm fluorine although an animal ingests high levels of fluoride for a long period of time and its bones may contain several thousand ppm fluorine. Bones play an important role in the regulation of tissue fluoride content (Singer et al., 1967). It is important to the fur industry to know how dietary levels of fluoride affect the health, pelt quality and reproduction in mink adults and kits. Fur ranchers are concerned about the effects of feeding diets containing bones with high fluoride content.

## MATERIALS AND METHODS

All test mink were from the pastel color group. Kits that were nursing their dams which were initially fed various diets, and adult male mink were fed either regular (control) diets or the same basal diets with added NaF. There were three and four groups of kits (designated as "K") and adult males ("A"), respectively (including controls), with six animals in each test group. Dams, their kits and the adult males were examined clinically, but due to the value of the dams to the breeding program only the kits and the males were sacrificed for necropsy.

Composition of a typical mink diet is given in Table 1. Diet composition may vary slightly

TABLE 1. Composition of commercially prepared mink diet.

| Ingredient | Percent of total diet |
|---|---|
| Scrap fish | 34 |
| Poultry offal | 5 |
| Whole poultry | 15 |
| Liver | 7 |
| Frozen egg | 5 |
| Frozen fat | 5 |
| Liquid fat | 2 |
| Poultry meal | 10 |
| Cereal | 15 |
| Potato flakes | 2 |
| Vitamin E | 0.025 |
| Aureomycin | 0.01 |
| Salt | 0.25 |

according to ingredient availability and/or cost. This diet contained 38% protein and 28% fat. The diets were processed in a facility owned by a fur farmer's cooperative (Fur Breeders Agriculture Co-op Association, Midvale, Utah 84070, USA). Desired amounts of NaF were added to 45.5 kg batches of feed and mixed for 10 min in a commercial dough mixer. Packages containing amounts needed for daily feeding were then frozen. The feed was thawed as needed so fresh feed was offered daily.

Fluoride levels in mink feed were based on information concerning the fluorine tolerance of dogs in studies by Greenwood et al. (1946) and others using rats or dogs (Muhler, 1954; Weddle and Muhler, 1957; Zipkin and Likins, 1957, Wuthier and Phillips, 1959; Bunce et al., 1962). Samples from fur rancher feed supplies were analyzed also to establish baseline values. The average fluorine content of the control diets was 25.5 ppm fluorine on a wet weight (as fed) basis and 64.0 ppm fluorine on a dry weight basis. Animals on this diet were in group I. Average fluorine contents of treatment diets II, III and IV were 46.0, 111.5 and 287.0 ppm fluorine on a wet basis, and 125.0, 307.0 and 759.5 ppm fluorine on a dry weight basis, respectively. The highest level (IV) was fed only to a group of adult males and not to the dams and their kits. The average fluorine content was based on analyses of samples from each feed batch mixed during the experiment. The total intake of fluorine/day/adult animal and the fluorine intake expressed as mg fluorine/kg body weight are shown in Table 2. This study was conducted using routine and practical management practices and procedures of the mink industry.

The majority of the adult mink were on the experimental diets for approximately 8 mo and the kits for approximately 7 mo. Nursing kits received relatively little dietary fluorine because the fluorine content of milk is low. The study period was planned to end when mink normally would be pelted (late November and December). However, after 82 days one adult male from each treatment and two kits (62 and 64 days of age) representing treatments KI and KIII were sacrificed to provide tissues for analyses and evaluation. Fluorine contents of tissues from these six animals reflected dietary levels of fluorine.

At the termination of the feeding phase of the study, the mink were sacrificed by an intraperitoneal injection of a euthanasia solution (T-61) from National Laboratories (American Hoechst Corporation, Animal Health Division, Somerville, New Jersey 08876, USA).

Pelts were carefully evaluated and graded by professional pelt graders. The animals were then necropsied and tissues and organs were collected for gross, radiographic and histologic evaluation and for chemical analyses.

The long leg bones, skulls and mandibles were defleshed, defatted with dry cleaning fluid and examined grossly. Samples from femurs, tibias and kidneys were prepared histologically. Femurs, tibias, humeri, combined radii and ulnar bones from animals within a group were pooled for analytical samples for each treatment level. Kidneys from each group also were analyzed for fluorine content. All analyses were made using the Willard-Winter distillation/titration method (Willard and Winter, 1933).

Results of these analyses are presented in Tables 3 and 4. Microradiographs of cross sections of representative femurs and humeri from the three kit groups and four adult male groups also were prepared and evaluated for visible effects of dietary fluoride levels.

## RESULTS AND DISCUSSION

Quality of pelts from experimental mink was compared with the quality of pelts

TABLE 2. Calculated daily fluorine intake of experimental adult male mink.

| Group | Average feed F content[a] in ppm | mg F/day/animal[b] | Average animal weight (kg) | mg F/kg body weight/day |
|---|---|---|---|---|
| Group I (control) | 25.5 | 5.8 | 2.338 | 2.48 |
| Group II | 46.0 | 10.5 | 2.208 | 4.75 |
| Group III | 111.5 | 25.3 | 2.034 | 11.93 |
| Group IV | 287.0 | 65.2 | 2.120 | 30.75 |

[a] Fluorine content calculated on a wet weight basis.
[b] Based on an average daily consumption of 226.80 g, water ad libitum 0.3 ppm F.

TABLE 3. Fluorine content of mink kit tissues at end of experiment.

| Group | Tissue identification | ppm F DFF* | ppm F Ashed | % Ash |
|---|---|---|---|---|
| KI (control), 25.5 ppm F diet | Kidney | 2.70 | | |
| | Humerus | 910 | 1,370 | 66.4 |
| | Radius and ulna | 830 | 1,270 | 65.3 |
| | Femur | 820 | 1,270 | 64.6 |
| | Tibia | 772 | 1,220 | 63.3 |
| KII, 46.0 ppm F diet | Kidney | 3.72 | | |
| | Humerus | 2,324 | 3,420 | 68.0 |
| | Radius and ulna | 2,107 | 3,175 | 66.4 |
| | Femur | 2,213 | 3,370 | 65.7 |
| | Tibia | 2,239 | 3,425 | 65.4 |
| KIII, 111.5 ppm F diet | Kidney | 5.77 | | |
| | Humerus | 4,609 | 6,850 | 67.3 |
| | Radius and ulna | 4,249 | 6,350 | 66.9 |
| | Femur | 5,110 | 7,850 | 65.1 |
| | Tibia | 4,133 | 6,350 | 65.1 |

* Analyses of pooled samples from animals in the groups listed. Calculated on weights of dried, fat-free (DFF) specimens.

TABLE 4. Fluorine content of adult male mink tissues at end of experiment.

| Group | Tissue identification | ppm F DFF* | ppm F Ashed | % Ash |
|---|---|---|---|---|
| AI (Control), 25.5 ppm F diet | Kidney | 7.03 | | |
| | Humerus | 1,336 | 2,000 | 66.8 |
| | Radius and ulna | 1,086 | 1,625 | 66.8 |
| | Femur | 1,215 | 1,875 | 64.8 |
| | Tibia | 1,071 | 1,750 | 66.1 |
| AII, 46 ppm F diet | Kidney | 5.01 | | |
| | Humerus | 2,686 | 3,925 | 68.4 |
| | Radius and ulna | 2,372 | 3,550 | 66.8 |
| | Femur | 2,485 | 3,675 | 65.7 |
| | Tibia | 2,580 | 3,925 | 65.7 |
| AIII, 111.5 ppm F diet | Kidney | 5.47 | | |
| | Humerus | 2,338 | 3,675 | 63.6 |
| | Radius and ulna | 1,999 | 3,050 | 65.5 |
| | Femur | 2,585 | 4,050 | 63.8 |
| | Tibia | 2,004 | 3,175 | 63.1 |
| AIV, 287 ppm F diet | Kidney | 10.30 | | |
| | Humerus | 4,695 | 6,725 | 69.8 |
| | Radius and ulna | 4,025 | 6,000 | 67.1 |
| | Femur | 4,716 | 6,950 | 67.9 |
| | Tibia | 4,248 | 6,350 | 66.9 |

* Analyses of pooled samples from animals in the groups listed. Calculated on weights of dried, fat-free (DFF) specimens.

from normal, nonexperimental mink. Quality differences were no greater between than within treatment groups. None of the pelts were downgraded.

Growth rates did not appear to differ between kit treatment groups. However, subjective data were not obtained because of the difficulties with the dam's behavior when their offspring were handled. There were no obvious clinical differences among treatment groups. In contrast, under field conditions, Eckerlin et al. (1986) reported agalactia in vixens with subsequent starvation of fox kits when the vixens were fed diets containing 97.6–136.8 ppm fluorine. These levels were calculated on dried feed. In other experiments involving different species, addition of 250.0 ppm fluorine to basal diets restricted food intake and growth rates of young domestic dogs, particularly when the magnesium level was inadequate (Bunce et al., 1962). However, addition of 200.0 ppm fluorine to their diets did not affect the growth of weanling rats (Chiemchaisri and Phillips, 1963).

None of the mink refused feed with NaF added. The animals appeared in good condition and all sacrificed animals had normal amounts of omental, perirenal and pericardial fat.

There was petechiation of the lungs in all animals, including controls. These lesions are characteristic of, and were attributed to, the euthanasia solution.

Some teeth of kits in group III (diets containing 111.5 ppm fluorine on a wet weight basis) had a dull, pale cream color with decreased translucency and small focal areas of opaque chalky-white discoloration. These dental lesions were considered to be fluoride-induced, but were more difficult to evaluate than in cattle, horses, sheep, dogs, deer, elk, moose and buffalo. These lesions were consistent with the re-

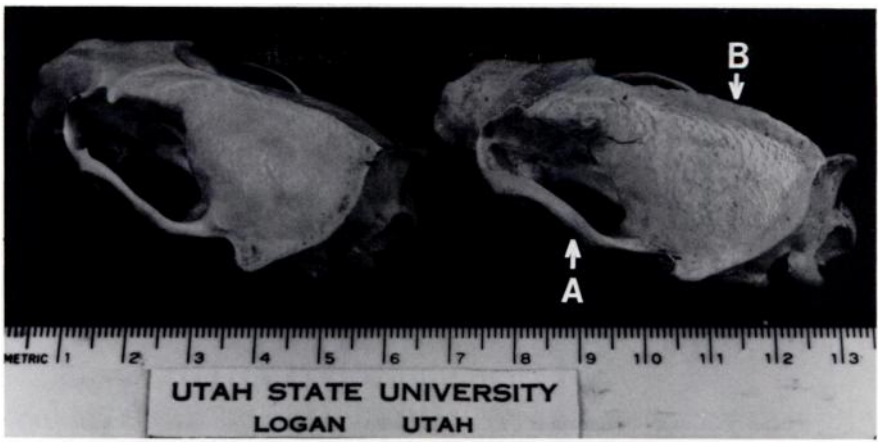


FIGURE 1. Macerated skulls from two adult male mink. The skull on the left is from an animal in group I (control) and is normal. The skull on the right is from an animal in group IV (high fluoride). Note the thickened zygomatic arch (A), enlargement of the external sagittal crest (B), and chalky-white feathering and ridging of the periosteal surface of the crania.

sults of other studies that have shown that fluoride ingestion has little or no gross effect on the enamel of teeth after they are formed and mineralized. Teeth in the adult mink did not show visible lesions.

Fluorine content of the kidneys (Tables 3, 4) generally reflected the level of fluoride ingestion. The one exception was the higher fluorine content in the adult control kidneys collected at the end of the experiment. We can offer no definite explanation for this exception. Kidneys serve as the major route of elimination of fluorine from the body. Thus kidneys contain more fluorine than other soft tissues or organs, probably due to urine in kidney tubules and collecting ducts. Soft tissues usually contain only small amounts of fluoride (<2.5 ppm). This is true in other species, including dogs (Carlson et al., 1960; Shupe et al., 1963).

Fluorine content of bones generally correlates well with fluorine ingestion levels and duration of ingestion. Correlation in some experiments has been as high as $R^2 = 0.957$ (Shupe et al., 1963). Bone fluoride levels normally increase as animals grow older, even in animals on normal, low-fluoride diets (Shupe et al., 1963; Singer et al., 1967). The bone fluoride contents also generally reflect dietary fluoride levels (Muhler, 1954; Wuthier and Phillips, 1959; Shupe et al., 1963; Stoddard et al., 1963). In the present study the fluoride content in bones from adult group II was higher than bones from animals in group III (Table 4). The kits accumulated fluorine at a faster rate than did the adults. Kits with actively growing bones will metabolize more fluorine as well as other bone components such as calcium and phosphorus. This age-related response has been seen in other species (Shupe et al., 1963).

There were visible changes in bones from adult groups III and IV (Fig. 1). There were no detectable gross, radiographic or microscopic changes in bones of adults in groups I and II. There was slight to moderate periosteal proliferation and thickening of the mandibles in group III animals. The zygomatic arch was thickened, the external sagittal crest was enlarged, and there was ridging and feathering of the periosteal surface of the crania. The mandibles and skulls from group IV animals had more pronounced changes than those from group III. The periosteal surfaces were rough, ridged and appeared chalky-white (Fig. 1). Gross distinct osteofluorotic changes in animals in groups III

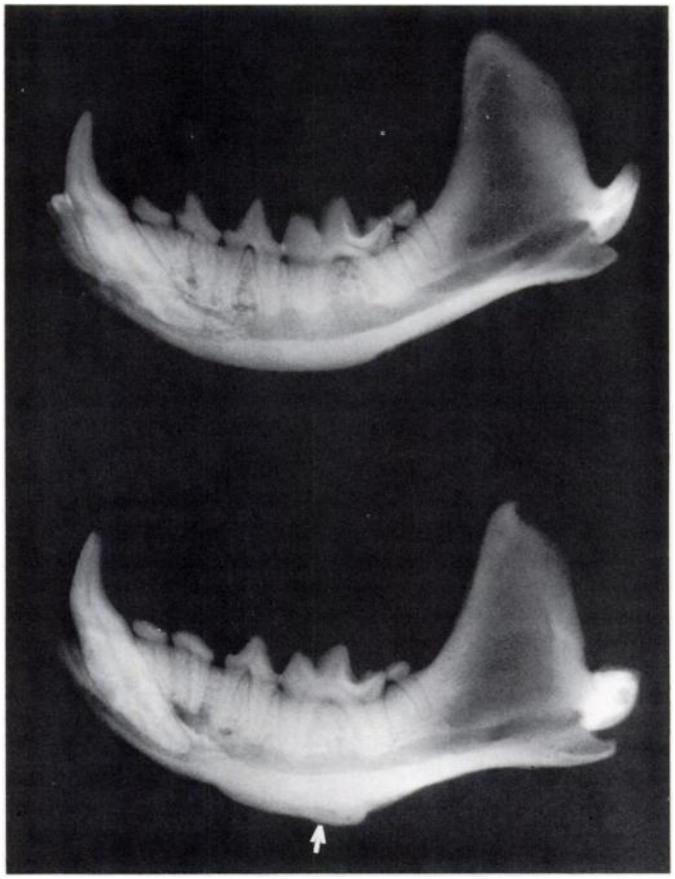

FIGURE 2. Radiographic images of mandibles from adult group I (normal)—top; and group IV (highest fluoride intake)—bottom. In the mandible on the bottom note the increased density, narrowed mandibular canal, and extra periosteal bone (arrow).

and IV were less discernible in the leg bones than in the mandibles and skulls. Definite gross mandibular and skull changes were not discernible in the kits.

There were distinct radiographic differences in adults of groups III and IV, but there were no detectable differences in groups I and II (Fig. 2). There were no discernible radiographic changes associated with higher fluoride intake in kits.

Microscopic bone changes were detectable in the femurs and humeri of adults in groups III and IV and kits in group III (Figs. 3, 4). The bone changes were most severe in adults in group IV. There were stratified layers of periosteal new bone, excessive resorption cavities, irregular distribution and clumping of osteocytes and zones of incomplete mineralization in some osteones. The changes were not as pronounced among adults in group III and there were slight changes in kits in group III. These microscopic changes are characteristic of changes seen in other species with osteofluorosis (Shupe et al., 1963; Johnson, 1965; Shupe and Alther, 1966).

Evaluation of the clinical, gross, radiographic, microscopic and analytical results and data from this experiment enabled us to recommend safe and realistic tolerance levels for fluorine for pastel mink kits raised for pelts and pastel mink raised and maintained as replacement breeding stock. It is not known if other color groups would re-

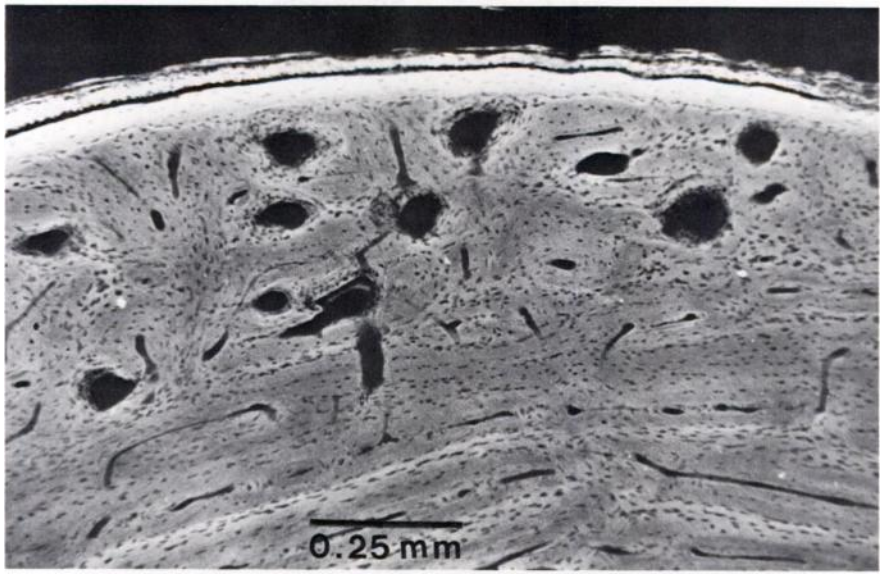


FIGURE 3. Photomicrograph of a microradiograph of femur cortex cross section from adult male in group IV (highest fluoride intake). Note light colored stratified layers of periosteal new bone (top), excessive resorption cavities, zones of incomplete mineralization of some osteones, and irregular distribution and clumping of osteocytes in some osteones.

spond differently, but probably only slight differences would occur because it is only the skeletal system that is affected. Tolerance levels for other fluorine-containing compounds would vary according to the solubility and bioavailability of the fluorine (Greenwood et al., 1946; Weddle and Muhler, 1957; Shupe et al., 1962; Johnson, 1965). Captive mink raised only for pelts and euthanized at approximately 7 mo of age can tolerate up to 100.0 ppm fluorine in their feed (on a wet weight basis) or 270.0 ppm on a dry weight basis. Feeding this level of fluorine for that length of time will not have any detrimental effects on pelt quality and growth, nor will it adversely affect teeth and bones. However,

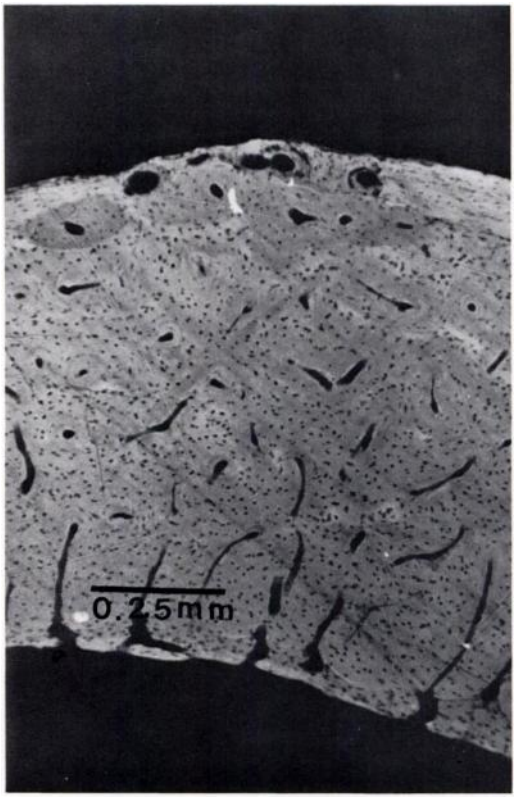


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FIGURE 4. Photomicrograph of a microradiograph of femur cortex from a 7-mo-old kit in group III. Note light colored extra periosteal bone (top) and abnormal porosity due to poorly formed and improperly mineralized osteones in the same area. These abnormal osteones also contain clumped and unevenly distributed osteocytes.

it is felt that feeding such a level of fluorine to breeding stock from birth eventually may have adverse effects on teeth and bones. These levels of dietary fluorine also may have insidious minor effects on normal bone structure and function, and eventually on animal performance. For these reasons we recommend that mink used for breeding stock should not ingest more than 50.0 ppm fluorine (wet weight basis or 135.0 ppm on a dry weight basis) of a very soluble fluoride, such as NaF, in their feed.

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