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PHYSICAL AND BIOCHEMICAL CHANGES IN FEEDS DURING PROCESSING

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ABSTRACT

Materials used for feeding fish may be subjected to drying, freezing, grinding, radiation, hard pelleting and expansion pelleting. During these processes, physical and chemical changes occur due to inherent enzymes, contamination by microorganisms, oxygen, temperature, pressure and ionization of molecules. These changes are not reflected in the gross composition of the major nutrient classes (protein, fat, carbohydrate, ash), but in the intrinsic nutrients, organic additives and digestibility. Experimental work showed the hard pelleting process to be destructive to added enzymes.

INTRODUCTION

Any attempt to supply fish with feed, except as natural food, involves processing. Culled animals, animal by-products, cereal grains, vegetables and their by-products may be ground, steamed, frozen, thawed, mixed, dried and pelleted. Following a combination of these treatments, feeds are thrown into ponds on the assumption that they are a contribution to the well-being of fish.

To be satisfactory as feed, materials fed to fish must be available, acceptable and nutritious. The purpose of processing is to accomplish these objectives economically. It is conceivable that the attainment of one objective is detrimental to another.

As feeds are harvested, processed and stored, they may be subjected to autolysis, putrefaction, air, light, heat, pressure and radiation. Each leaves its mark on the nutritive properties of a feed and also on its ability for autolytic digestion. The original value may be so greatly altered during the interim between harvest and feeding, that an appropriate question would be, "What nutrient quality can be expected in fish feeds?"

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EFFECTS OF PROCESSING

FREEZING — Aside from the change in texture from a semi-liquid to solid state, quick-freezing results in less change in feeds than does any other method of processing. No significant decrease in nutrient content can be attributed to proper freezing and holding at 0° F. for several months.

Frozen feeds deteriorate if improperly stabilized by low-temperature storage, proper packaging and antioxidants. Dehydration or "freezer-burn" causes toughening of fish and meat products. Oxidation of oils accelerates the destruction of several nutrients, loss of vitamins A, E and biotin being reported by Tarr (1962). Thawing may be accompanied by decrease of nutrients, unless liquid expressed from tissues is used.

A danger associated with the use of frozen feeds is the possible activity of pathogenic bacteria and certain enzymes during prolonged freezing and thawing (Hastings and Butler, 1955,). Pasteurization prevents the spread of disease introduced by animal viscera and inactivates thiaminase found in some raw tissues. The time and temperature involved in pasteurization are not destructive to essential nutrients, as shown by the successful use of heated, frozen fish viscera as a diet for young salmon (Law, *et al*, 1961).

DRYING — The texture of dehydrated feeds introduces a new form of diet, different from a natural food. Acceptance of dry feeds may be slow and require some conditioning. Dried feeds may be reconstituted to simulate fresh food. Much of the dry feed used in fish feeding is consumed after partial rehydration.

Drying is accomplished by air, sun, freezing and artificial heat. Tarr (1962) found commercially dried cod fish identical in food value to fresh cod, although some autolysis and nitrogen loss occurred during the drying process. Prolonged high-temperature drying which brings the product temperature above its dew point, results in decreased nutrient value. Vitamin A and biotin cannot long withstand heat in the presence of oxygen. Thiamine and folic acid are thermolabile. Other nutrients which may resist wet heat are lost by continued heating in the dry state.

Enzyme-resistant linkages are often formed in the preparation of fish meal and meat scraps. These show up in animal tests as reduced digestibility, although the original quantity of amino acids is found by chemical analyses. Amino acid supplementation frequently corrects the low-protein value of over-dried feeds; however, this is not successful for some types of over heating (March, 1962).

STEAMING — Directly or indirectly, steam is used to (1) soften grains before rolling, (2) coagulate wet animal by-products, and (3) inactivate microorganisms and enzymes. Temperatures and time necessary to achieve these objectives are relatively harmless to nutrients. Continued steaming as required to sterilize contents of large containers (four-pound cans) decreases the quantity and quality of amino acids subsequently tested. For feeds which are critical as growth diets, calculated over-fortification in advance will adjust for the increment of nutrients lost by steam processing. By this means several generations of dogs have been raised entirely on canned feeds.

Products steamed under atmospheric pressure reach a temperature of about 210° F.; those subjected to steaming in hermetically sealed containers, as in the commercial process of canning, may reach 230° F. Little, if any, inherent enzyme activity remains in feeds after steaming, unless in dry components which do not conduct heat readily.

HARD PELLETING — A soft feed mixture of dried, ground ingredients, is compressed through holes of a special die into pellets or cubes. The bulk density increases from about 30 lbs./ft.^{3} to 40 or 42 lbs./ft.^{3} during the process. Steam conditioning adds about six per cent moisture and 100 to 120° of temperature. A pressure of 10,000 pounds per square inch is attained. The extruded pellet is quickly cooled and dried, returning to the environmental temperature and moisture in about five minutes.

Some chemical changes occur in feedstuffs and feed additives during hard pelleting. Significant quantities of unstabilized vitamin A and beta carotene are lost. Ten per cent over-fortification with stabilized vitamin A is practiced by feed manufacturers to compensate for loss during pelleting and storage.

Autolytic enzymes (alpha and beta amylase) present in whole grains are still active after grain is ground and pelleted (Hastings, 1961). A small quantity of raw starch is gelatinized during pelleting, and some reducing sugars are formed (Hastings, 1962). These biochemical changes occur on surfaces of ground grains and in dust-like particles which are easily wetted by the quantity of steam used. Livestock and poultry have sufficient enzymes to hydrolyze raw starch to sugars for body functions; therefore, no appreciable advantage results from gelatinizing starch for these animals. Fish (Buhler and Halver, 1961; and Phillips, Tunison and Brockway, 1948) make better use of soluble starch and small carbohydrate molecules, such as cooked grain and reducing sugars than they make of raw starch. Some improvement in feed efficiency for fish may be expected by using pelleted feeds, rather than those in meal form. Fish may also benefit from enzymes present in their feed. Barrington (1957), referring to work by Schlottke, observed that natural food was digested more quickly than artificial food, possibly because of hydrolytic assistance by inherent enzymes.

EXPANSION PELLETING — The average formula feed containing grain, can be changed in an expander from a mixture of small solid particles to a porous, irregular-shaped ball. Freshly expanded pellets look like fresh bread. An all cereal grain mixture can be expanded to a bulk density of less than 10 lbs./ft.^{3}. High-protein feeds such as fish meal and soybean meal, are changed little, except to be formed into a pellet.

The patented expansion processes start with an addition of about 20 per cent water, introduced partly as steam. Mechanical compression with no escape of heat, creates very high temperatures. Up to 350 pounds per square inch pressure and over 300° F. are common during expansion pelleting. Raw starch is gelatinized 90 to 100 per cent. Inherent enzymes are totally inactivated. Protein quality is often decreased by the condensation of amino acid radicals with carbohydrates to form the Maillard reaction.

The expansion process produces a floating feed. This feature makes the process attractive for certain uses. It is expensive compared with other feed milling processes, both in terms of equipment, steam consumption, heat for drying and lost nutrients. Instead of over-fortification of a feed mixture before expansion, vitamins, amino acids and medications are often prepared in liquid form and sprayed on the finished pellet as a coating. Fat sprayed on pellets increases their water-repellency. Colors and odors may also be added in like manner.

RADIATION — Several types of radiation are effective in preventing feeds from decomposing during storage. These are ultra-violet light, infra-red and radiofrequency electromagnetic wave lengths, ultra-sonic waves and ionization as from high energy cathode rays or radioactive materials. The types recognized and defined by the Food and Drug Administration (1963) for processing foods, are the gamma radiation from radioactive cobalt, and electron beam radiation from an accelerator.

Advantages of using radiation for feed processing are (1) effectiveness of inactivation of microorganisms, (2) the small rise in temperature, and (3) the small amount of chemical change. Materials of appreciable thickness can be treated in containers made of glass, plastic or metal (Hannan, 1956).

Radiation directly increases the oxidative destruction of some nutrients. Ascorbic acid in natural foods is about 50 per cent lost by a radiation dosage of 500,000 reps (roentgen-equivalent-physical units). Protective measures may be taken to avoid nutrient destruction caused by intense oxidation by (1) use of oxygen receptors, (2) use of low temperatures, and (3) lower dosages of radiation.

EXPERIMENTAL

Two commercial enzyme products were observed to have specifications which could make them suitable in assisting fish to digest artificial feeds. They showed high activity for raw starch and pectins, and contained minor quantities of protease, cellulase and dextrinase. Fungal enzyme "M," a pharmaceutical grade of alpha amylase, derived from a selected strain of *Aspergillus oryzae*, and a fungal enzyme "K", a pectinase, were added to fish test rations in such quantities as to enable accurate laboratory measurement of their activity.[2]

Feed-enzyme mixtures were pelleted in the feed processing laboratory of the Stuttgart Station. Steam was injected into the augar conveying feed to the pellet die where a stationary roller continuously compressed the conditioned mixture into and through holes 1/8″ in diameter. Pellets were discharged at a temperature of 180° F. and a moisture content of 14.1 per cent. Cooling and drying to environmental conditions took place within five minutes.

Laboratory tests for recovery of added enzymes are described graphically in Figure 1. The mash form of the feed mixture contained 100 per cent of each enzyme material. Pelleted feeds contained six per cent of enzyme "M" and 17 per cent of enzyme "K."

CONCLUSIONS

Poor recovery of added enzymes in pelleted feeds indicates that they are sensitive to some phase of the processing, probably steam conditioning. Enzyme products used were powders, easily wetted by the volume of steam contained in five to six per cent added moisture.

Other dietary and medication requirements supplied by materials which constitute a feed formula, may not be present in calculated amounts after processing. Insufficient research has been done on the analyses of processed feeds to know the "recovery" factor for each essential element. When this is known, certain processes may have to be modified to produce a complete or supplemental diet. Raceway fish development, where a balanced feed is needed, and the control of diseases by adding drugs to feeds, require that the effects of processing be part of the knowledge of nutrition and pharmacology.

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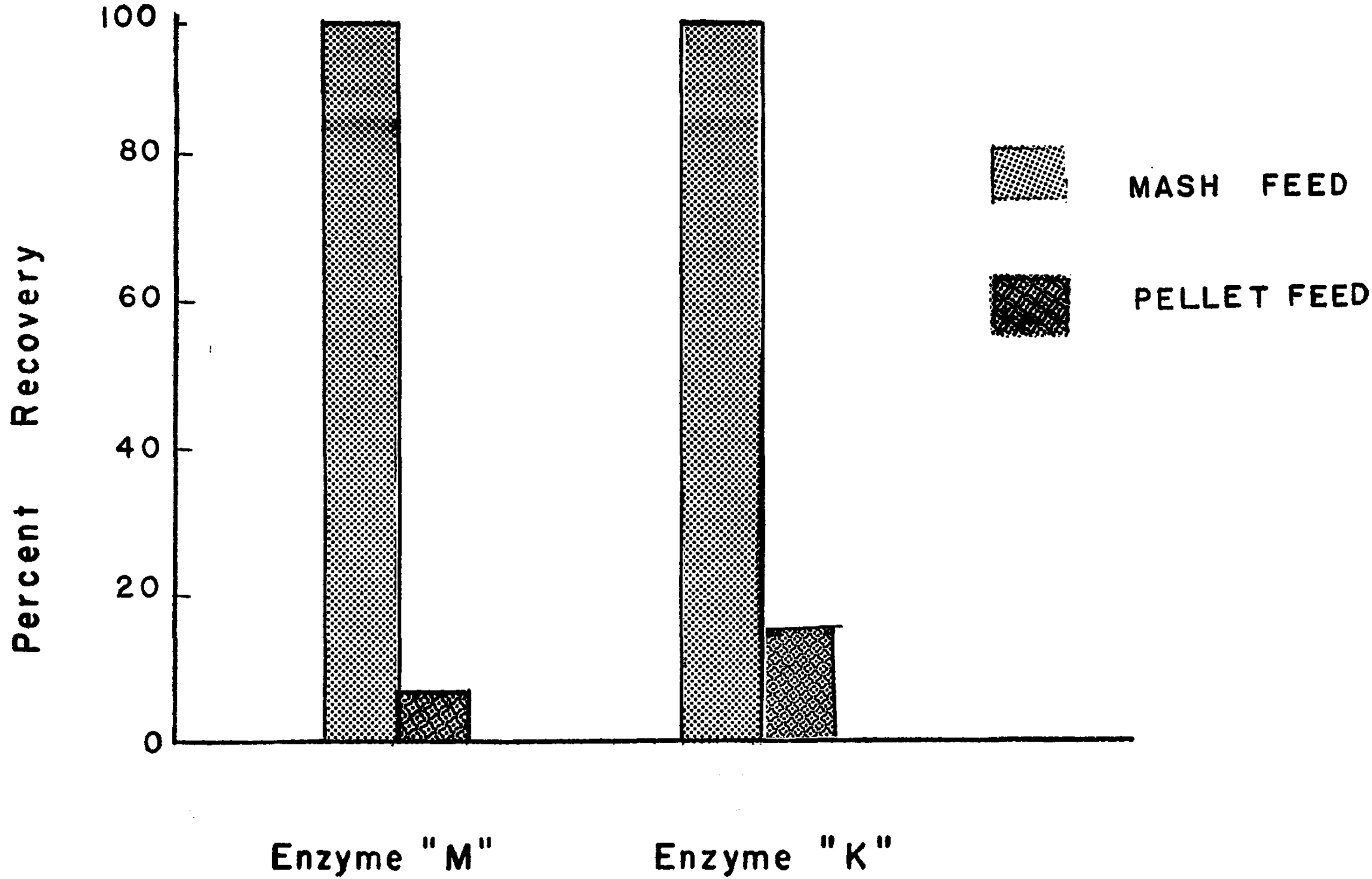

Figure 1. Recovery of enzymes added to rations.

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THE NEED, USE, AND VALUE OF FERTILIZERS

Everything and everybody have to eat if they are to live and serve their purpose. What is eaten by an organism tremendously influences its growth, development, and performance. All too often we see men, plants, and animals which due to the lack of the proper kind and amount of food, fail to develop normally. Consequently, those that do reach maturity at all have to overcome great odds to perform normally.

This is manifested in the corn production in this area. It is not difficult to average 80 to 100 bushels per acre, but the actual production is much nearer one-half that amount. If we want to grow 100 bushels of corn, there are certain essential management factors which must be recognized and provided. We must select the corn land, feed the crop properly, plant plenty of seed of an adapted hybrid, and control the pests.

Though we know that each of these factors must be provided for, at this time we will only think of feeding the crop. This is one of the most serious limiting factors in production. One approach to feeding the crop would be to consider the amounts of the various plant foods actually eaten by it. This approach without some knowledge of plant physiology and soil chemistry can be very misleading; but along with a basic understanding of plant physiology and soil chemistry, the kind and amount of plant foods eaten by a good crop can be a helpful guide.

In the case of corn, as in most crops, the plant is made up largely of carbon, hydrogen, and oxygen. But these plant foods come from water and air and under well-managed conditions may not be the most seriously limiting factors. The other plant foods contained in a 100-bushel crop of corn are grouped into three divisions and are shown below:

I. Primary Plant Foods
  A. Nitrogen—157#
  B. Phosphorus—60#
  C. Potash—122#

II. Secondary Plant Foods
  A. Calcium—38#) Lime
  B. Magnesium—26#)
  C. Sulfur—16#

III. Micro-Plant Foods
  A. Boron—.08#
  B. Copper—.07#
  C. Iron