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FISH WASTE AS SILAGE
FOR USE AS AN ANIMAL FEED
SUPPLEMENT

by

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d, W.J., Parrott, G.A., and D.G. Iredale. 1985. Fish waste as silage for use as an animal feed supplement. Can. Ind. Rep. Fish. Aquat. Sci. 158: iv + 10 p.

A system to utilize discarded processing plant fish wastes by converting , silage for use as an animal feed supplement was established at Lac La Biche, perta as a development project under the Department of Fisheries and Oceans sheries Development Program. Processing of the wastes, the equipment used, oblems encountered, costs of producing the silage and end product use as an imal feed ingredient are presented.

y words: fish silage, liquid fish, fish hydrolysate, fish waste.

RESUME

d, W.J., Parrott, G.A., and D.G. Iredale. 1985. Fish waste as silage for use as an animal feed supplement. Can. Ind. Rep. Fish. Aquat. Sci. 158: iv + 10 p.

Un procédé permettant l'utilisation des d6chets des usines de préparation poisson convertis en fourrage de supplément nutritif pour les animaux a été s au point à Lac-la-Biche (Alberta), clans le cadre d'un projet de mise en leur réalisé en vertu du programme de d6veloppement des pêches du ministère s Pêches et Océans. Le rapport fait état de la transformation des d6chets, l'équipement utilisé, des problèmes rencontrés, des coûts de production de fourrage et de l 'utilisation finale du produit comme ingrédient de la nourture animale.

s-c16s: fourrage de poisson; hydrolysat de poisson; déchets de poisson.

INTRODUCTION

Part of the Department of Fisheries and Oceans, Fisheries Development Program provides for the conduct of projects with a product development focus and projects to improve the handling and processing of fishery products, both having the objective of enhancing industry competitiveness and improving economic returns to the primary producer. This report describes a development thrust with these project areas wherein a process was identified and the technology transferred and established to utilize processing plant fish wastes. The project consisted of using normally discarded fish wastes from a processing plant in Canada's western inland fishery to produce a silage as a liquid feed supplement for hog diets.

Although the collective amounts of waste, i.e. viscera, skeletal frames, heads, etc., generated in the inland fishing industry is considerable, the scattered nature of production sources and processing facilities where wastes are generated, as well as irregular landings of fish, result in relatively small volumes of waste being accumulated at any single location. Because of this, and since the viability of fish meal manufacture is largely dependent on large and continuous volumes of waste, the option of fish waste liquefaction was selected. Other factors supporting the choice of this process included its relative simplicity, minimum capital equipment requirements and low energy cost.

The choice of Alberta for the project was in direct response to the regulatory needs of that province which requires that all fish be eviscerated and dressed within the confines of a processing plant, in turn resulting in the need for the further disposition of the waste.

The location of Lac La Biche in Alberta for the project was selected partly because of continuing problems with disposing of fish plant waste at the local sanitary landfill site. Apart from the production of odors of decomposition, the wastes attracted animals and were therefore being considered for exclusion from the landfill. Further, the local fishermen's Cooperative expressed interest in the project. The volume of fish handled and the wastes generated were considered appropriate to support small pilot plant production of fish silage, and the proximity of the Cooperative in relation to a user market for the end product was considered suitable relative to minimizing transportation costs.

Methods of silage production, either by acid preservation or fermentation, have been known since the 1920's. The acid preservation method of producing silage has been in use commercially in Denmark for approximately 30 years and in Norway for some considerable time. In these countries the silage has been used as an animal feed ingredient. In other instances the material has been used as a plant fertilizer. Regardless of the intended use of silage, the liquefaction process involved is similar. The fish waste is comminuted and the pH reduced through the addition of acid to enhance the activity of the naturally present enzymes in the waste material to accelerate digestion and consequent liquefaction. The lowered pH also inhibits bacterial degradation, controlling putrefaction and the associated odors of decomposition.

SYSTEM DEVELOPMENT

A trial system, because of space limitations in the Lac La Biche Fishermen's Cooperative plant as well as the regulatory requirement to separate such a process from fish intended for human consumption, was initially located remote from the plant. For this, a small 3.05 m x 4.57 m (10'x15') frame building (Fig. 1) having an existing well water supply, was leased on private farm property and an electrical service connected. Because of the lack of refrigeration to control bacterial putrefaction and its attendant malodors, the intent was to size a system capable of hydrolyzing the accumulated ground and acidified waste offal from the fish plant on a daily basis, i.e. within 24 hours. As indicated by Tatterson (1976) a temperature of at least 20°C is desirable or liquefaction occurs rather slowly and although the enzymes responsible for liquefaction can become inactivated as temperatures rise, silage heated to 40°C has still been found to liquefy rapidly. Therefore, by elevating the hydrolyzation temperature it was anticipated that a batch process could be accomplished in a 24 hour period. Further, harder bone particles that might remain following the batch process, would be further reduced following a subsequent and relatively short period of storage in barrels used for distribution, yielding a material suitable for animal feeding.

The choice of a combination of formic and propionic acids was based on the work of Gildberg and Raa (1976) who, recognizing that formic acid-preserved silages resist microbial deterioration, liquefy rapidly and do not require neutralization before feeding to animals, found that a mixture of formic and propionic acids to produce a silage from cod viscera was even more resistant to microbial deterioration even in moist mixtures with straw meal. Since the fish plant wastes that would be used in this present instance would consist primarily of viscera and would in all likelihood be combined with a conventional hog cereal diet, a silage preserved with these two combined acids was considered appropriate. Added to this, the cost of propionic acid was lower than formic acid and less of the combined acids were required to achieve the necessary pH of 4.5 than if formic acid alone (the acid generally recommended to preserve silage) was used.

The ensiling procedure required particle size reduction of the fish waste by grinding and further combining the ground waste with 85% formic acid and 99% propionic acid in the proportions of 7.5 kg (7.8 L) formic acid, 7.5 kg (7.43 L) propionic acid and 1 000 kg of ground waste to achieve a pH of 4.5 in the ground fish waste/acid mixture. The ensiling vessel was required to he of a material with non-corrosive contact surfaces and fitted with preferably, a motor driven agitating paddle to ensure thorough ing and homogeneity of the acidified fish te which would also be used for continuous rring of the mixture during the digestion cess. Finally, bearing in mind the 24 hour ch process intent, there should be a means of ting the mixture to accelerate hydrolysis ng an indirect heating method.

In practice (Fig. 2) grinding of the fish te was accomplished with a heavy duty grinder ing a 3 hp electric motor and 12 mm diam. nding plate perforations that had been used grinding **whole** raw fish for animal feed in a al fur farming operation.

The digestion tank, previously a bulk milk ler, had interior dimensions of approximately m x 1.8 m x 0.6 m deep (5′ x 6′ x 2′) and a acity of 1 320 L (290 gal) (a preferred tank ld have been cylindrical to facilitate mixing formity). It was of stainless steel and had ater jacket with a recirculation pump that ld be fitted with electric heating elements, heat and maintain temperature uniformity of ground fish waste/acid mixture during hydro- is.

Because the digestion tank was not ini- lly fitted with a motor driven stirring pad- (although one was added at a later date), a d ribbon blender was included as an inter- iate mixer for the initial blending of the und fish waste with the acids. Following s, the mixture was transferred to the diges- n tank and stirred as required during the rolyzing process.

The acids, the formic supplied in 25 kg lb) plastic containers and the propionic in kg (436 lb) plastic lined steel drums, were sured volumetrically using a graduated cylin- with the amounts added based on the calcula- weight of the ground fish wastes.

The ground, acidified fish waste, once rolyzed, was transferred, using a standard hp sump pump, from the digestion tank to stic lined 205 L (45 gal) steel drums for porary storage and eventual distribution.

Subsequent to the establishment of this ot operation, construction was started on a 2 m x 6.4 m (40′ x 21′) extension to the Lac Biche Fisherman's Co-operative plant that luded a 6.4 m x 3 m (21′x10′) room to house silage processing equipment as well as some ited storage space for the finished silage. s consisted of a separated room accessed from exterior of the plant, to safeguard against potential threat of contamination of fish d for human consumption, a concrete floor ped to a centrally located drain and an ractive ventilation system to remove odors.

With the completion of this addition, the age processing operation was moved from the ginal location and installed in the upgraded ility (Fig. 3 and 4). Also, at this time, e modifications were made to better accommo- e inconsistencies that had been experienced the plant supply of fish wastes as well as to rove efficiency (Fig. 5). This included lacing the original digesting tank with a larger but similar unit having interior dimensions of 2.3 m x 1.02 m x 0.91 m deep (84″ x 40″ x 36″) and a capacity of 2 000 L (440 gal). This larger tank would handle the fish wastes generated during the plant's peak production periods. During lower production periods the fish wastes, once ground and combined with the acids, could accumulate in the tank while slowly hydrolyzing over several days until the tank reached capacity. At this time the tank heating system would be started, to accelerate and complete the hydrolysis, following which the silage would be pumped to the storage drums. This tank also came fitted with a motor driven stirring paddle that could be used to blend the ground fish waste with the acids, thereby eliminating the need for the ribbon blender, previously used, and would also provide mechanized continuous or intermittent stirring of the ground fish waste/acid mixture during hydrolysis (Fig. 6). Further, to reduce energy costs the digestion tank jacket water was heated from an instantaneous gas fired water heater, located remote from the tank, which provided on demand, a constant supply of temperature controlled water to the jacket recirculation pump.

Although the system worked adequately, and actual liquefaction of the bulk of the fish wastes was achieved in a shorter time period than anticipated, a heavy sludge consisting of fish scales, some fish roe contained with the viscera as well as some larger bone particles, none of which digested, created problems with transferring the silage to the storage drums. Initially, a drain in the base of the digestion tank was used to draw off and pump the silage to the storage drums. In practice, the heavy sludge particulate plugged the drain, necessitating an alternate silage draw off location. This was overcome by closing the bottom drain and extending a hose into the tank, to draw off the silage above the sludge.

SILAGE UTILIZATION

In general, in descending order of volume, the viscera from whitefish Coregonus clupeaformis, northern pike Esox lucius, tullibee Coregonus artedi and walleye Stizostedion vitreum formed the basis of the fish wastes used.

The silage produced was a thin brown liquid characterized by a not unpleasant realty odor and because of incomplete digestion of fine bone particles, a somewhat gritty suspension. Provided the fish waste used was fresh, very little odor was produced during the actual process. When stored and allowed to settle without agitation, the silage separated into three distinct fractions, an oily upper layer, an aqueous middle layer (the major fraction) and a lower sludge sediment.

The amount of silage produced was approximately equal to the weight of the fish wastes used, which in turn were found to be about 12% of the weight of the whole fish, dressed, processed and shipped from the fish plant.

Although the original Intention was to make the silage available as a feed supplement to both hogs and cattle, it was used only as a hog feed supplement. Two hog producers within 50 km of Lac La Biche were identified as potential users of the silage.

The nutrient properties of the silage varied according to the species used as well as to whether or not whole fish or fish heads were included in the waste.

The proximate composition (Table 1) of the silage showed the moisture to range from 74.80 to 78.30%, the protein from 13.20 to 14.75%, the oil from 4.53 to 4.60% and the ash from 1.52 to 1.61%. These ranges would suggest that it would be desirable to maintain a bulk storage inventory of the silage to level out any fluctuations in composition. This way, periodic analyses of the composite batches of silage could be carried out rather than batch to batch analysis. As well, such an inventory would ensure a consistent supply of the silage to a user market.

Table 1. Proximate composition of silage.

Sample Day	Moisture (%)	Protein (%)	Oil (%)	Ash (%)
January 1985				
10 (a)	76.80	14.75	•	•
10 (b)	74.80	14.70	4.53	1.61
18 (a)	78.30	13.60	*	•
18 (b)	76.60	13.20	4.60	1.52

(a) Alberta Agriculture, Soil and Feed Testing Laboratory, Edmonton, AR.
(b) Fisheries & Oceans, Uestern Region, Southern Operations Directorate, Chemistry Laboratory, Winnipeg, MB.
• not determined.

As expected, because of the liver content of the viscera, the oil level in the silage was higher than desirable. Tatterson (1982) pointed out that if fish silage is to be included in animal feeds at a practicable level, an oil content not exceeding 2% in the product is advisable to avoid the possibility of taint in the carcass of the animal.

Apart from using a less oily waste material to ensure an oil content of 2% or less in the silage, de-oiling can be achieved either by centrifugation, which would add to the cost of the process and its economy would be dependent on high volume and the sale of the oil to offset the equipment and its operational cost or, by allowing the silage to settle into the previously described separate fractions and skimming or decanting off a proportion of the oily layer.

Although de-oiling was not carried out and the silage was used in hog diets on an "as is" basis, there was no reported incidence of tain ing in the hog carcasses.

In August, 1982, there was a feeding tri with the silage (F.X. Aherne, Department Agriculture, University of Alberta, Edmonto Alberta, unpublished data) to evaluate its eff cacy as a protein supplement for starter pig the oil level was not a consideration. Aher demonstrated that the "as is" silage could used effectively to replace some of the soybe meal in pig diets. However, as the feedi equipment used was suited to "dry" feeds, would probably not be feasible to include mo than 5% (dry matter basis) of the silage in co bination with other conventional low moistu feed supplements, concluding that even at th level there would be a considerable saving cost over other protein supplements and pigs f such a diet would perform as well as those fed soybean control diet. The satisfactory use fish silage to supplement feeds of growing pi as well as bacon pigs has been well demonstrat by other workers including Smith and Adams (1976), Hillyer et al. (1976) and Whittemore a Taylor (1976). Further, fish silage made fr the processing wastes of several species whitefish (Atlantic coast) and used as a prote source for livestock and poultry was also test by Winter and Javed (1978), who concluded th the silage was an acceptable form of supplemen al protein for both calves and broilers.

SILAGE PRODUCTION COSTS

Costs shown in Analysis A reflect tho associated with the Lac La Biche Fishermen Co-operative plant installation. Also, sir the Lac La Biche Fishermen's Co-operative pla was used by the Department of Fisheries a Oceans as a demonstration location, the equi ment costs were borne departmentally and a therefore not included.

Analysis B reflects total costs that wou likely be expected in a new installation.

Both of these analyses assume there wou be no cost for the fish wastes since they are by-product that must be disposed of and cou even represent a financial liability to a fi plant. It would also seem questionable wheth labor costs should be included since the ti apportioned to the process is minimal and cou well be included as part of the existing respo sibilities of the fish plant workers. Howeve for the purpose of these analyses, labor cos are included.

ANALYSIS A

Item	Cost/Ton of Sila
Materials:	
fish wastes	
formic acid (85%),	
use level :0.75% @ $2.42/kg	$21.
propionic acid (99%),	
use level :0.75% @ $1.903/kg	14.

Labor:
3.75 hours @ $6.00/hour 22.50

Although the time apportioned per tonne of silage produced was recorded, no actual hourly rate was identified. Therefore the following rationalization is used to arrive at an hourly rate:

The fish plant operator is paid on the basis of volume of fish processed through the plant annually.

The approximate annual volume is 136 000 kg (300 000 lb) for which he receives approximately $0.088/kg. Allowing $0.088/kg for handling the fish waste would represent a value of $12000.00

$$\frac{\$12000.00}{250 \text{ working days} \times 8 \text{ h/day}} = \$6.00/\text{h}$$

Energy:
natural gas @ $2.45/1 000 cf. 5.05
electricity @ $0.04/kw/h 1.08

$64.05

The selling price of silage was $29.40/tonne representing a net loss to the Fishermen's Co-operative of $34.65/tonne. This below value selling price was due in part to the market being limited to a single hog producer user (although as previously indicated two hog producer users were identified, one went out of business). Added to thfs, the liquid nature of the silage as a feed supplement created some resistance to its use.

Notwithstanding these constraints (which could be overcome in an alternate silage production location with access to a wider market as well as the introduction of liquid feeding SyStems such as used in Scandinavian countries), on the basis of the protein content of the silage of approximately 14% in comparison to fish meal with a 72% protein content and a selling Price of approximately $800.00/tonne[1], the market value of the silage should have been $155.00/tonne. Similarly, when compared (again on a protein equivalent basis) to soybean meal with 48% protein at a current price of approximately $240.00/tonne[1], the selling price of the silage would be S70.00/tonne. As shown, $70.00/tonne is close to the Fishermen's Co-operative cost per tonne of producing silage, however, if the price of soybean meal approaches $400.00/tonne (as in 1981) an equivalent silage value would be $116.00/tonne.

ANALYSIS R

The following, although based on the Lac La Biche experience, assumes a separate silage processing facility adjacent to a fish processing plant in close proximity to an agricultural user market and. amortized costs based on new investment.

Capital Costs		Cost/Tonne of Silage
Facility:		
Building; 20' x 20' @ s45.oo/ft²	$18 000	
Mech. and Elec. installation	5 000	
	$23 000	
Equipment:		
Digestion tank (used)	S 700	
Instantaneous gas water heater	850	
Water recirculation pump	250	
Controls	200	
Grinder	1 500	
Transfer pump	300	
Bulk storage tank (15 OOOgal)	2 000	
Unit heater	450	
Plumbing and electrical	1 250	
	$7500	
Facility amortization @ 10% yr over 20 yr	$2055.60	
Equipment amortization @ 10% yr over 10 yr	1 179.36	

$$\frac{\$\ 3\ 234.96/\text{yr}}{80 \text{ tonnes}} = 40.40$$

Operating Costs

	Cost/Tonne of Silage
Materials:	17.50
Fish wastes (500 000 kg annual fish plant volume with 12 percent recovered viscera/offal - 60 000 kg - at no cost, Plus 20 000 kg of whole fish by-catch at $0.07/kg ($0.03/lb) for a total of 80 tonnes annually or $17.50/tonne)	
Formic acid (85%), use level :0.75% @ $2.42/kg	21.32
Propionic acid (99%), use level :0.75% @ $1.903/kg	14.10
Labor:	
3.75 hours @ $6.00/hr	22.50
Energy:	
Estimated (This' will vary with the location influencing the source and cost).	7.00

Overhead Costs

Facility maintenance
@ 5% of capital cost/yr $1 150

1 Animal Science Department, Pig Nutrition and Management, Univ. of Man., (Records of Feed Ingredient Prices 1985).

Equipment maintenance @ 8% of capital cost/yr	600
Insurance @ 1 1/4% of value/yr	380
	$2 130/yr

$2 130/yr / 80 tonnes = 26.63

$149.45

Although there is considerable scope for reducing this cost per tonne of $149.45 in such areas as raw material and labor costs, types of facilities available and economies of scale (e.g. the digester tank, as in the Lac La 8iche upgraded facility has a capacity of 2 000 kg which if used to capacity for 100 days could process 200 tonnes of silage), any real profit potential will depend on the producer obtaining a fair market price for the silage based on its protein unit value.

CONCLUSION

Although the apparent costs of producing fish silage outweigh the selling price experienced by the Lac La Biche Fishermen's Co-operative, with some concerted and aggressive marketing, efforts as well as the introduction and encouragement of the use of suitable feeding systems, the demand for this type of feed supplement could increase. Potentially, the production of silage could provide income as well as a means of utilizing fish wastes and by-catch in situations where their disposal creates a problem or a cost to a fish processing plant. Since the product is bulky its production should be located in close proximity to a user market with the market large enough to provide sufficient user alternatives. According to Whittemore and Taylor (1976), the protein quality of fish silage is at least equal to that of fish meal. This, in addition to the impact of increasing energy costs that are likely to make conventional sources of animal feed protein ingredients more expensive, may make ensiling, with its low energy requirements, increasingly more attractive in producing a protein ingredient alternative from the conversion of fish wastes and by-catch to a nutritious liquid animal feed.

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The authors wish to express their appreciation to the 8oard of Directors of the Lac La 8iche Fishermen's Co-operative for their interest and cooperation, Dave McArthur, Director, Regional Economic Development Council, Lac La 8iche, for his continued interest and advice, Harvey Yoder, District Agriculturist, Alberta Department of Agriculture, Lac La Biche, for his assistance in coordinating the usage of the silage, Frank Aherne, Department of Agriculture, University of Alberta for conducting feeding trials and finally, Robert Garnett, former Department of Fisheries and Oceans, Southe Operations Directorate, Alberta District Manag for initiating project ground work.

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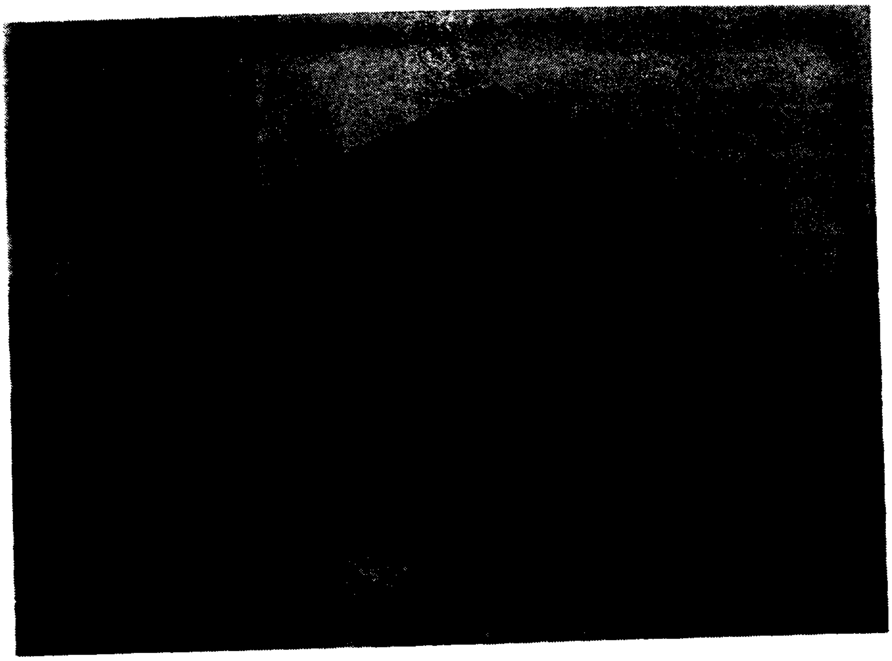

Fig. 1. Initial **Facility.**

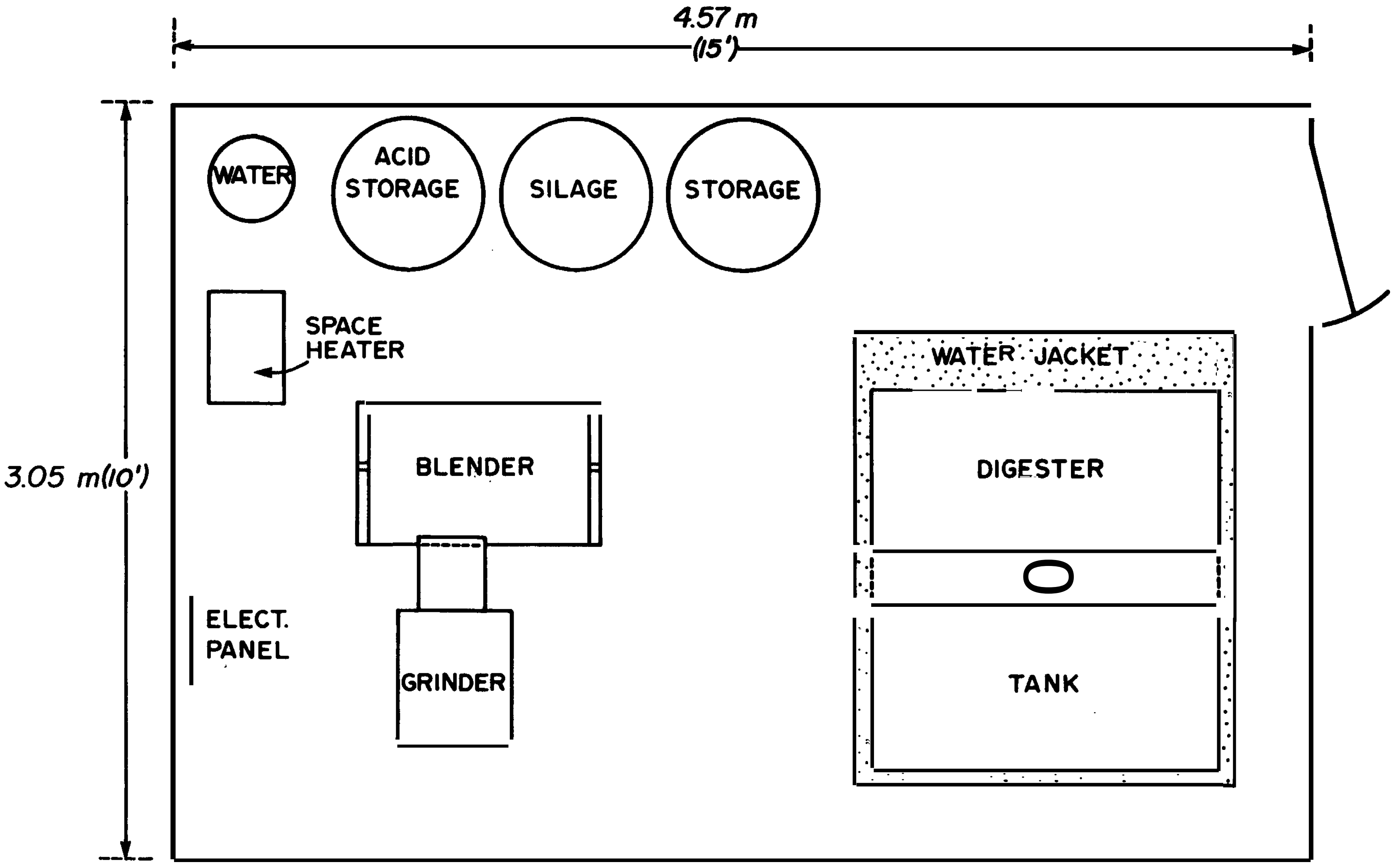

Fig. 2. Schematic of Initial Trial System.

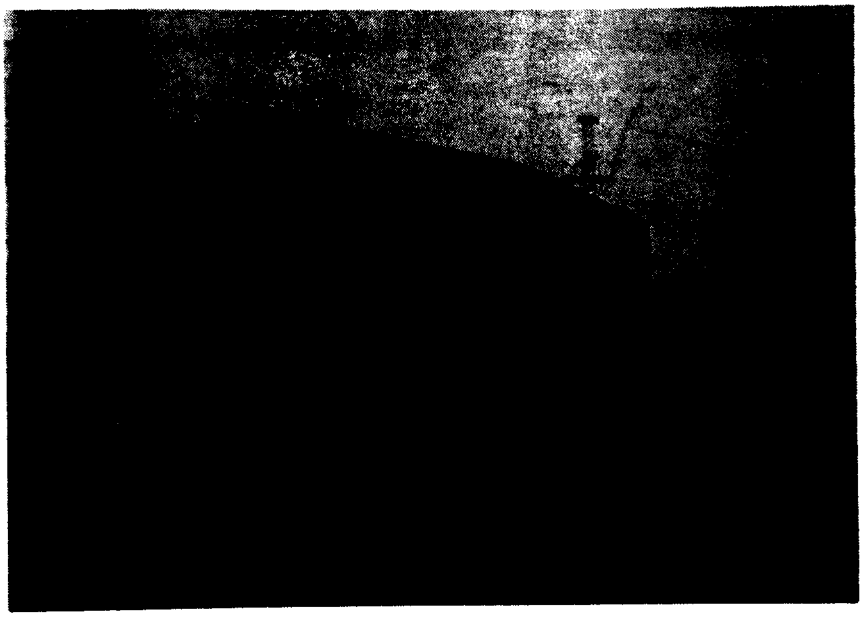

Fig. 3: Upgraded Facility - Exterior View.

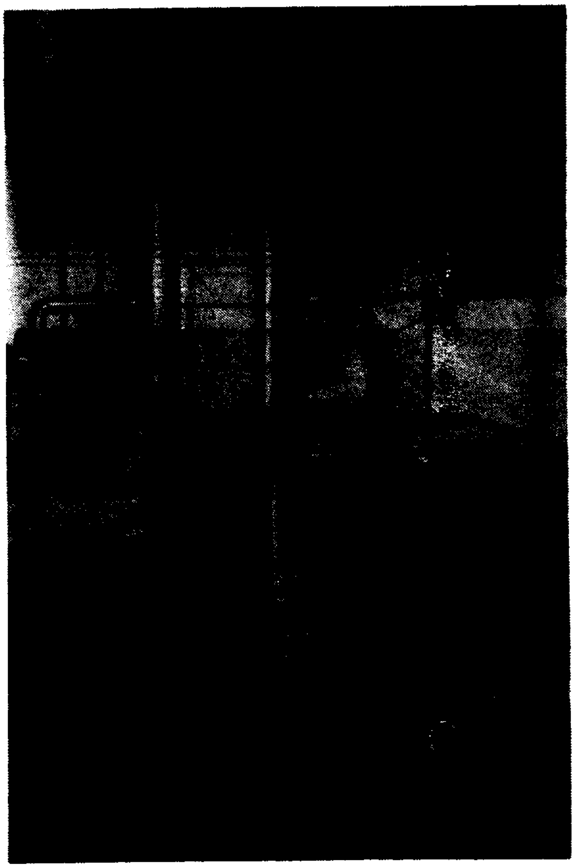

Fig. 4. Upgraded Facility - Interior View

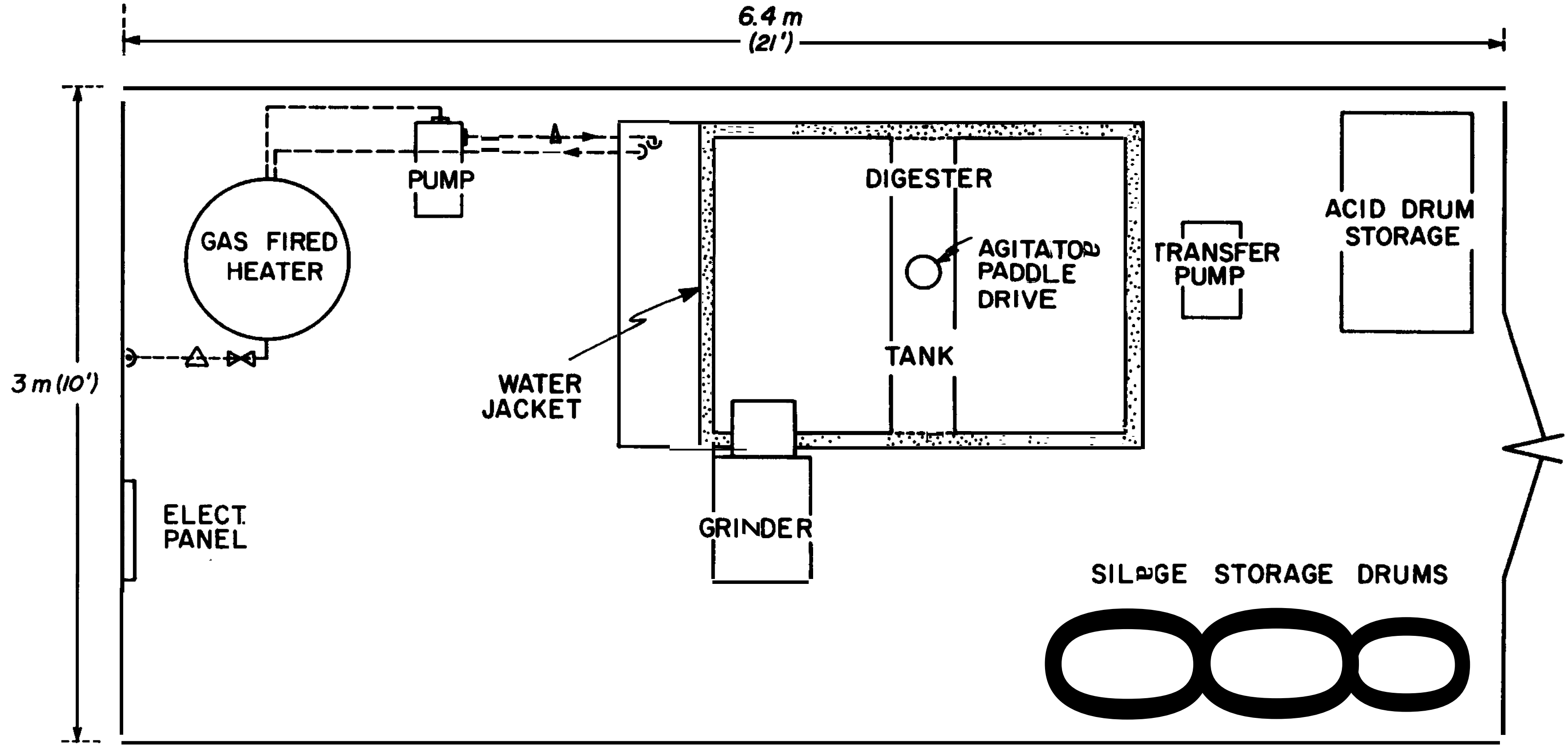

Fig. 5. Schematic of System in Upgraded Facility.

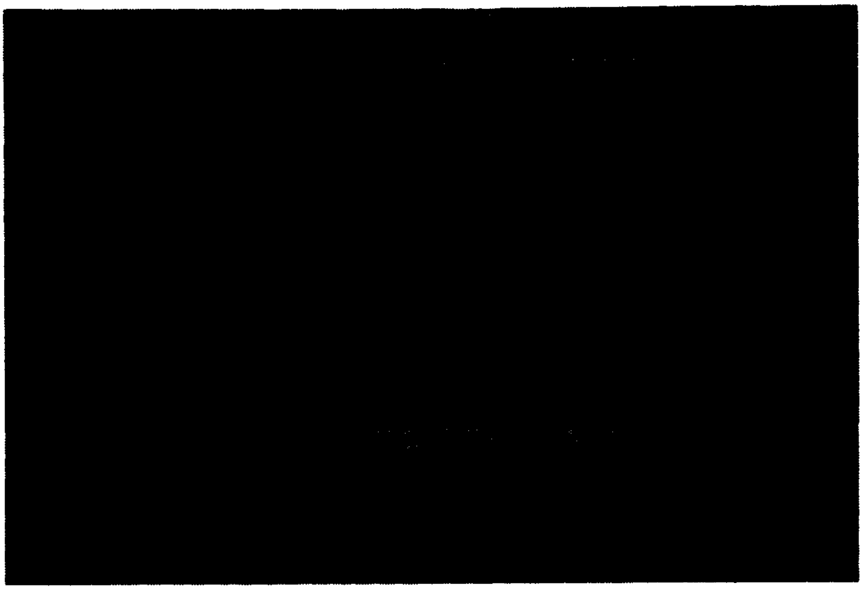

Fig. 6. Digester Tank Showing Agitation Paddle.