ECONOMIC ASPECTS OF NITROGEN STORAGE OF GRAINS.

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ABSTRACT

In this paper the economics of the nitrogen preservation technique of grains is compared with other storage methods, such as turning of the cereal grain bulk, disinfestation-fumigation, ventilation and refrigeration.

A complete analysis of storage center components is carried out. However, since the main objective of the work is the comparison between the various storage technologies, those cost items which can be considered equal in the different techniques or are independent of these are not quantified (general costs, personell etc.).

The economic evaluations carried out on the basis of direct industrial experience and literature data show that:

- nitrogen storage of grains is competitive in respect to other storage systems;
- the problem of gastightness of the silos, when treated at the moment of the silo construction, can be solved with no substantial increase of costs;
- the operating cost determined by nitrogen consumptions depends on the mode of supply of the gas and on the size of the storage plant. In any case this cost is in the order of the cost of chemical disinfestations or lower for storage complexes of large dimensions (over 50,000 tons).

INTRODUCTION

The scope of this work is to furnish evaluation elements on the application of the nitrogen technology for grain preservation in comparison with the traditional systems.

A homogeneous comparison between the different technologies is very difficult because grain preservation plants have design and construction characteristics which are always very different and can significantly influence the unit operating costs.

In order to perform the study, it was necessary to accept simplifying hypotheses to fix a common basis for the comparison. Two analyses were performed:

a) Analysis of the costs concerning the preservation process only

In this case, only the costs of the specific equipment used and of the utilities consumption for the application of the preservation process have been considered.

b) Full analysis of all costs of a storage center

This analysis is more correct since the choice of the preservation technology may have an influence over the magnitude and the distribution of all the costs that form the final preservation cost.

However this analysis is limited to the definite realization considered.

The results of the two types of analyses allow to obtain a picture, complete enough, of the economic aspects of the nitrogen preservation technology.

These evaluations should be considered preliminary and the costs data only indicative values since they were worked out on the basis of data coming from different, non homogeneous sources.

ANALYSIS OF THE COSTS CONCERNING THE PRESERVATION PROCESS ONLY

In this analysis we consider only the costs of the specific equipment used for the application of the preservation technology and the costs relevant to the utilities consumption for the operation of these facilities.

All the other costs:

- the cost of the silos
- the cost of the auxiliaries, roads, land etc.
- the cost of the grain conveying mechanization
- the cost of maintenance, handling etc.

are considered to be constant and unaffected by the preservation technology.

This is only a hypothesis because additional costs for the gastightness of the silo are required for the controlled atmosphere preservation technology.

Neverthless gastight silos (galvanized seamed sheet silos, dome shaped reinforced concrete silos etc.) may cost less than non gastight (concrete vertical silos, vitrified sheet-steel etc.).

On the other hand the operating simplicity connected with the use of the nitrogen technology allows considerable reductions in the labour costs. In fact some typical operations of the traditional systems are completely excluded, such as the frequent controls of the stored product, its turning and, above all, the treatments with chemical disinfectants that require the assistance of specialized personnel.

The other preservation technologies considered for the comparison are:

- turning of the product and chemical disinfestation
- ventilation and chemical disinfestation
- refrigeration.

Through the above mentioned hypothesis, the comparison is not homogeneous if the efficiencies of the different technologies are not taken into account.

It is not possible to compare on the same basis "preventive" and very efficient technologies like controlled atmosphere or refrigeration and "curative" and/or less efficient technologies like turning, ventilation and chemical disinfestation.

A common basis may be found with one of the two following assumptions:

- the initial characteristics of the preserved product being equal (moisture content equal to the critical value for example), we can evaluate an average loss of product relevant to each preservation technology;
- the results of the preservation being equal (zero loss for example), we can evaluate the savings permitted by the more efficient technolo-

gies that allow to preserve poor quality products and/or with higher moisture content.

1. Comparison at the initial characteristics of the preserved product being equal.

In table 1 the investment cost and the running cost are summarized for each preservation technology:

- for turning the investment cost refers to the temperature control and chemical distribution facilities; the running costs refer to the electrical energy consumption for turning and to the chemical consumption;
- for ventilation the investment cost refers to the fans, distribution pipes, temperature control and application of chemicals; the running costs refer to the electrical energy consumption for ventilation and to the chemical consumed;
- for refrigeration the investment cost refers to the cooling plant, fans and distribution pipes; the running cost refers to the electrical energy consumption;
- for controlled atmosphere technology it is assumed to supply the plant with liquid nitrogen, so that the investment refers to the gas distribution and control plant; the running cost refers to the nitrogen consumption.

For all the investment, cost depreciation is estimated at a rate of 17% per year. In table 1 the average loss of product that can be estimated for each preservation technology is also indicated. These values arise from the existing literature data and from direct experience acquired.

Losses are indicated in certain ranges, since they are statistical values. Furthermore, all other conditions being equal, they depend on variable basic data, namely:

- on product physical characteristics (fragility and pulverizability, presence of impurities in the interstices, etc.);
- on the evaluation of quality losses: they differ in connection with the different utilization of the product, with the basic value as marketable goods, etc.

TABLE 1 SAVINGS ALLOWED BY THE NITROGEN TECHNOLOGY IN COMPARISON WITH OTHER PRESERVATION SYSTEMS (ITALY - 1978)

	Transfer of products and chemical disinfestation	Ventilation and chemical disinfestation	Refrigeration	Nitrogen technique
Investment cost for preservation installations ($/ton)	1.0	2.0	6.0	5.0
- ammortization ($/ton)	0.2	0.3	1.0	0.8
- operating cost ($/ton)	0.5	0.5	0.3	0.3
- product losses (%)	1.0 ÷ 2.0	0.5 ÷ 1.0	0	0
- product losses ($/ton)	1.5 ÷ 3.0	0.7 ÷ 1.5	0	0
Total cost ($/ton)	2.2 ÷ 3.7	1.5 ÷ 2.3	1.3	1.1
Savings allowed by nitrogen technology in comparison with the others ($/ton)	1.1 ÷ 2.6	0.4 ÷ 1.2	0.2	-

For the evaluation of such losses an average value of 150 $/ton has been assumed for the preserved product.

It is then possible to calculate an overall cost of preservation for each technology examined.

From a comparison of these costs it appears that the most efficient and economical are those preservation systems which, on the basis of the results of the more detailed calculations, involve higher investment costs. Particularly the nitrogen preservation system appears to be most economic, since it allows a saving in the order of 1 $/ton/year as compared to all other technologies and of 0.2 $/ton/year as compared to the refrigeration technology. These evaluations refer to temperate zones. It is clear that the savings become much higher in tropical countries, where losses with traditional storage techniques are higher due to the climatic conditions.

2. Comparison at the result of preservation being equal.

Reference is made, hereinafter, to the case of maize preservation for a period of time of six months in a 27,000 ton storage complex in 1978 in U.S.A.

The informative principle of this analysis is that, while by the preservation system based on ventilation it is possible to preserve in the area concerned, without any losses, a product having 15.5% maximum moisture, with the nitrogen preservation system, it is possible to preserve, for the same period of time of six months, a product having an initial moisture content of 19%.

This possibility involves a saving in the cost for drying which is expressed in the following as a lower cost of the maize at the moment of harvest and purchase.

The cost of maize at 15.5% moisture is, in U.S.A., about 2.00 $/Bu (1 Bu = 0.027 ton); maize with higher moisture is penalized by a 4 c/ /Bu discount for each unit of percent exceeding 15.5. Thus the cost (C in $/Bu) of the maize with X moisture higher than 15.5 is:

$$C = 2 - 0.04\ (X - 15.5)$$

The comparison of the costs for preserving maize having 15.5% moisture by means of ventilation and of the costs for preserving maize having a moisture varying from 17 to 19% by means of the treatment with nitrogen, is made in table 2 on these bases.

The initial cost of the maize and the preservation costs are referred to the dry weight of the product in order to avoid considerations on the quantity of water associated with the maize.

The basic data for the evaluation are the same as in point 1. In this case too, it is assumed that liquid nitrogen will supply the plant.

From the comparison of the costs of maize dry weight at the end of the preservation period it appears that it is more convenient to preserve maize having 19% moisture by means of nitrogen than to preserve maize having 15.5% moisture by means of ventilation since it is possible to have a saving of about 1.4 $/ton.

The application of nitrogen technology to products having lower moisture results in smaller advantages and, in the border-line case, for maize having 17% moisture, we have approximately the same final cost as in the case of ventilation of maize having 15.5% moisture.

FULL ANALYSIS OF ALL COSTS OF A STORAGE CENTER

This analysis is extracted from a study, supported by the Italian Ministry of Foreign Affairs, evaluating the possibility of the introduction of the nitrogen technology into a tropical country.

For the nitrogen technology application two different plants are considered:

- Dome-shaped reinforced concrete silos with proper internal coating adequate to attain the required gastightness. The storage complex considered is made by 12 bins with a total capacity of 50,000 tons of bulk cereal. An on spot nitrogen production plant is designed in order to supply the required quantity of the gas. The equipment for the loading and the unloading of the cereals from the bins is very simple and is made by fixed and mobile screw conveyors.
- Storage complex as described above. The alternative is in the equipment for the loading and unloading of the cereal, that is made with

TABLE 2 SAVINGS ALLOWED BY THE NITROGEN TECHNOLOGY FOR MOIST MAIZE PRESERVATION IN A 27,000 TON STORAGE COMPLEX (USA - 1978)

	Traditional storage technique	Nitrogen technique		
Maize Moisture Content (%)	15.5	17	18	19
Initial cost of Maize ($/Bu)	2	1.94	1.90	1.86
($/ton)	74.07	71.85	70.37	68.89
Initial cost of dry matter ($/ton d.m.)	87.66	86.57	85.82	85.05
Cost of the installations for the preservation				
- ammortization ($/ton)	0.11	0.80	0.80	0.80
- operating cost ($/ton)	0.01	0.28	0.28	0.28
- total	0.12	1.08	1.08	1.08
- total referred to dry matter ($/ton d.m.)	0.14	1.30	1.32	1.33
Final cost of dry matter ($/ton d.m.)	87.80	87.87	87.14	86.38
Savings referred to dry matter ($/ton d.m.)		– 0.07	0.66	1.42
Savings in 6 months ($)		– 1,570	14,610	31,050

a fixed plant.

For the traditional preservation technology (turning of the product, chemical disinfestation etc.) we consider 5 different storage complexes representative of the most common types of silos utilized in tropical countries (Balwanth Reddy, 1976):

- Conventional Godowns (C.G.)

These are horizontal structures utilized for bag storage of grains having 5000 tons capacity, with a floor dimension of 124 m. x 21.7 m. and 5.6 m. high brick walls with three compartments and longitudinal platform on one side. Road and rail sidings are normally provided for receipt and despatch of grains.

- Flat Bulk Storage Godowns (B.G.)

These are flat godowns suitable for handling grains in bulk. Their shape is similar to the conventional godowns.

- Reinforced Concrete Circular Bins 23.5 m. diam. and 10.5 m. high (C.B.)

These bins are lower in height than typical silos, they have a flat bottom and dome shaped top.

- Reinforced Concrete Vertical Silos (V.S.)

These silos are tall structures, 30 to 40 m. high and 8 - 11 m. in diameter. They have high capacity loading and unloading equipment, drying and aeration facilities, capability to mix grains and fumigation on site.

- Port silos (P.S.)

The structural shape of these silos is similar to R.C.C. Silos. They are installed in batteries close to the berth. They have additional pneumatic unloaders, of up to 800 tons per hour capacity.

1. Investiment costs

The investment costs for each of the described plants are reported in table 3.

The items considered are:

- Land

The requirement of land for storage varies according to designs. Thus, bulk storage, vertical structures, such as silos and bins would require less land, compared to the conventional flat storage facilities.

Our estimation of the element of land cost is based on its requirement for different designs and sizes of depots; and its cost in different regions.

The cost of land would vary from location to location, depending upon the nature of land, proximity to road, rail or main cities or due to its strategic importance.

- Approach Road

The initial cost of construction of internal roads is affected by the extension of the storage complex and by the construction materials (concrete, bitumen etc.).

- Railway Siding

Similar to approach roads, the length of railway siding varies according to the extension and location of the depot from the main line.

- Ancillaries (Office, Compound Wall, Foreign Amenities, etc.)

In a storage depot, in addition to the main structure, administrative complexes, water supply and drainage systems, canteen block, lavatory and sanitary arrangements, compound walls/fencing, quarters for watchman, etc., are provided, depending on the size and staff strength.

- Equipment

It includes the loading and unloading facilities costs. For the nitrogen technology it includes the cost of nitrogen production and of the distribution plant.

TABLE 3: SUMMARY OF INITIAL CAPITAL INVESTMENT COST PER TON OF STORED PRODUCT-1979 (US $/ton)

	TRADITIONAL PRESERVATION TECHNOLOGY					NITROGEN TECHNOLOGY	
Item	C.G. Conventional godowns unit of 5,000 ton capacity	B.G. Flat godown for bulk storage of 10,000 tonnes unit	C.B. R.C.C. circular bins of 20,000 tonnes	V.S R.C.C. silos of 20,000 tonnes	P.S. Port silos of 50,000 tonnes	D.S.1. Dome--shaped R.C.silos of 50,000 tonnes	D.S.2. Dome--shaped R.C.silos of 50,000 tonnes
Land	1.66	1.66	1.57	0.56	4.62	0.70	0.70
Civil works (35 years for C.G. and 50 years for silos)	36.96	46.20	46.20	75.77	140.46	27.49	29.91
Railway siding (15 years)	4.81	4.81	4.81	3.14	2.96	4.81	3.14
Approach Roads (10 years)	2.22	1.85	1.85	3.14	2.96	1.85	3.14
Ancillaries (35 years)	4.71	4.71	4.71	4.99	4.62	4.71	4.71
Equipments (10 years)	0.73	16.63	18.48	64.68	161.90	14.33	33.71
Total capital US $/ton	51.09	75.86	77.62	152.28	317.52	53.89	75.31

Civil Works

The initial costs of construction of godowns and silos are included. This includes also foundation roofing, floor finish, etc. From the values indicated (Balwanth Reddy, 1976), it is possible to draw the costs of silos and godowns working according to the conventional preservation technology (table 3). Table 3 also shows the costs of airtight silos to be utilized for the application of the nitrogen technology.

The overall investment costs obtained indicate that the investment costs for storage according to the nitrogen technology are equivalent or even lower than those referring to units functioning according to conventional technology.

2. Running Costs

It is understood that these are inclusive of material and labour. They can be divided into fixed costs, depending on the capacity of the storage unit, but not on the quantity of cereal grains treated, and variable costs, which are proportional to said quantity.

The fixed costs are (table 4):

- Depot Establishment

The cost relevant to the permanent staff engaged in managing the depot. For storage units working according to the nitrogen technology, the costs for personnel are considered equal to the values relating to conventional preservation, even though in this case a lesser operational activity is required for the preservation of the cereal grains.

- Head Office and Other Overheads

It regards the cost of head office and regional office staff engaged in import, procurement, transportation, distribution operations and other activities.

- Maintenance and Repairs Cost

The annual maintenance and repair are evaluated as a percentage of the present value of capital cost.

TABLE 4 SUMMARY OF ANNUAL CURRENT COSTS.PRICES PER TON HANDLED AT 100% UTILIZATION, ONE ANNUAL TURNOVER - 1979 (US $/ton)

	TRADITIONAL PRESERVATION TECHNOLOGY					NITROGEN TECHNOLOGY	
Item/ton	C.G. conventional godowns	B.G. bulk godowns	C.B. circular bins	V.S. silos	P.S. port silos	D.S.1.	D.S.2.
1. Maintenance of buildings	0.54	0.62	0.62	0.91	1.58	0.42	0.44
2. Maintenance of equipments	0.03	0.67	0.75	2.61	6.63	0.58	1.36
3. Local taxes	0.14	0.22	0.23	0.49	1.05	0.16	0.25
4. Depot establishment	4.07	2.01	2.01	3.14	3.14	3.14	3.14
5. Head office oversheads	0.96	0.96	0.96	0.96	0.96	0.96	0.96
6. Handling	2.09	1.04	1.04	1.04	1.04	1.27	1.04
7. Grain loss	3.70	1.85	1.85	1.85	1.85	--	--
8. Energy	0.03	0.24	0.24	0.48	0.48	0.48	0.48
9. Preservation	0.44	0.44	0.44	0.44	0.44	0.35	0.35
10. Dunnage	0.35	--	--	--	--	--	--
11. Insurance	0.55	0.55	0.55	0.55	0.55	0.55	0.55
12. Gunny	10.16	5.08	5.08	5.08	5.08	5.08	5.08
Total cost US $/ton	23.06	13.70	13.77	17.55	22.71	13.00	13.65

For simplicity, we propose to take the maintenance charges as 1 per cent for civil works and 2.5 per cent on equipment on a linear scale.

- Local Taxes

The taxes on assets including the corporation tax on land and buildings, is taken at the usual rate of 25% of the present value of capital cost.

- Loading In and Out Charges

Also known as handling charges in the godown or silo, the operations involved are:

a) Unloading from truck and stacking to the required height, in the case of conventional godowns;

b) Unloading from the wagon and stacking;

c) Destacking and loading into trucks/wagons;

d) Weighing and standardisation charges.

Weighing and standardisation operations are not involved in every case and are required only for about 10 per cent of the grains handled.

Handling in and out is basically a labour-intensive operation and it should be confined to conventional godowns. Because of the existing systems of arrival and despatch in bags, even silos incur certain handling cost.

- Storage Loss

Storage loss is dependent on the initial conditions of the grains, pests, type, duration of storage and preservation methods. We have estimated the annual grain loss in conventional godowns for bag storage as 2% and the corresponding figure in bulk silo/bins as 1 percent in case of conventional preservation.

Nitrogen technology providing the preventive protection of the cereal,allows to obtain no product loss. The cost of grain loss per ton of grain is calculated on the basis of 180 $/ton cereal cost.

- Preservation Cost

It includes the cost of chemicals used for prophylactic and curative treatment.

In the case of nitrogen technology the protection treatment is achieved by nitrogen, coming from the gas production plant. The treatment cost indicated corresponds to the cost of the utilities consumed by the plant for 1 year preservation assuming the following unit costs for the utilities:

- electric power	3.5 ¢/Kwh
- GPL	15.4 ¢/kg
- cooling water	1.8 ¢/cm

- Cost of Dunnage

This is required only in the case of conventional godowns and CAP storage to provide protection against surface dampness.

- Cost of Gunny

At present a large part of the distribution of foodgrains in tropical countries is in bags. The purchases are normally in bags. From the procurement stage onwards, since the present handling, weighing and transportation systems are in bags, gunnies are utilized both for silo and conventional storages. In the case of silos, the bags are slit open to pour grains into hoppers of elevators used for filling the bins.

The bulk discharge is rebagged before handling and loading into trucks or wagons. Therefore, the use of gunny is unavoidable in both systems of storage at present.

- Energy Cost

It refers to the energy required for the operation of conveyers, bucket elevators, operation of the locomotives and generators.

The same costs are considered irrespective of the preservation technology. Actually, the costs of energy are higher in the case of conventional preservation, where the cereal is turned to aerate and cool, than in the case of preservation according to nitrogen technology, where the energy costs only relate to the loading and unloading of the product.

- Insurance Cost

Grains are insured against fire, theft, etc., and the prevailing insurance charge is 0,55 $/ton. The same incidence has been considered for the case of nitrogen technology even though it probably allows a certain saving due to the reduced fire hazards it involves.

3. Analysis of Preservation Costs

It appears that the investment and running costs for storage units working according to the nitrogen technology are equivalent to or even lower than those referring to units working according to conventional technologies.

For a more reliable comparison, however, it is necessary to take into account the different duration of the various components of the storage unit.

All the costs can therefore be referred to a common base of duration (50 years) summing up the discounted present values, at 10% interest, of the replacement costs of components with life shorter than 50 years (table 5). Furthermore, the various running costs per year that will be incurred in the various cases shall also be considered. In order to calculate an overall cost, it is necessary to calculate the discounted present value, at 10% interest, of the subsequent yearly payments anticipated for the running of the plant for the base duration of 50 years (table 5).

The summation of the present values of the investment and running costs results in the local preservation costs for the various cases considered, as referred to the yearly preservation cycle and to 100% utilization of the storage capacity. These costs are referred to a common base and allow immediate comparison. It therefore appears that nitrogen technology involves overall preservation costs lower than those involved by the conventional technologies even where the latter is applied to very economical silos such as the conventional and the flat godowns.

An equivalent but more convenient expression for preservation costs is possible by expressing them as costs per ton per year. This is obtained by estimating the capital costs as a uniform annual series on

TABLE 5

SUMMARY OF PRESENT VALUES, AT 10% INTEREST, OF CAPITAL COST AND CURRENT COST FOR ONE ANNUAL TURNOVER AND 100% UTILIZATION OF STORAGE CAPACITY - 1979 (US $/ton).

	TRADITIONAL PRESERVATION TECHNOLOGY					NITROGEN TECHNOLOGY	
Item	C.G.	B.G.	C.B.	V.S.	P.S.	D.S.1.	D.S.2.
P.V. of capital cost	54.98	89.42	91.61	194.94	419.60	65.33	98.93
P.V. of annual cost	251.70	149.54	150.30	191.55	247.88	141.89	148.99
Total present value	306.68	238.96	241.91	386.49	667.48	207.22	247.92

TABLE 6 SUMMARY OF ANNUAL TOTAL COSTS PER TON AT 10% INTEREST, FOR ONE TURNOVER AND 100% UTILIZATION OF STORAGE CAPACITY - 1979 (US $/ton)

	TRADITIONAL PRESERVATION TECHNOLOGY					NITROGEN TECHNOLOGY	
Item	C.G.	B.G.	C.B.	V.S.	P.S.	D.S.1.	D.S.2.
Annuity figures based on present value of capital cost	5.55	9.02	9.24	19.66	42.32	6.59	9.98
Annual current cost	23.06	13.70	13.77	17.55	22.71	13.00	13.65
	28.61	22.72	23.01	37.21	65.03	19.59	23.63

the basis of the present value estimates of investment costs of table 5 at 10% interest and 50 years, and adding to this the running costs recurring every year. Table 6 provides the total cost per ton handled in different designs, with the implicit assumption that there is only one turnover with capacity utilization at 100 per cent.

The overall preservation costs, even where they are expressed as yearly costs, are lower with the nitrogen technology than with the conventional technology.

The saving in the yearly costs allowed by the nitrogen technology as applied to storage units D.S.1, compared to conventional preservation costs with the most economical type of unit (B.G.), is about 3.13 $ per ton per year corresponding to about 156,500 $ per year for a 50,000 ton storage unit.

CONCLUSIONS

The results of this study show that the nitrogen technology for the preservation of grains is competitive, from an economic standpoint, as compared to the other technologies used.

In the cases examined, the investigation showed that a saving of about 1 $/ton year is obtained by treating the cereal according to the nitrogen technology.

These economical advantages arise from 1) the reduction in quantitative and qualitative losses of product, 2) the widening of the range of products to be stored (high moisture maize, for example), 3) the possibility of using very large and cheap structures that cannot be used with traditional preservation technologies.

The increasing costs of energy sources necessary for grain drying and that for chemicals for grain disinfestation permit to predict more and more economical advantages arising from the nitrogen technology.

REFERENCES

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