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Final Project Report

Subject US/SUD/88/266

The Conversion of the Babanousa Dairy Plant
into a Karkadeh Powder Production Plant

NATEC Project No. NA 90 9364

Part I: Aspects related to the Conversion of the Babanousa Milk Powder Factory into a Karkadeh Powder Factory

Part II: Sector Analysis of Karkadeh Production in Sudan

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CONTENTS

PART II

SUMMARY

The first part of this report deals with the problems for a conversion of the milk powder factory at Babanousa into a karkadeh powder factory. A field study in the Sudan with an particular audit of the Babanousa milk powder factory was carried out. The main statements of the revealed informations are not too much optimistic for a future production, because the sophisticated process of high quality karkadeh powder production in comparison to the milk powder production is not possible with the present existing equipment. It needs to be carried out with devices, which can be handled more flexible in a continous production run. The existing factory equipment, which is of older Soviet Union origin, is partly damaged and several devices have to be replaced by a better suited equipment for the karkadeh production. At a first inspection it seemed to be doubtful, whether the factory could be run after two and a half years standby. But it became evident in 1992 that the Babanousa factory is still workable. But it should be taken into account that the presently existing 28 years old equipment will be out of order in the next future. In March and April 1992 40 tons of karkadeh powder were manufactured. Some of the necessary equipment for the manufacture of high quality karkadeh powder could be used only intermittently. The cost calculation for the present production of powder in Babanousa resulted in karkadeh powder prices which are in line with the world market price.

For a minimum restoration to keep the factory workable for the next three years a capital expenditure of 262.000 US-$ will be necessary. A restoration for a long-term productivity needs to include the replacement of several equipment which is still workable, but do not fulfil the technological requirements for a karkadeh production. The most important technical disadvantage is the huge spray-dryer, which is not suited for a karkadeh production. The restoration for a long-term productivity needs another 680.000 US-$.

Because several engineering and technical problems cannot be solved without great effort, a conversion of the Babanousa milk factory into a karkadeh powder factory will not be an economic promissing solution for a karkadeh powder production in Sudan. Therefore it seems to be necessary to look for an alternative production place and to restorate the factory only for an interim pe-

riod. To overcome the desolate situation of the facilities, a list of equipment which has to be replaced is given in this report together with an explanation of the technological advantages for a future powder production.

In the second part of the Report detailed information about the agricultural aspects of the growing and harvesting of hibiscus sabdariffa calyces is outlined. The description of the possible growing areas together with a hint to the yield and an explanation of the harvesting and cleaning procedures of the raw materials are given. Product specifications and influences on the quality are discussed for the whole production from the harvesting time until the packaging and storage of the produced powder are described.

Ways on a short description of the Sudanese infrastructure and the technical possibilities a marketing strategy for the export and local market is lined out. Ways on the outlined infrastructure and marketing strategy the possibilities for local and foreign investments for a karkadeh production in the Sudan are developed. For a capital expenditure of 612.000 US-$ smaller factories at El Obeid, Kosti, and Wad Medani are judged in comparison to the restoration of the Babanousa factory. It is clearly shown that according to the better infrastructure all three places show a much better economic efficiency rate than the Babanousa factory will do.

Therefore it is recommended to do a small restoration of the Babanousa factory to keep it workable at the next three years and use the factory as a training centre and look for investors to set up new smaller factories with a more suited technology for the karkadeh production at the other one or two of the above mentioned places revealed in this study.

INTRODUCTION

Background Information

In the early 1960's a dairy plant has been established in the Sudan at Babanousa to process milk into butter, cheese, butter fat and also milk powder. In the Western part of the Sudan, a traditionally high livestock population existed and milk was collected for processing from the areas surrounding the factory. The dairy plant, constructed and sponsored by the development department of the USSR, was commissioned in 1969 and even at this time no sufficient milk was available although certain supply problems already existed especially with regard to the milk quality and constant quantity supplies. The milk procurement, however, became more and more difficult as the cattle "holding" nomads moved South during the summer time so to find better feeding areas for their cattle thereby leaving the traditional milk-producing areas near the dairy plant. During several years of draught, the nomads stayed South and the dairy plant had to slow down its production and had to finally stop it for lack of milk raw material.

In order not to close down the factory, alternative production possibilities were sought and found by using the available dairy equipment for the production of karkadeh powder from locally available rosella calyces (hibiscus sabdariffa) and also from gum arabic. Both rosella and gum arabic are abundantly available in the area of Babanousa.

The production of gum arabic powder was controlled by the Sudan Gum Arabic Company (GAC) which had to stop gum arabic powder production at the Babanousa factory because the international quality standards for exports could not be met in the long run.

It is the intention of the Government of the Sudan to build up and develop the industrial production of quality karkadeh powder for which a considerable market demand exists particularly in arabic (muslim) countries. Market studies carried out with the assistance of the International Trade Centre have confirmed the market demand on quality karkadeh powder.*)

The product development and process research work was therefore of special importance. The factory, therefore, continued with and concentrated on the production of karkadeh powder with the available milk processing equipment. Although the production goes on and the product has found a market in the Sudan and for exports, the factory was faced with serious problems very negatively affecting its production efficiency and the product quality calls for improvement as well. Among others the following problems were described as to be of importance.

- The hydroscopic property of the karkadeh powder which causes drying (spray-drying), storage, packaging and other problems;

- The acidity of the karkadeh extract causes part corrosion of certain equipment;

- The colour of the karkadeh powder as well as of ready-made soft drinks is fading to a pale-yellow within a rather short period.

Besides this, some other problems occurred in the last three years. Information how to handle the above mentioned problems should be revealed within this project.

The production of karkadeh powder at the Babanousa factory was closed down for economical reasons and because of technological problems occurring by the breakdown of the production equipment which could not be repaired by the factory workshop easily until now.

Realizing that these problems cannot be solved by industrial production experiments the Government of Sudan wishes UNIDO to assist by carrying out the required product and process research and development work resulting in the definition of the technological processing parameters and in the definition of the most suitable equipment within the framework of this project.

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*) Report of: ITC/DTC/455 (May 1982) P. Marcell, The market for karkadeh in USA and European countries, Proj. SUD/50/34

AIM OF THE PROJECT

The aim of this project was to assist the Government of Sudan by carrying out the necessary product and process research and the development work for the definition of the most suitable equipments for the production of karkadeh products. The outcome of this project work should be used as a basis for the final decision to be taken by the relevant authorities of the Government of Sudan:

- The final conversion of the Babanousa dairy plant into a karkadeh powder production factory

- The establishment of alternatives or additional karkadeh production plants in the Sudan, which are in line with the overall raw material availability and the market demands.

PART I

ASPECTS RELATED TO THE CONVERSION OF THE BABANOUSA MILK POWDER FACTORY INTO A KARKADEH POWDER FACTORY

1. Present situation of the Babanousa factory

1.1 General Remarks

A factory audit of the Babanousa factory was carried out in the beginning of November 1991. The audit consists of an inspection of the whole factory equipment and was conducted together with the technical management of the factory. During the inspection an intensive discussion and an internal questionnaire was held together with the factory management and a chemical engineer of IRCC. In the discussion it was confirmed by the technical management that the factory did not work since May 1989.

During the inspection it was established that the production equipment was partly in a desolate condition. A detailed view on the state of the factory facilities is given in Appendix I. Beyond repairing problems, which could not be solved satisfactory, karkadeh raw material could not be made available at Babanousa for different reasons in the last three years before 1992 because of lack of money and other priorities at the Government of Sudan to which the factory belongs at present. But also some main technological problems occurred in the cause of the inspection.

1.2 Technical and technological aspects

With the exception of the leaching vessel all installed equipment of the factory is the standard equipment for a milk factory. For the leaching of the karkadeh calyces an extemporized large open vessel is used, which is placed outside of the factory (see Appendix I, Fig. 2-4). It is an equipment for a batchwise discontinuous working and has several disadvantages. The removing of the extracted calyces is ineffective and time consuming procedure. The leaching rate is comparable low, because no aggitation of the liquid during the leaching procedure is possible. The yield of the extraction procedure is low. Therefore at least two, mostly threee extraction cycles are necessary. The total leaching process is carried out without a roof protection, so that undesirable materials like birdsmud and dust may contaminate the product.

The extract is decanted and immediately passed through a riddle to remove larger particles (Fig. 5 of Appendix I). The iron wire sieve is broken because of the corrosion caused by the low pH-value of the extract. Only a riddle of stainless steel (V4A) will stand this procedure. These storage tanks (see Fig. 6 of Appendix I) are in good order with sufficient capacity. In the next production step the extract is separated from any solid material in a centrifugation process. The used centrifuges are common available milk centrifuges, which do not work very effective and have the disadvantage not to be stable for the acid liquor (see Appendix I, Fig. 7). A repaired centrifuge (see Appendix I, Fig. 8) was available during the inspection. But because no acid resistant material like stainless steel (V4A) is used, further corrosion will occur after a short time of work.

In the last four months of the last production period in 1989 and for the whole production in 1992 no separation step was carried out because of the breakdown of the centrifuges. This might possibly have influenced all other processing steps in a negative sence. Besides a lower quality of the product the missing separation steop may have led to problems in the evaporation unit, but in particular may have given rise for a demolation of the atomizer unit in the spray dryer. No visual inspection of the inner side of the evaporating unit was possible during the inspection.

The tanks before the evaporation unit did not show any weakpoints and are of sufficient capacity (Appendix I, Fig. 9). The same is true for the feedertanks (Appendix I, Fig. 10).

From the two separate vacuum evacuation units only one is in a good order and was used for the karkadeh production (Appendix I, Fig. 11). This system consists of a preheater and an evaporation vessel, which is optimized for milk production and was never adapted or optimized for the karkadeh extract concentration. Because of the heat sensitivity of the product it is doubtful that this evaporation equipment can be optimized to obtain high quality karkadeh powder.

The two feeder tanks before the spray drying unit are in good condition and of sufficient capacity (Appendix I, Fig. 12).

The spray drying unit (total view given in Appendix I, Fig. 13) with a capacity of 700 kg extract per hour is a very large unit. Such a huge spray dryer unit cannot be handled flexible and has to be run under very constant conditions over a period of several hours. This is in contrast to the requirements for the production of karkadeh powder under the present available conditions, which are carried out batchwise. Due to the fact that the spray dryer was used in the conditions for milk powder production problems occurred in the powder production. The different density of the hibiscus extract droplets in comparison to milk concentrate and the sticking behaviour of the dryed powder an efficient spray drying could not be obtained. Instead of producing droplets the liquid is sprayed to the wall, so that most of material stick to it and is partially burned. To remove this solids from the wall, mechanical scratching and knocking is necessary. By this procedure the inner surface of the dryer was damaged (see Appendix I, Fig. 14, 16 and 17). Only 10 to 20 % of the produced karkadeh was really spray-dryed powder. Up to 80 % sticked to the wall. The uneven surface of the inner wall of the spray-dryer will on the one hand strengthen sticking and on the other hand result in a stress corrosion of the inner skin-material in the future. The atomizer did not show any visual remarkable defect (Appendix I, Fig. 15), but it could not be tested whether it really works. To use such a large spray-drying unit for the production of a high moisture and temperature sensitive material as karkadeh, which is in accordance with the information from the supplier of the spray-dryer, Messrs. NIRO, is not possible for technological reasons.

The transport pipes to the dust cyclone and the packaging station as well as the vibration riddle and the cyclone itself did not show any problematic destruction and seem to be workable (Appendix I, Fig. 18, 19, 20 and 22). The stirring panel of the spray dryer did not look very promising. Some of the measuring instruments were obviously broken (Appendix I, Fig. 23).

During the whole period of karkadeh production the ammonia cooling system, which is installed to remove the moisture of the air, was not used. Therefore, in a period of high relative humidity even the small amount of real produced powder, which was transported through the pipes and the cyclone became lumpy. The ammonia cooling unit was not used until the milk production was stopped in 1976. Ammonia is available at the Babanousa factory. The pumping and the compression system do not show obvious failures or distortion (Appendix I, Fig. 28 and 29). The cooling transfer system looks highly corroded (Appendix I, Fig. 30). It could not be checked by visual inspection whether corrosion occurs in the inner side of the whole system. But it seems not to be in a state for a successful reinstallation.

The packaging of the product was carried out manually in polyethylene bags. This was not done very professional. No effective workable scaling equipment exist. The scaling rims of the hand scaling machine were in a bad condition. The bag material is too thin to give a sufficient moisture protection and the sealing equipment, which is used for closing the bags (shown in Appendix I, Fig. 24), is insufficient and will give rise to open seals. This is dangerous for the storage of a moisture sensitive product like karkadeh powder.

The Babanousa factory is located in an area, which is not connected to any electricity network. Therefore, the factory is equiped with its own electricity power station consisting of two large and one small diesel generator. Only one of the diesel generators (Appendix I, Fig. 25) was workable at the end of the last production period in 1992. The diesel is of older Soviet Union origin. Problems to make available spare parts and particularly the lack of any workshop equiped with a turninglathe and drilling machinery to manufacture broken parts of equipment at the factory is of disadvantage for a continuous workable factory.

The factory is also equiped with three steam generators from which only one was workable at the last production period. After finishing the production, the steam vessel was not filled with water and it might be possible that after such a period of time - the generator was not used for 2 1/2 years - the vessel and the pipe may strongly be corroded (Appendix I,

Fig. 27). It was recognized that the inside of the shamott burning chamber is partly damaged and does not look very promising. Another disadvantage of the steam generators is that they are overdimensioned and not equiped to be run a reduced level. This means that high amounts of fuel will be used to generate steam and this will unnecessarily increase the production costs.

Two wells for fresh water exist at the factory area. Both of them have a deth of 170 meters. They were working and the pumping system was in good order. The total water supplying system seems to be satisfying. Some tubes and valves seem to be corroded and have to be replaced in the near future. Stores for raw material are in good order and of sufficient capacity. Most of the lorries and cars at the factory are damaged. Some of them showed broken tires, cylinder heads and seals.

2. Evidence of factory productivity

In view of the worse circumstances revealed during the audit in November 1991 it should be demonstrated whether the main facilities could be operated successfully after being at a standstill for a period of more than two years. In March 1992 the factory was started working again, and in a period of two months karkadeh powder was manufactured. A short description of the operating procedure performed at the Babanousa factory in 1992 provided by the IRCC, Khartoum explains the details as follows:

Production was started on the 14th of March 1992, because of a delay in the supply of the oil used for operating the pump which feeds the boilers with water, and stopped on the 13th of May 1992. During this working period the plant produced 43 tons of karkadeh powder (i.e. below the annual average in the earlier 17 years). The production stages were very similar as before. Exception was that the clarifier centrifuges were not operated because they were corroded by the high acidity of the extract.

As usual in all operating periods before, the ammonia cooling section, which should be used to dry the air for the spray-dryer and cools the powder coming down from the dryer and leads it to the cyclones, was not operated.

During the working period the plant had to stop production for short periods due to some failures in the different sections of the plant. The obstacles encountered during the production were:

a) Lack of spare parts for some important sections, e.g. the boiler, which did not enable carrying out maintenance as required.
b) The problem of sticking of the powder to the inner wall of the dryer (this occurs mostly from April onwards due to the high humidity in the atmosphere).

The produced powder was packed as usual (in polythene and paper bags) and transported to Khartoum where it is stored.

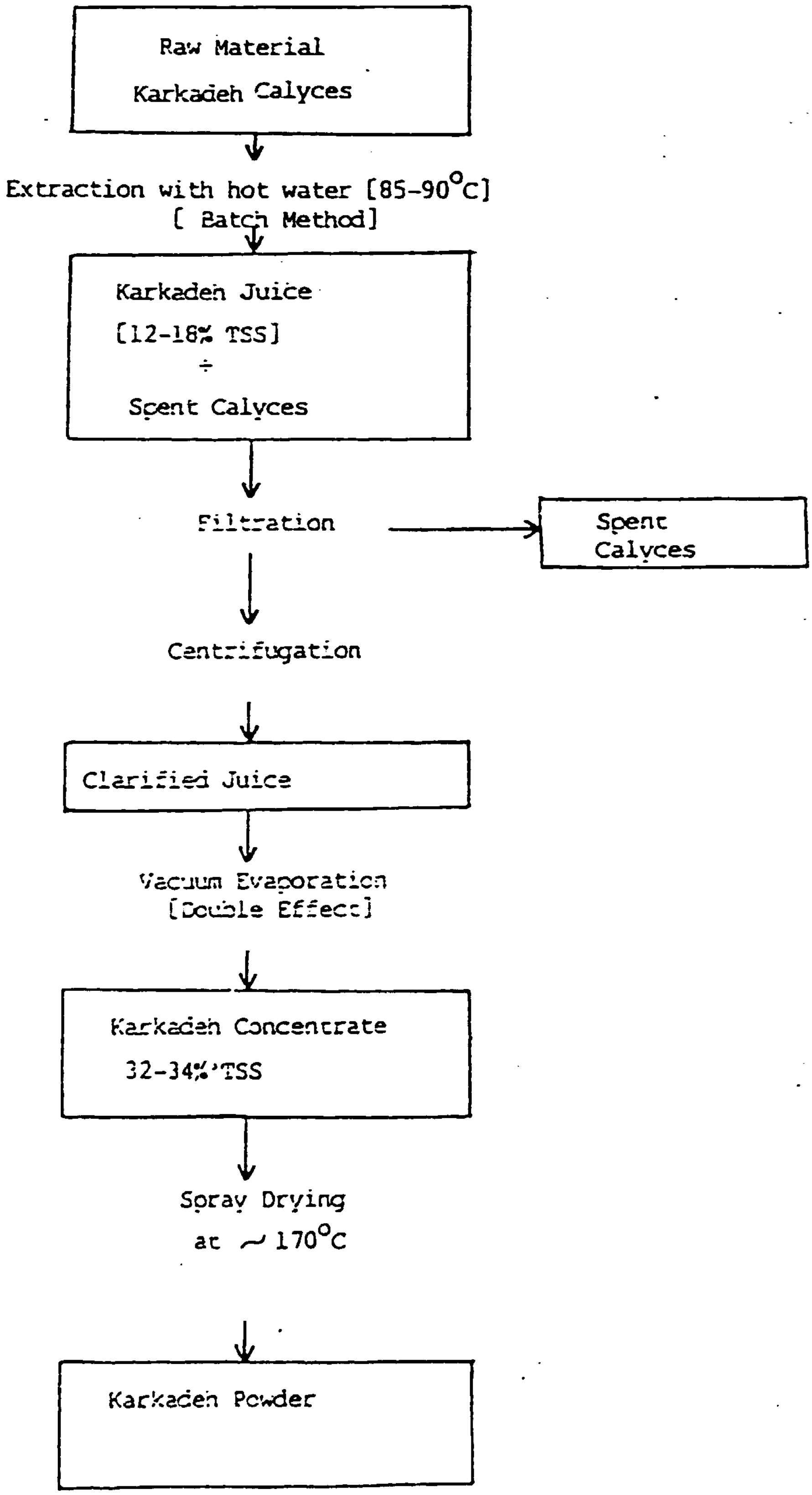
Raw material:

The plant activities during 1991/92 season were financed by the private sector (The Sudanese Investors Company) with the aim of exporting the produced powder. The raw material (karkadeh calyces) purchased by the financer amounted to 110.5 tons at a price of 129,800 Sudanese Pounds per ton (factory gate price). The raw material was purchased from different growing areas surrounding Babanousa Town.

Factory operation:

The traditionally used process for producing karkadeh powder is shown in the diagram on page 17:

Fig. 1


Raw Material
Karkadeh Calyces
Extraction with hot water [85-90°C]
[Batch Method]
Karkadeh Juice
[12-18% TSS]
+
Spent Calyces
Filtration
Spent Calyces
Centrifugation
Clarified Juice
Vacuum Evaporation
[Double Effect]
Karkadeh Concentrate
32-34% TSS
Spray Drying
at ~ 170°C
Karkadeh Powder

2.1 Production problems at the Babanousa factory

Ammonia cooling system:
As usual in the very past karkadeh powder production at the Babanousa factory the ammonia cooling system was not used and more and more parts of the facility, e.g. the clarifier centrifuge and the boiler to evaporate the extract, could not be used or were operated intermittently. The obstacle of not using the ammonia cooling system for air drying during the powder production in the factory is the main reason for the sticking of the dried material at the wall of the spray-dryer.

Spray-dryer:
A further reason for the sticking is the large scaled spray-drying system itself. A spray-drying equipment of this large scale can only be handled successfully at a very constant density of the liquid, because the correct speed of atomizing unit depends strongly on the density of the liquid and the optimal working conditions (rotations per minute, temperature and air velocity have to be revealed carefully by trial and error methods). Furthermore a large spray-drying equipment needs control by a sensitive electronic steering mechanism for a continous and successful operation, which needs a quick and professional service. Nevertheless, as already mentioned on page 13, such a huge unit is an unsatisfactory equipment for the karkadeh powder production.

Centrifuge:
The missing use of the clarifier centrifuge results in a product of low quality, particularly with respect to the sand content and the presence of cellulose fibre. Some samples of karkadeh powder manufactured at the Babanousa factory in 1992 were analysed at the NATEC Institut and showed a relatively high ash content of more than 13 % in bulk material. The samples were obtained via the most important hibsicus importer in Germany (Alfred L. Wolff). The missing clarification procedure is presumable the reason for the high amount of ash which is normally 8-10 % in the case of highly clarified extract.

After all it became evident that the factory is still workable. But it must be taken into consideration that, besides the principle technological problems with the spray-dryer and other main parts of the factory equipment (e.g. Diesel and steam generator are of old age (28 years), the possibility of a breakdown increases in the near future.

2.2 Technical judgement

Taking into consideration all information which could be important for the production of karkadeh powder from the audit of the Babanousa factory the following statement can be given:

The production conditions and the equipment for the karkadeh powder production instead of milk powder production have to be drastically changed to obtain high quality products.
The production of karkadeh powder is a much more sophisticated process than the production of milk powder and the equipment available in the factory is not optimal for a high quality karkadeh production process.

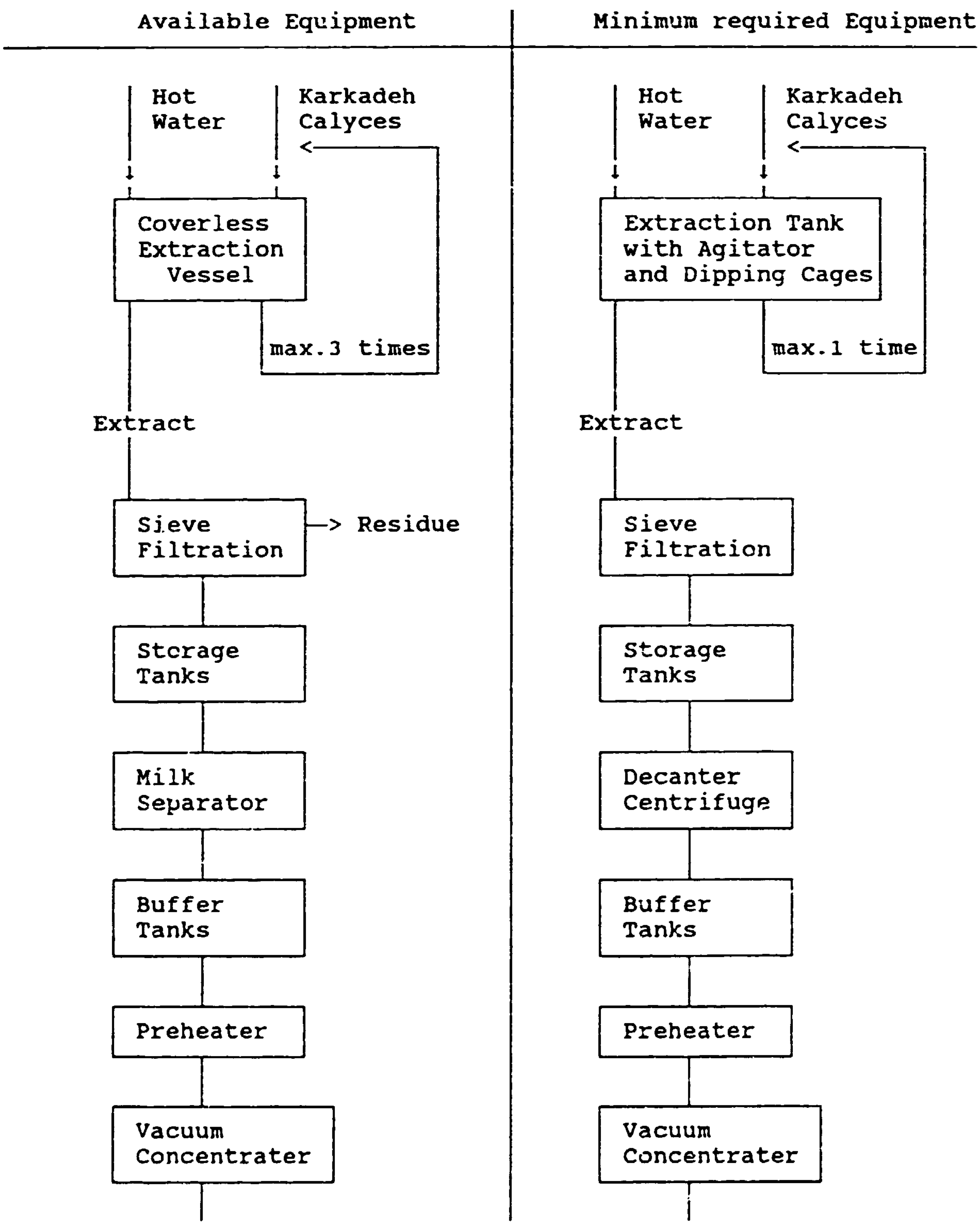
Several parts of the production equipment are damaged and have to be replaced preferably by devices, which are better suited for the karkadeh powder production.

The location of the Babanousa factory is not optimal for the delivery of hibiscus calyces raw material. The infrastructure of the Babanousa area gives some restrictions for a karkadeh powder production to be operated economically.

In the flow chart of page 21 and 22 the present available equipment and course of manufacture at the Babanousa factory is demonstrated in comparison to the minimum required facilities and manufacturing procedure for a standard quality powder production.

Attention might also be drawn to the point that the factory was run in the past discontinuously, partly due to the fact that no money was available to buy raw material or fuel. The reason was that the factory was under the control of the government, which could not spend money for the factory because of other priorities in the national economic interests. No discontinuously running production factory can work very economically but in particular, a sophisticated production process will only be economically successful without interruptions of longer periods of time. Therefore a lot of technical problems have to be solved for the restoration of the factory.

Fig. 2
Flow Chart of
Karkadeh Powder Production in Babanousa



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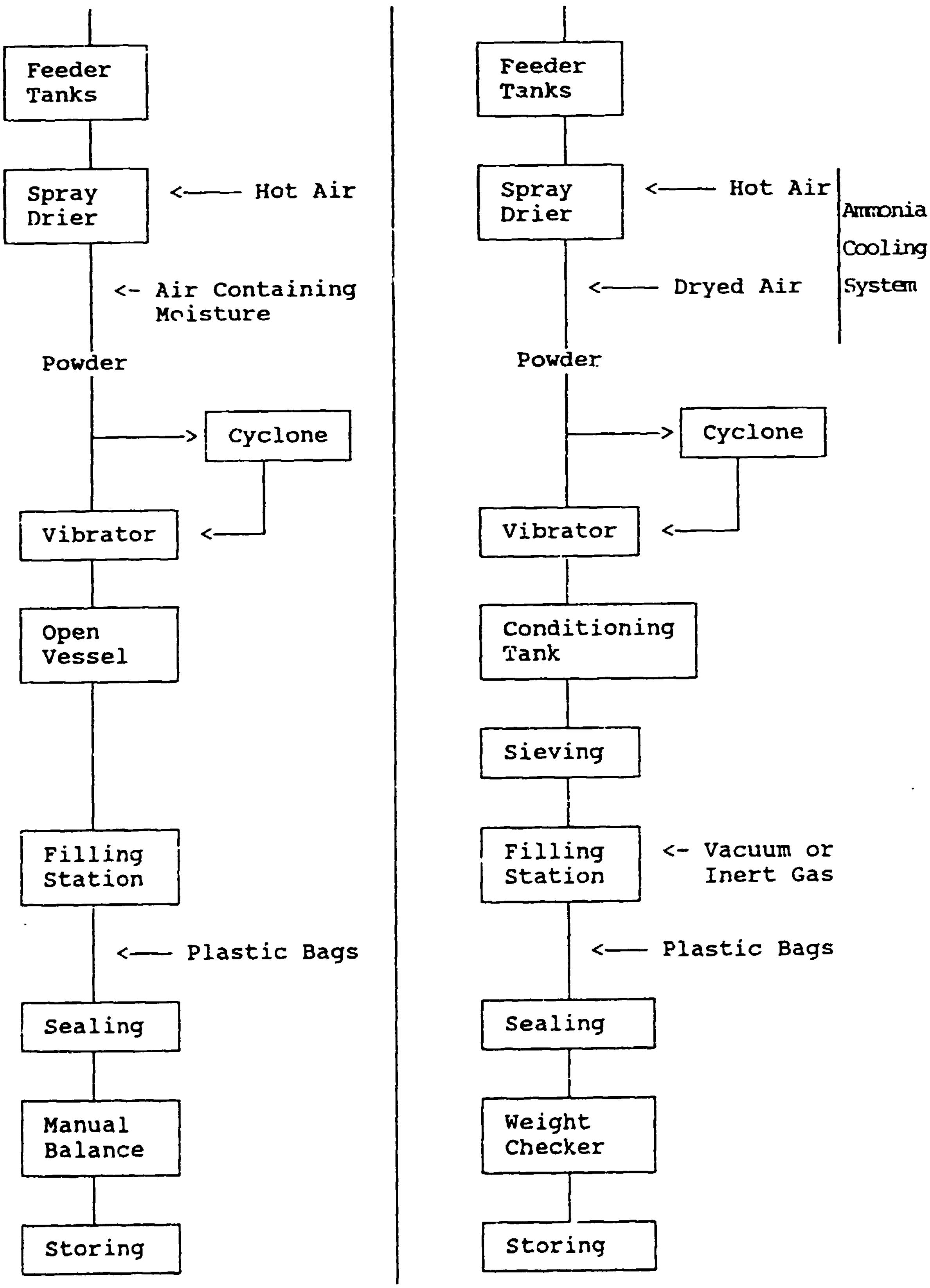
Feeder Tanks
Spray Drier
Hot Air
Air Containing Moisture
Powder
Cyclone
Vibrator
Open Vessel
Filling Station
Plastic Bags
Sealing
Manual Balance
Storing
Feeder Tanks
Spray Drier
Hot Air
Dryed Air
Ammonia Cooling System
Powder
Cyclone
Vibrator
Conditioning Tank
Sieving
Filling Station
Vacuum or Inert Gas
Plastic Bags
Sealing
Weight Checker
Storing

2.3 Production cost

To obtain new and relevant production cost figures, IRCC, Khartoum has prepared a calculation for the production cost of the karkadeh powder production from March/April 1992:

The production costs were calculated per ton of karkadeh powder. The transportation cost of the raw material grown in five major areas surrounding Babanousa was calculated for 1 ton of raw material per kilometer, and it was found to be Ls. 25. The various cost items were calculated as follows:

The raw material:
The raw material cost was calculated based on the fact that the factory produces 2 tons of powder per day from 5 tons of raw dry karkadeh calyces i.e. 2.5 tons of calyces produce 1 ton of powder. The average cost of one ton of calyces at the factory site is Ls. 129,800. Therefore, the cost of raw material needed to produce 1 ton of powder = 2.5 x 129800 = Ls. 324500.

Cost of water for extraction:
Calculation was based on the fact that one ton of raw karkadeh calyces requires 10 tons of water. The cost of 1 ton of water is Ls. 60; therefore the cost of water for leaching 2.5 tons of calyces = 2.5 x 10 x 60 = Ls. 1500.

Cost of water for steam generation:
The cost of water for steam generation was based on the fact that the boiler produces 2.5 tons of steam per hour i.e. 60 tons per day (24 hrs.). Therefore the cost of water for steam generation for the production of 1 ton of powder = 60 x 60/2 = Ls. 1800.

Cost of fuel for boiler:
The cost of fuel for the boiler was based on the experience that the boiler consumes 5 tons of furnace per day i.e. it consumes 2.5 tons of furnace for production of 1 ton of powder.

Cost of fuel for electricity generation:
The cost of fuel for electricity generation was, calculated based on the fact that the engine consumes 1200 kg of fuel per day. According to information from the factory management the engine generates 400 Kwh, while the actual need is 300 Kwh because some parts of the factory equipment are not in use since the factory stopped milk processing.

Cost of lubricants:
The cost of lubricants was based on the fact that the lubricants are changed every 500 hrs. during which period seven barrels of oil are used.

Wages:
The wages were calculated per day and divided by 2 because the factory is supposed to produce 2 tons of powder per day under normal working conditions.

Packing material:
The powder was packed as usual, i.e. 10 kg of powder in one bag. The packing material was already available in the factory from previous seasons. The bags are supposed to be anned in tin cans for export. The overall packing material cost per ton was found to be Ls. 9290.

Product transportation costs:
The powder transportation cost was calculated based on actual freight rates from Babanousa to Port Sudan by railways. The cost for transportation of 1 ton is Ls. 4077.

Storage cost:
The powder is being stored in Khartoum at a cost of Ls. 100 per ton per month. It is expected that the powder will be exported within 4 months after arriving at Khartoum. The storage cost is, therefore equal to 4 x 100 = Ls. 400.

Maintenance:
The maintenance done for the factory before and during the production process costed Ls. 37000. The following Table shows the total cost of production of 1 ton of the powder (f.o.b. Port Sudan).

Table 1

FOB Cost of 1 ton of Karkadeh powder for March/April 1992

No.	Description	Unit of Measurement	Quantity	Cost/Unit	Total Cost Ls.
1.	Karkadeh calyces	t	2.5	129800	324500
2.	Wages:				
	Direct	Ls.	-	-	1963
	Indirect	Ls.	-	-	1417
3.	Water	t	55	60	3300
4.	Fuel & Lubricants	t	-	-	28728
5.	Maintenance	Ls.	-	-	37000
6.	General & Admin. Overheads	Ls.	-	-	1630
7.	Packaging Material	Ls.	-	-	9290
	Total	Ls.	-	-	407828
8.	Taxes 28 %	Ls.	-	-	114191
9.	Factory Commission 15 %	Ls.	-	-	61174
10.	Storage cost	t	1	400	400
11.	Transportation Cost to P.S.	t	1	4077	4077
	Total				587670
12.	Export Tax 5 %				29383
	Total				617053

The present exchange rate (121) of Ls. into US-$ gives 5099.6 US-$ per ton karkadeh powder f.o.b. Port Sudan.
This cost level is in line with the market price of 6000 to 6500 for Sudanese karkadeh powder, but could be reduced by a more optimized processing.
From the above calculation it is evident that wages do not influence the production prices significantly.

3. Restoration and replacement of the factory facilities

The restoration of the factory for an undisturbed production run was considered with regard to the broken or damaged facilities, which have at least to be replaced, and in the light of the possibility to obtain a product of contant quality. Crude offers from equipment manufacturers were collected, but no figures for the installation cost could be obtained for the Babanousa area. Therefore the latter were estimated from experience with other African countries to be in the order of 15 % of the purchase price. - In Table 2 only equipments which have to be replaced at least to keep the factory workable for the next 3 years are mentioned together with the cost for buying and the estimated installation cost.

Table 2

Equipment	Purchase Price US-$	Installation Cost US-$
Steam Generator	75.000	15.250
Clarifier Centrifuge	112.500	16.800
Boiler Spare Parts	10.000	2.000
Spare Parts and maintenance of other equipment	20.000	10.000
Total Cost	217.500	44.050

Total capital expenditure: US-$ 261.550

The steam generator is still workable, but as mentioned on page 14 it is doubtful whether the steam unit can be operated uninterrupted for a longer period of time and a total breakdown is expected in the near future.

The clarifier centrifuge has to be replaced by a decanter centrifuge made of stainless steel. Otherwise the acid liquid will lead to a strong corrosion as happened in the past and the equipment will not be used for a longer period.

Finally, several spare parts for the maintenance of the evaporation system are needed for a continuous run of the whole system. As most of the equipment is of former Soviet Union origin, it seems to be doubtful to obtain spare parts from the original manufacturer. This means, that for a sufficient maintenance some extra money for spare parts, which cannot be predicted exactly, should be available. An amount of 20,000 US-$ seems to be sufficient taking into account that the factory has a very good workshop and can carry out a lot of maintenance thereof.

With the total capital expenditure of US-$ 260,000 to 280,000 the factory will be workable for the production of karkadeh powder for a period of assumably three years under the assumption that the Diesel and all other devices will be still workable in that period. All calculated figures are valid on the understanding that the presently used process for the karkadeh powder production is carried out only with slight deviations from the procedure applied in the last seventeen years.

For a long-term production of karkadeh at the Babanousa factory a drastic change of most of the equipment is necessary. Primarily the large spray-dryer has to be replaced by two smaller units.

To avoid the strong sticking of the powder at the rain period, an ammonia cooling system is necessary. This ammonia cooling system is needed to obtain dry air during the operation at the time of high humidity. It cannot any longer be used after a standstill of more than 15 years and has to be replaced.

A further steam generator has to be installed for an alternating run during production.

A packaging machine has to be installed to avoid the quick moisture uptake of the powder in a period of high humidity. The use of such equipment also guarantees a much better capability of the powder during transport and shipment to Port Sudan.

In Table 3 the additional equipment, which has to be replaced for a longer-term production is collected.

Table 3

Equipment	Purchase Price US-$	Installation Cost US-$
Ammonia Cooling System	128.000	19.000
2 Spray-drying Units	185.000	27.800
Further Steam Generator	75.000	15.250
Filling & Packaging Machine	15.000	2.250
Diesel	200.000	30.000
Total Cost	603.000	67.300

Total capital expenditure: US-$ 676.000

4. Recommendations for the Babanousa factory plant

In view of karkadeh powder production at the Babanousa factory the following main statements can be pointed out:

In 1992 it was shown merely due to the diligence of the staff and the management that the factory is still workable and can be run on a comparable low level of powder production, although some of the equipment is broken-down and cannot be used any longer. The breakdown of further equipment is ecpected in the near future.

In principle the factory equipment can be used for the production of spray-dried karkadeh powder, but most of the equipment is over-dimensionized for a highly moisture and temperature sensitive product like karkadeh powder. This results in an unefficient production of comparable low quality. Beyond this the equipment is with the exception of the spray-dryer of older Soviet Union origin and in a relatively desolate condition.

Management and staff have a lot of skill in operating the facilities and the workshop tools, but do not have sufficient experience in the technology of spray-dried powder products in general.

The calculated production costs for the karkadeh powder production at Babanousa under the present circumstances are in line with the world market price of karkadeh powder in 1992.

The nearness of Babanousa to the some hibiscus sabdariffa growing areas by the railway connection of the town makes it possible to run a karkadeh powder factory at this place. But the long distance to Port Sudan and the slow running railway transport is a big disadvantage for the economic production.

The factory belongs to the Ministry of Industry and therefore the financial situation to buy raw material, fuel, spare parts and make investments is not secured, if other priorities require too much of the Ministry's budget.

Under the above mentioned facts and on the understanding to increase the karkadeh production in the Sudan it is recommended to restorate the Babanousa factory only for an interim period of time for a powder production and to install new smaller factories step by step for a karkadeh production, which from the technical and economcal point of view could be run more effective (see page 70 of Part II of this Report).

In the first step a restoration of the necessary equipment for a not optimal but reasonable economic condition is necessary to keep the factory workable for the next three to five years. The capital expenditure for the replacement and restoration of the presently available equipment is 260,000 US-$. With this investment cost the factory equipment will enable the existing staff to manufacture about 40-60 tons of karkadeh powder per anno. The factory staff and the staff for new factories can be trained in place during this period to become more acquainted with the requirements to run the facilities for a high quality karkadeh powder production. But they should also have a special training at the manufacturer of the spray-drying equipment (NIRO).

It should be pointed out that the geographical position of the Babanousa factory and the circumstances to life there, may become an obstacle for ingenieurs and installation staff of the equipment manufacturers to come to that place. At present none of the contacted equipment manufacturers was willing to talk about business travelling and travel cost for the assembling of the equipment and for any training in place.

Therefore the training of persons of the staff at the equipment manufacturer seems to be a suitable solution. At the beginning of such training with two persons is already included in this project in foreseen to be arranged in the early 1993.

PART II

SECTOR ANALYSIS OF KARKADEH PRODUCTION IN SUDAN

1. Agricultural aspects and raw material manufacturing

1.1 Growing areas for hibiscus sabdariffa

1.1.1 General view

A map of the Sudan State is given in Appendix II. The total area of the Sudan is 2.505.813 qkm or 967.500 square miles[1]. This area is about 7 times as much as that of the Federal Republic of Germany. The population is according to the statistical data of 1991[2] 23.4 mio people with a main population density per square kilometer of about 9.

The country consist very roughly of three physical and vegetational areas according to the general climatic conditions (see sub-map of Appendix II). From the Northern political frontier to Egypt at 22. degree latitude to the 16. degree latitude with the exception of the East coast area and the area near the Nile River, the whole country is a dessert area. This region is followed from the 16. degree of latitude to the 10. degree of latitude by a savannah area with 200 to 1.000 mm of rain presipitation. This region is a main area where hibiscus sabdariffa is grown. From 10. degree latitude to 4. degree latitude - the latter is the South political frontier of the Sudan - a topigraphical higher area with wood, jungle and swampy grounds exist with rainfall of more than 1000 mm p.a.

Along the River Nile which is running through the country from the South to the North, a strip of about 30 km in latitude is an irrigated area, beginning at the 10. degree of latitude at Malakal down to Wadi Halfa. Only in the region South of Khartoum to Wad Medani the irrigated area is somewhat broadened because of the split of the Nile into the White and

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1) International Atlas Rand McNally & Co, G. Westermann, Kummery & Frey (1981).

2) International Statistic Date of world population, Rand McNally & Co (1988).

Blue Nile. The latter is coming more from the East. Hibiscus sabdariffa is grown until now in the irrigated area only near Wad Medani.

1.1.2 Natural rain-fed areas

Until now the most of karkadeh plant cultivation is mainly by rain. The major growing states are Kordofan and Darfur States, where karkadeh is grown as a minor crop (intercropping with other major cropy like sorghum, millet and sesame). There are no available statistical data for production in Darfur State.

The major producing area in As-Salam Province is Al Miram area which is the seventh railway station to the South of Babanousa at a distance of 133 km from it. This area is usually not affected by drought compared to other areas in Northern Kordofan State.

As mentioned above karkadeh in these areas is not cultivated solely in the farms, but as a minor crop (intercropping), this is why the figures of production and productivity in Table 4 are very low. On the other hand the figures of harvested areas are also low, and sometimes very low, compared to the cultivated areas because in some areas the rains were not enough for the plant to produce the flowers, and hence the harvested areas is low.

There are other four important but less major karkadeh growing areas which supply the factory with the raw materials, namely:

a) At-Tiboun: The third railway station to the West of Babanousa at a distance of 60 km from it.

b) Adeela: The fifth railway station to the West of Babanousa at a distance of 90 km from it.

c) Abu-Zabad: The tenth railway station to the North-East of Babanousa at a distance of 200 km from it.

d) Um Chak: Lies to the North-East of Babanousa at a distance of 38 km from it. It is linked with Babanousa by sandy road.

The first two areas (a & b) belong to Ad-Daen Province in Southern Darfur State. Abu-Zabad belongs to An-Nahud Provice in Northern Kordofan State, while Um Chark belongs to As-Salam Provice (see map Appendix II). The latter two areas are less productive at present.

According to information of the Babanousa factory management at the biggest export-crops market at El Obeid considerable amounts of karkadeh calyces were brought to the market from Southern Darfur State in the year 1991/92. This area is linked with Babanousa by railway from Nyala (see map Appendix II).

From the foregoing Babanousa town is an important centre for the rainfed karkadeh-growing areas. Its nearness to the major growing areas reduces the cost of transportation of the raw material which has much void volume when packed intact in the sacks.

Babanousa is located near to the Northern border of the Kurdufan savanne area. The factory is situated very close to the place where the railways coming from the two directions of Nyala in the West and Wau in the South meet each other. The rail is going to the North-East to Khartoum and Port Sudan.

In the peripherie near to Babanousa no motor way or asphalt road is available for a material transportation without difficulties.

The area where hibiscus sabdariffa is grown is at least 50 miles away from the Babanousa plant. The main areas for hibiscus sabdariffa plants grown at farms are distributed over an area of 50.000 squaremiles in Eastern and Southern direction of Babanousa. Therefore, the delivery of raw material for the production of karkadeh powder at the Babanousa plant is rather complicated and not very economical.

1.1.3 Irrigated areas

It is the policy of the Sudanese Government - within the exports promotion programme - to expand cultivation of many crops including karkadeh.

The appropriate areas for expansion in the existing irrigated agricultural projects are the "Gezira Scheme" South of Wad Medani in the Central State, and "Rahad Agricultural Corporation" East of Wad Medani in the Central and Eastern States. These two areas favour the choice of Wad Medani, the second largest city in Sudan, as a suitable place for establishing a new karkadeh processing plant. The city is linked to the existing irrigated areas - as well as their proposed extensions - and also to Port Sudan by railways and highways. The infrastructure for industry in the city is good. There is a university with well-equipped laboratories and a department for food science and technology.

According to items which appeared in a local newspaper (10 August 1992) arrangements are being made to grow karkadeh plant as a pure crop this very season in an area of 11000 (eleven thousand) feddans in the irrigated area near Al Gegar in Ar-Rank Province in North of Upper Nile State (see map Appendix II). Both Al Gegar and Ar-Rank lie on the now being constructed highway which links Khartoum with Malakal (capital of Upper Nile State), Juba (capital of Equatoria State), and Uganda. According to the same source karkadeh cultivation in this area is financed by the Saudi "Wadi Sagr Fatima Company". The area to the South of this area is rain-fed, and it is usually not affected by drought, so extension is possible.

1.2 Estimated crop yield

There is little known about the total crop yield in all areas of the Sudan. The following Table 4 shows the cultivated and harvested areas, as well as production and productivity in the different provinces of Kordofan State in the last season 1991/92.

Table 4

Karkadeh production in Kordofan State in the season 1991/92*)

Area - Feddans: One Feddan = 4200 Sq.metres = 0.42 Hectare
Production - Tons
Productivity - Tons/Feddan

Province	Cultivated area	Harvested area	Production	Productivity
Ad-Dalan	14036	7712	63	0.008
Rashad	-	-	-	-
Kadugli	-	-	-	-
As-Salam	22592	21927	2059	0.93
Sheikan	40854	2105	3	0.0015
Um Ruwaba	130910	26278	197	0.0075
An-Nahud	65069	41279	543	0.013
Bara	4203	-	-	-
Sodari	-	-	-	-
Total	277664	99301	2865	0.028
			Productivity/harv.area	

*) Source: Agriculture Statistics & Economic Dept.
Ministry of Agriculture, Khartoum, Sudan

Table 4 shows that the highest production (72 % of the total amount of karkadeh calyces), and also the highest productivity (0.93 %) were those of As-Salam Province in Southern Kordofan State.

The lastet issue of the Foreign Trade Statistical Digest issued by the Bank of Sudan (December 1990) showed that the quantity of karkadeh calyces exported during 1990 (January - December) amounted to 12.217 (twelve thousand, two hundred and seventeen) tons. If this quantity - which is produced mainly in the rain-fed areas - is processed locally into powder and then exported, the revenue is expected to be very much higher. This quantity would give about 4880 tons of powder.

1.3 Harvesting procedures

The general view of the different possibilities of production and processing of karkadeh in the Sudan includes several aspects. The flow chart of page 38 demonstrates the principal passways, which have to be taken into consideration.

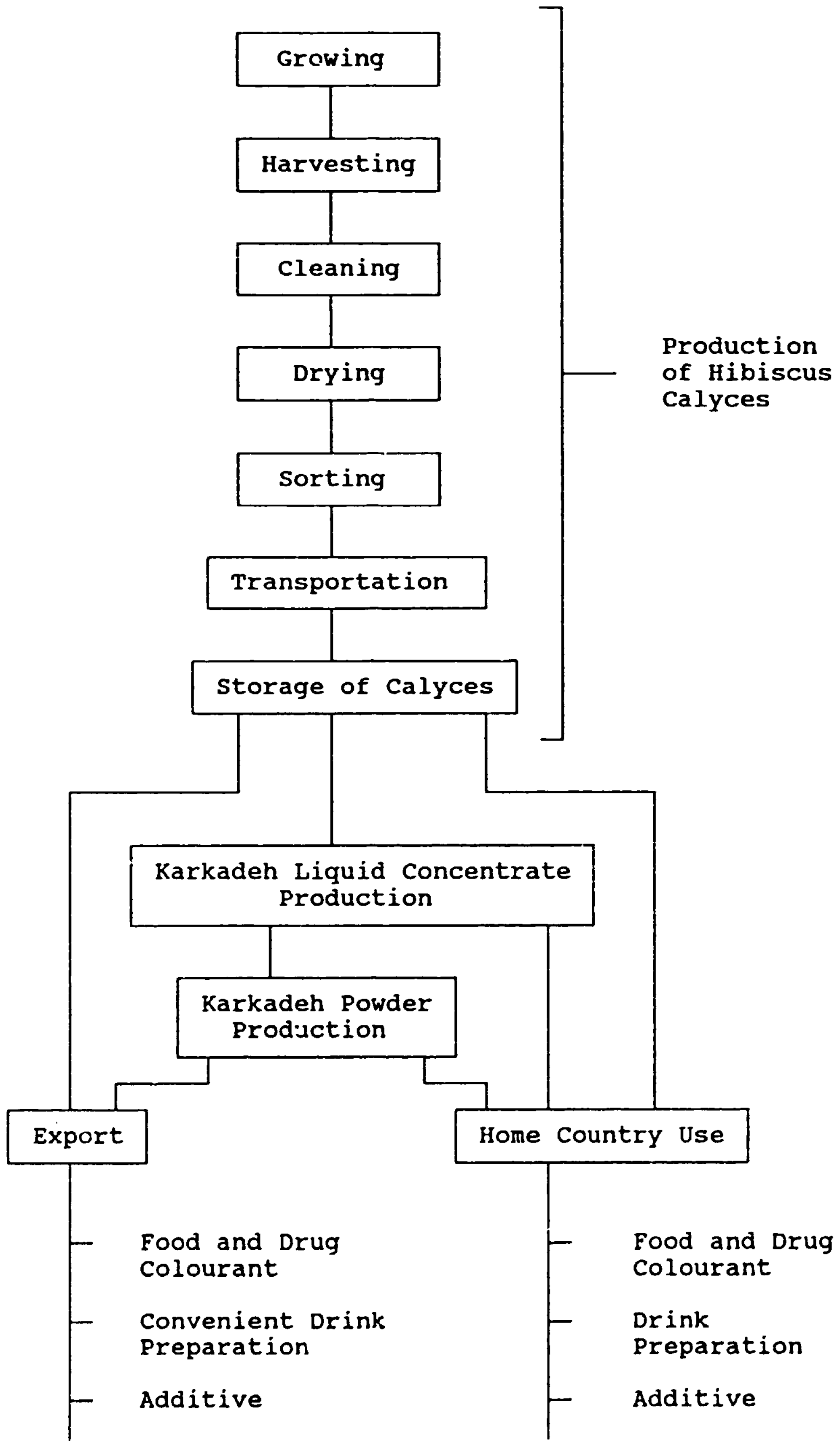

Fig. 3 flow chart of the possibilities of Karkadeh production

1.4 Cleaning of raw material

To avoid too much unwanted materials in form of sticks, capsules, seeds, leaves, sand and other crops, which are present in the harvested material, hand picking is the most appropriate procedure of collecting the calyces. Nevertheless, during harvesting or drying, several amounts of unwanted materials will be present in the harvested material. It is therefore necessary, that some cleaning procedures have to be applied to the raw material before extraction is started. Otherwise the quality, particularly the stability of colourant the final product will seriously be deteriorated. The reasons are as follows:

The presence of metal ions particularly iron, copper, and manganese may cause fast deterioration of the colour during extraction and storage of the final product, because they catalizes an anthocyanin oxidation process. Such metal ions are present in dust, sand, soil, plant sticks and crops.

In the European and United States legal requirements for colourants to be used for foodstuffs, cosmetics and particularly drugs, an increasing demand for the avoidance of by-products is recognized. Therefore, care for impurtities should already be taken in the earliest product step of production.

To overcome this problem besides a manual picking out of visible large unwanted crops, sticks and leaves riddle seeving should be applied with the dried raw material before extraction. Whether any centrifugial air classifier or separator may be used for cleaning and separating the raw material into fractions will be of any advantage in the karkadeh production seems to be doubtful. Conventional cyclones are comparably sophisticated equipments and will have no positive effect on the classification, because the different shape and dimension of the calyces and the impurities, which may be catched during harvesting and therefore, no raw material with significantly less impurities or better classified products will be obtained. Nevertheless, it should be taken into consideration that a cleaner and better classified raw material contained by simple sieving or cleaning system would improve the quality of raw materials provided for export.

In Table 5 the analysis obtained from 5 kg of dried calyces of Sudanese origin obtained by manual selection and the result of an extraction test carried out in the laboratory of the NATEC Institut is shown as an example. The relatively high amount of unwanted plant material may lead in the extraction procedure to an unacceptable amount of by-products. The amount of dust and sand was less than 0,1 % by weight and will not give rise to too much problems, if the extraction procedure and the centrifugial separation is carried out quickly.

Table 5

Hand separation of hibiscus sabdariffa calyces, Sudanese origin, and total water extraction test

raw material dried hibiscus calyces	in grams	in %
total material	5000	100
water content	400	8
hand separated impurities	145	2,9
sticks	15	0,3
leaves	--	--
seads	60	1,2
others	70	1,4
total extracted material	750	15
sand	3	0,1

2. Factors affecting the quality

2.1 Weathering conditions

Besides particular legal requirements, which are based on health aspects, the quality of karkadeh powder is mainly determined by the flavour and colour.

The generation of colour and flavour in the flowers of hibiscus sabdariffa depend in a complex way on the weather conditions during growing of the crop. Crop growing under test condition generates flowers with a stronger flavour and higher intensity in colour, and it is found calyces of hibiscus sabdariffa grown under ideal weathering conditions.

For food additives and drugs prepared of agricultural materials the quality of the manufactured product depends not only on the production technology, the correct use of the manufacturing equipment and the optimal processing conditions, but also on the cultivation of the plants and on the harvesting conditions of the respective material.

Several studies exist concerning the plant growing conditions, the influence of fertilizer on the growing as well as on the yield of flowering and the cultivation of plants in different areas and breeding selection for new varieties (Lit. 30, 33, 40, 41, 47, 63, 64, 66, 67, 69, 70). From these field and greenhouse experiments carried out in the period of 1980 to 1987 in Nigeria, Thailand, Egypt, and West-India nearly all necessary information for a delection of the optimal hibiscus sabdariffa variety, the optimal sowing-time and the most effective cultivation of the plants with the highest yield of calyces can be obtained. Climatic conditions and influences on the growing of hibiscus varieties are described in (Lit. 12, 13, 25). More details are given in the literature review (Project Report, Part I, issued November 1990) on this project.

Investigations concerning the optimal harvesting conditions of calyces are reported in several extensive greenhouse studies by E.R. Khafaga, and H. Koch in 1980 (Lit. 36, 37, 38, 39, 40). They investigated the optimal harvesting time for the calyces of five hibiscus sabdariffa strains from Egypt, Senegal, India, Thailand, and Central America. The optimal harvesting time is reported to be 30-50 days after the flowering with a slight deviation in the different investigated strains. The maximum content of anthocyane, organic acids, and polysaccharides was used as a basis in the ripening period for the optimal harvesting time.

In the same study the influence of ripening period and the best way to dry the calyces was investigated. It is clearly shown in these studies that the content of the precious components, particularly the anthocyane, is four-times as much at the optimal harvesting time as at the beginning or the end of the ripening period.
From what is published in the literature and after discussion with boternists of the German university of Göttingen and of Khartoum the following statement about the plant growing selection and harvesting of calyces from hibiscus sabdariffa can be made:

No drastical change from the anthocyanins and fruit acid content of the calyces can be obtained by the particular influence of fertilizer. Nevertheless, the optimal soil condition should be revealed in the different growing areas for hibiscus sabdariffa in Sudan to obtain a strong flowering for the different varieties of hibiscus sabdariffa plants.
Genetic selection of optimal flowering plants can only be done in plant growing test over a period of several years. Any effort in selecting plants particularly suitable for automatically harvesting cannot be of large economical advantage and will finally only lead to a raw material of low quality.
The optimal harvesting time for all types of hibiscus sabdariffa calyces is 30 to 50 days after the flowering. It is strongly recommended to convince the farmers to keep the whole harvesting procedure within this period of time.

Immediately after harvesting the plucked calyces are normally dried in the sun at all hibiscus sabdariffa growing areas in the Sudan by spreading the calyces in more or less thin layer on the ground. This is a simple procedure, but has the disadvantage that sand and dust is coming into the calyces and that a high amount of the anthocyanin colour is destroyed by the UV-light of the sun. A much better procedure for drying on the fields or farms is to store the flecked calyces on grids 30 to 50 centimeters above the ground covered by a sunshade manufactured of dark coloured polyethylene or polypropylene films.

The advantage of this procedure is to keep out high amounts of unwanted impurities in comparison to material dried directly on the ground. The black film gives protection to the calyces against the sunlight and raises the temperature of the material and therefore shortens the drying period.

Black coloured polyethylene or polypropylene films will not be stable for more than 1 or 2 seasons, but the films prepared from recycled plastic materials will become more inexpensive, because it is appreciated very much to find further uses for recycled plastic materials from packaging waste in West-European countries.

2.2 Manufacturing procedures

General view:

Only very few papers have been published dealing with the production and stability against temperature and moisture of karkadeh as a final product. The results for the reconstruction characteristics of spray-dried karkadeh prepared with different polysaccharide encapsulating agents are reported (Lit. 1). In this study it is shown that the product with the lowest moisture sensitivity could be obtained by using gummi arabic as an additive for encapsulating. But some difficulties with the wetability and the flowability of the product have to be overcome. The paper of Main et al. (Lit. 44) deals with the spray-drying of anthocyanin concentrates for the preparation of food colourants. In this paper the outlet temperature of the spray-drying air was found to be below 90°C as the highest temperature which did not give large degradation of anthocyanin.

In a paper of Nour (Lit. 50) the stability of the red colour of karkadeh in jam and squash is reported to be stable for 3-4 months at room-temperature and 45°F. Huang (Lit. 27) investigated the decolourization of anthocyanins by fungal enzyms and showed that a drastical decolourization takes place at a pH-value higher than 3.5 within a short time.

The most important information for the stability of karkadeh was found in the five papers of Khafaga et al. (Lit. 36-40), in which the optimal harvesting conditions for the calyces and the best drying conditions have been studies systematically in view to keep the product defining components as high as possible. In the manufacturing process during extraction, evaporation and drying procedures, a loss of flavour and colour cannot be avoided. But optimal extraction times low evaporation temperatures and optimal times for optimal temperatures for the spray-drying process, a desisive deminish a loss of quality. Therefore it is important that the manufacturing equipment is of the right dimension, and the process conditions have to be optimized and carefully kept within the limits which have to be revealed experimentally.

The karkadeh powder production starts with the extraction process and ends up with the packed powder. The ideal pathways and processing steps of a modern karkadeh production are given in Figure 4. The flow chart shows all important steps to manufacture a high quality product. On the following pages the different steps and problems are discussed in detail.

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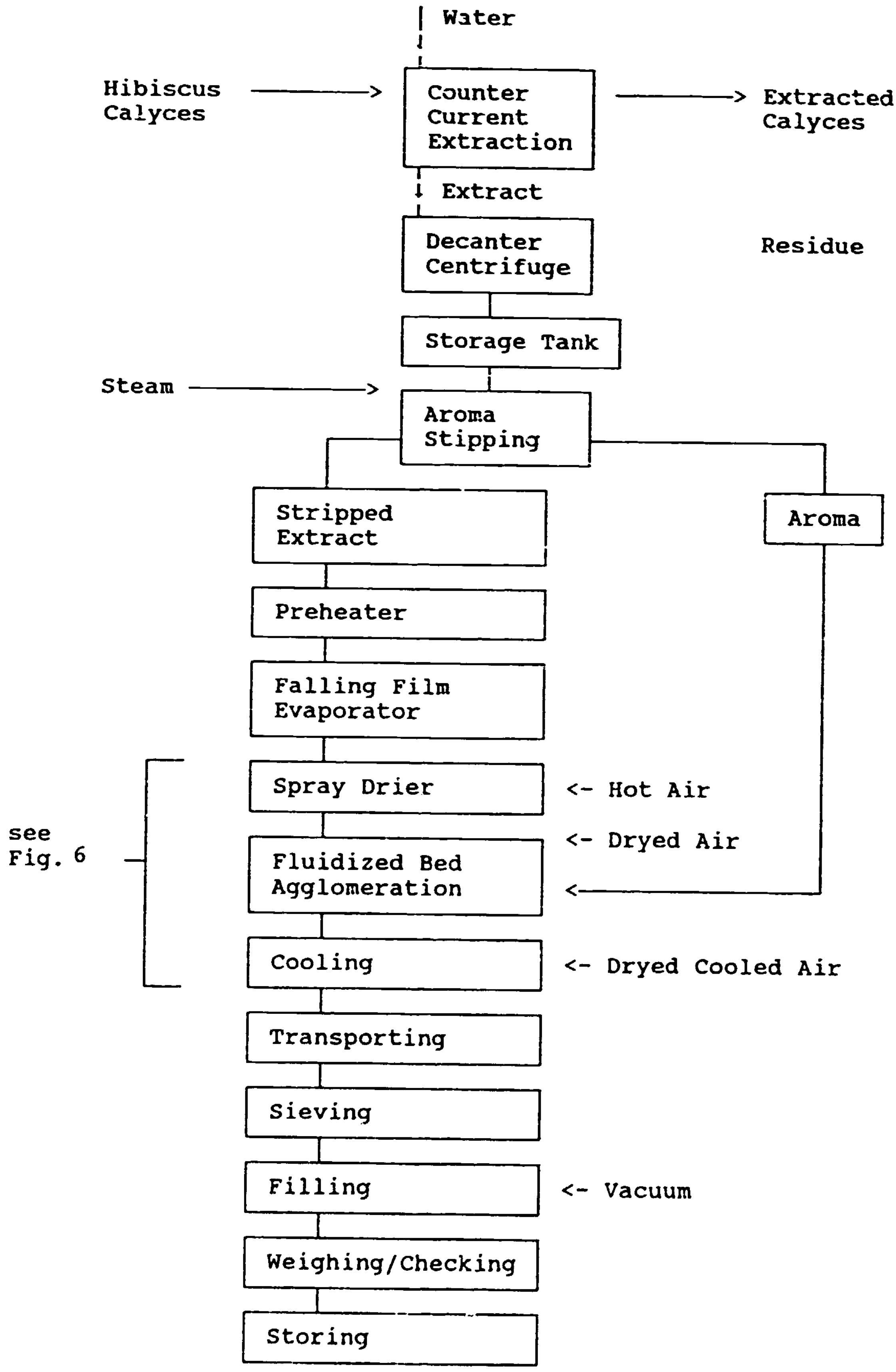
Fig. 4
Flow Chart of
Modern Karakadeh Powder Production

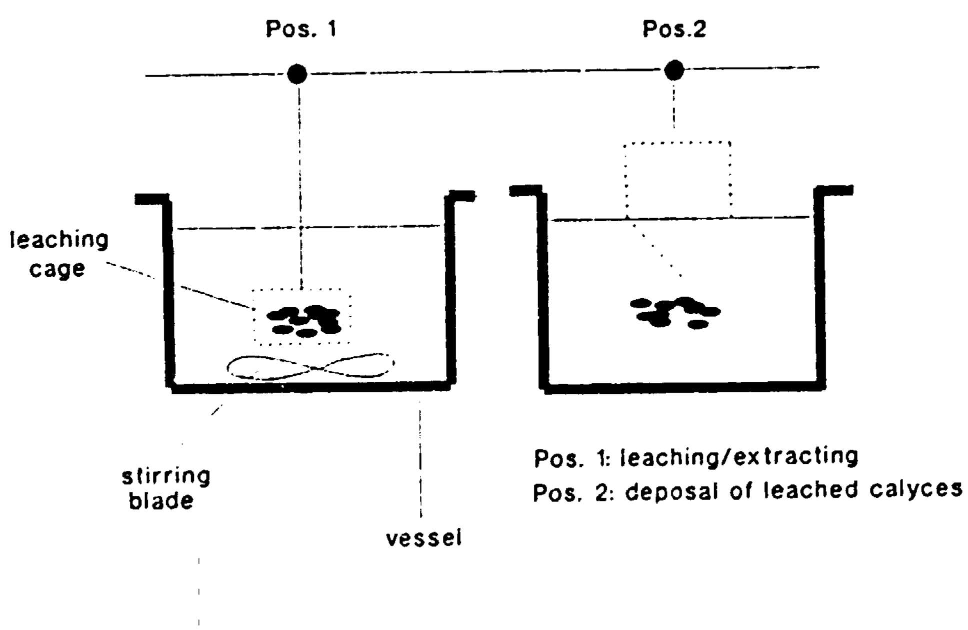


Extraction (leaching):

The most appropriate way for the extraction procedure contains the idea of percolation, which means the extraction of the soluble constituent from the solid material by means of a solvent. It is known from the literature and from own experiments, that the most important components which have to be extracted from the dried calyces, exhibits a good solubility in hot water. There is no doubt that the most appropriate technique for getting the highest leaching efficiency would be to use devices for a continuous extraction. But devices like the Hildebrand-Extractor or similar equipment, as is offered e.g. by Riniker AG and Extraction Technique AG are proveded with sophisticated controlling systems and are very complicated to run. The idea of cheaper device, which may be constructed extemporary from available facilities should therefore taken into consideration at places, where technical support in repairing and handling the equipment cannot easily be obtained. To achieve on the one hand short extraction times and to avoid on the other hand high amounts of water, which has to be removed in an energy consuming process afterwards, the total leaching procedure should be carried out with dipping systems using vessels with an agitator system. A possible construction is given in Figure 5.

Fig. 5

Extraction Device - Dipping Technique



From laboratory experiments using five liter glass vessels, ceramic dipping cages and a normal laboratory agitator (Jahnke & Kunkel) with 120 protations per minute, more than 90 % of the total extractable matter in comparison to an entire Soxhlet extraction was obtained after three dipping periods of ten minutes. The extraction temperature was 80°C. The amount of calyces extracted in the cage was 200 g. The amount of used water for the three conscentive extractions and the total dry matter received after evaporation of the water is shown in Table 6.

Table 6

Laboratory extraction test of hibiscus sabdariffa calyces Sudanese origin

matter used in the extraction test		obtained extracted matter in % of the total extractable matter *)	
200 g calyces	water	test No. 1	test No. 2
first extraction	2 1	57	53
second extraction	2 1	25	27
third extraction	1,4 1	12	11
		94	91

*) The total amount of extracted matter was determined by 6 hours Soxhlet extraction with water at 80°C.

Immediate further processing of the extract will result in a more colour stable liquid and final product. Before concentrating the extract should be cleaned from larger raw material particles by a riddle in the first step. For the separation of the relatively low amount of about 0.5 % to 2 % of solids or colliode particles a stainless steel centrifuge, as manufactured e.g. by Alpha-Lavalle or Westfalia, would be the most appropriate equipment. Such a standard separator cannot be operated economically with feedlickers containing more than 1 % of suspended solids unless some form of automatic sludge discharge is provided. The solids with several percent of humidity inside the operators must be removed periodically. This opening of the bowl and scraping out the sludge is a time consuming process. Therefore, this type of work cannot be recommended in the case of larger batches to be handled in one shift. The most appropriate equipment, which is easy to handle and can be used in a continuous process, will be a decanter centrifuge, delivered by Alpha Lavalle or Westfalia in several standard sizes.

Concentration of extracts:

To obtain extracts, which are suitable for a spray drying process, the diluted liquid has to be concentrated by an evaporation process. It is very important in this process not to destroy too much of the extracted material particularly the anthocyanins. This means that a short hold up time of the product in the evaporator is essential.

The optimal equipment to achieve such short heating times is the falling film evaporator, in which the liquid is distributed down the inside of vertical heated tubes by some form of patent distrubiture. The limitation on the concentration possible obviously occurs with this type of equipment when the product starts to solidify in the lower part of the tube. Only a small preheating unit is necessary, because of the very efficient evaporation rate of this type of evaporator.

Heat sensitive liquors are being handled also very effective in the Butlovac evaporator. In this construction, the quantity of liquid in the evaporator is minimized and hence reduces the likelihood of spoiling the product. Nevertheless, any multiple effect vacuum evaporator which are the most common used simple designed equipments could be used, but when comparing the economics of the different equipment it is of interest to note that the latter one will show the highest steam consumption and the strong temperature treatment of the product therefore will result in a larger spoiling effect.

Spray-drying:

The most appropriate method to obtain materials in form of powders from a high concentrated liquor of heat sensitive products is the spray-drying process. The spray-drying of hibiscus sabdariffa calyces extracts on laboratory or pilot plant scale are describes in the literature.*)

Nothing is reported in the literature on the industrial manufacturing of karkadeh. In most of the papers dealing with the spray-drying of karkadeh the moisture sensitivity of the obtained karkadeh powder is said to be responsible for problems with sticking of the powder in particular to wall of the spray-dryer equipments. In private communication with several professional manufacturers of dried fruit powders and other sugar and polysaccharides containing instant powders, it was pointed out that they have carried out a lot of trials with karkadeh extracts. It was mentioned that the problem of sticking could be overcome by using the right spray-drying conditions. No details about the spray-drying conditions could be obtained because it is not in the interest of a manufacturer to give agway technical know-how. From the revealed information it cannot be excluded that not the high moisture sensitivity but the low pH-value of the liquid attaches the surface of the dryer wall and a slight corrosion will cause the sticking of the product. Own laboratory trials with a Büchi spray-dryer consisting of glass, did not show any sticking of the powder.

The sticking of the product on the wall of the spray dryer is followed by two further problems: **The heat sensitive product will be destroyed after a short period of sticking.**

After some hours of sticking the partly burned material cannot be removed from the wall by a simple water washing process.

It is therefore of high importance that sticking of the product must be

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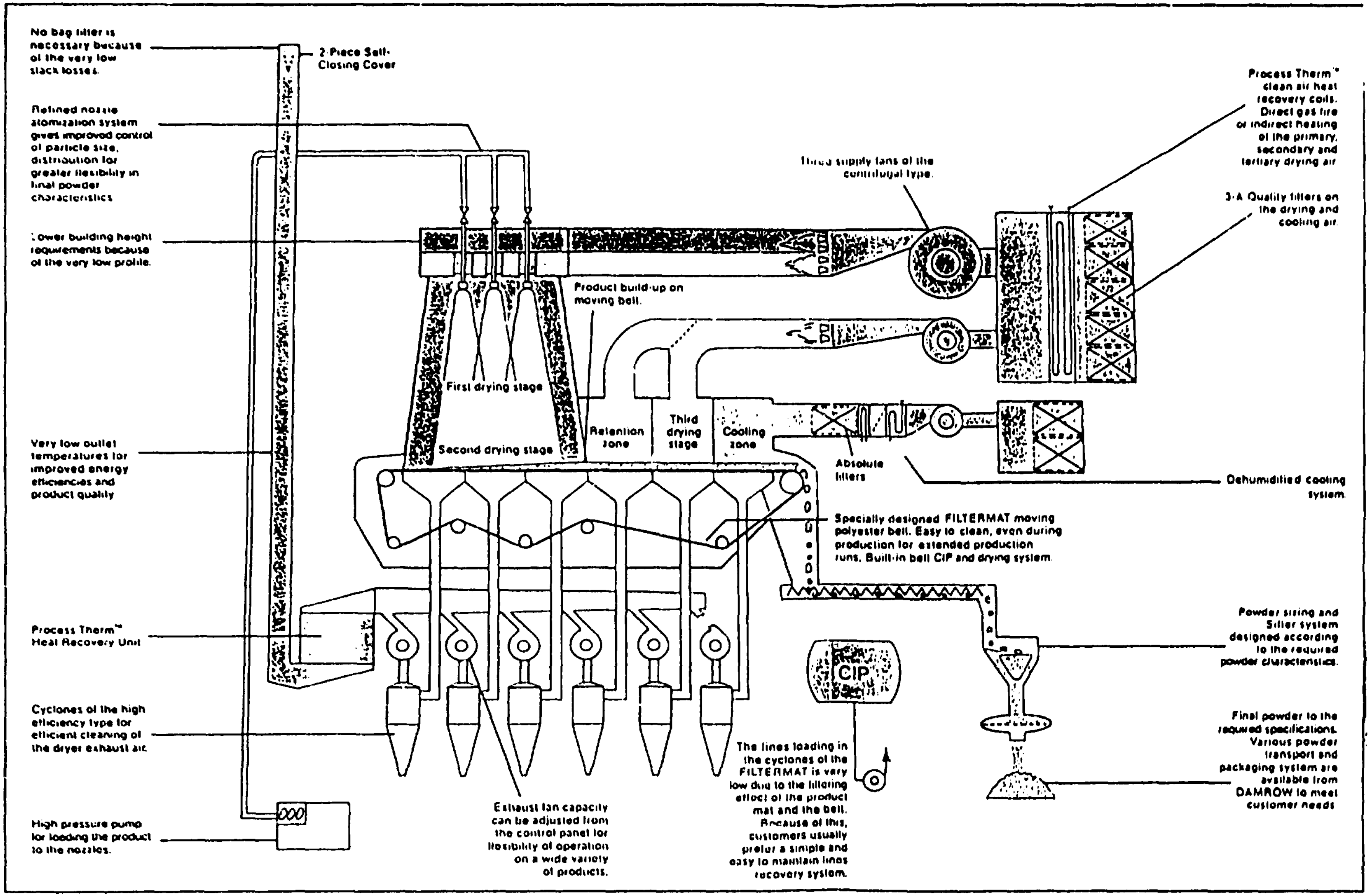
*) see Lit. Rev. Project Report Part I, issued Nov. 1990, in this Project and Hassen A. Alkhantani et al., Journ. Food Sci. 55 (1990), p. 1073

avoided carefully by elaborating a special spray-drying condition, which is different in all the parameters for any spray-drying system and cannot be predicted from laboratory results or from results obtained in tests with a different spray-drying system.

The product obtained in the normal spray-drying process may contain too high amounts of fine grains or do not have at all the right grain distribution. It may also contain inhomogenius or a too high water content. A further water reduction or agglomerisation of the powder may be then obtained by using a second step a fluidized bed drying. Such a process may be used with a separate equipment step or can be carried out in a combined equipment given in Figure 6. Such equipment is delivered by Damrow, Denmark, and is used successful at several instant powder manufactures. Because of the high cost and the sophisticated stearing mechanism it is without doubt that this equipment could not become a suitable production facility in the Sudan in the near future (see page 64).

The powder processed in the dryer has to be cooled and moved with a pneumatic air system towards the dust separator and to the packaging station. Because of the high moisture sensitivity of the product it is of high importance that the air used for the powder transport through the pipes to the dust separation cyclone and to the packaging and filling station should be sufficiently dried. In the Damrow equipment mentioned above, the air-drying system for the fluidized bed drying step and the cooling of the powder is already incorporated in the total layout of the equipment.

If a separate air-drying system is applied, any cooling system, particularly any high or low pressure evaporating or absorption ammonia system may be used to dry the air before it enters the transport pipes and the dust separator. The air of the pneumatic transporting system should not contain more than 15 % rH at 25°C. This requirement can easily be achieved by the above mentioned air-drying systems and will diminish the sticking and lumping of the powder.



- Figure 6 -

Three-Stage Spray Drying System

2.3 Packaging and storage

Karkadeh powder qualities are also influenced by the storage conditions. Oxigene and moisture have to be avoided during storage as good as possible. Microbiology activity and chemical reactions with oxigene can cause changes of flavour and the growing of fungies and other microbes in the product.

To achieve a stable and sufficiently storable product for the different applications in the Sudan as well as for export, produced karkadeh powder has to be protected against moisture uptake immediately after processing and over a long period of storing. Therefore, immediate packaging of the product is necessary in the factory. Unpacked products should not be stored in the filling station for a period of more than 30 min. The store tank and the filling equipment should be tightly closed and covered with at least predried air to avoid high moisture uptake of the product.

The packaging material has to fulfil the following requirements:

a) Protection against moisture for a period of several month under the usual transport and storing conditions e.g. shipment by lorries and seatransport under tropical climatic conditions.

b) No component of the packaging material, which is said to give health problems, should migrate into the product during the whole period of storing and shipment of the final packed product.

c) The final pack should be easy to fill and to close.

d) The packaging material should always be available and of low costs.

A very comfortable packaging, which fulfils the requirements mentioned under a), b) and c), are inside lacquered tin cans. These materials are expensive and not always available, particularly in the Sudan they are costly and rare. A much better solution would be to use extruder blown polypropylene bags, which can be supplied in form of tubes. Using a sufficiently strong heat sealing and cutting equipments it is possible to form bags from such polypropylene tubes suitable for transport on pallets and shipping containers. A sufficient moisture protection is obtained with the thickness of polypropylene films is in the range of 150 to 175 um. The water vapour permeability of a 5 kg polypropylene sack of this thickness will not allow an uptake of moisture by the product of more than 1 g per month. This is valid on the understanding that a totally closed sealing of the bag is obtained in the filling station. The latter requirement can easily achieved by the use of several heatscalling equipments supplied e.g. by Hamog UK, Brugger, Germany.

3. Product uses

Since a long period of time karkadeh is used for drinks and beverages. The dried calyces are widely used for the preparation of teas consumed with hot and cold water. Karkadeh powder manufactured from water or alcohol extracts of the calyces is used for refreshing drinks and beverages in many moslemian countries in the world and recently in a growing amount in the United States and West-European countries. Because of the loss of natural flavours during the extraction procedures drinks and beverages of karkadeh are often besides the addition of sugar used with additional natural or artificial flavour components.

Another important application of karkadeh is its use as natural colourant for industrial manufactured foods. Particularly in the presently growing tendency in the food industry to turn away from synthetic colourants the use of natural red colour is of growing importance. Jams, jellies, weeds, sausages, refreshing drinks, cakes and other industrual manufactured foods demand for growing amounts of natural colourants, which should easily applied. The latter requirements are properly fulfilled in the case of karkadeh powder. The colourant stability of the anthocyanins is preserved by the presence of food acids and the dilution with the polysaccharide by-component makes the dosage easier in comparison with a pure anthocyanin colourant.

3.1 Product requirements and specifications

Modern food manufacturing is bound to a lot of regulations and requires to be carried out within a tight quality assurance system. This means that a lot of specifications have to be fulfilled for any ingredience which is used for industrial manufactured foods.

This means that both, raw material as well as manufactured powder or any concentrate of karkadeh, has to fulfill general requirements implemented by the national and international health authorities in the food regulations. Some special requirements, which depend on the particular use of the product have to be agreed in trading contracts. These requirements have to be fulfilled particularly for export into West-European countries.

The legal requirements taking into account also safety and health aspects differ somewhat from nation to nation. A summary of the general requirements valid in the EC and the most other European countries as well as in the United States, Canada and Australia for a food additive (food colourant) is given in the list on the following page:

Maximum limits for contaminants

	(mg/kg)
- cadmium	0.1
- mercury	1
- selen	0.5
- thalium	1
- aresen	5
- lead	10
- antimone	1
- polycyclic aromatic hydrocarbones	0,001
- aflatoxines	0,004
- organochloropesticides	0,1

Regarding the raw material (calyces) only:

- acid content
- extractable amount of colour
- sand
- total ash
- water content

has to be agreed for the delivery in case of export.

The parameters for the specification of a powder product should therefore contain at least:

- bulk density
- solubility in water at 20°C and 50°C
- transparency
- colour at nm
- acid content
- grain distribution
- wetability
- ash
- heavy metal content

Methods for the determination of the legally required aspects are standardized for the United States in the FDA-regulations and are presently in discussion for the European Community in the CEN-group. Definition of a lot for delivery and sampling is not defined precisely, but should be done in accordance with the gernal rules pointed out in the Codex Alimentarius as well as in the standards of food sampling in the FDA-regulation as well as in the CEN-documents.

4. Infrastructure

4.1 Energy

In the country only two larger thermal energy stations at Khartoum with a production between 50 to 100.000 kw exist. Distributed mainly at the Western part of the country there exist 8 or 9 thermal energy stations with a production of 10.000 kw. Hydroelectric station producing 210.000 kw at Ed Damazin and a smaller one of 30.000 kw at Sennar produce electrical energy which is mainly used in the El Markazia area and Khartoum area where is fruit, textile, metal working industry. The electricity supply in the country is with the exception of the Khartoum and Wad Medani area only spread about 10 to 30 miles around the energy station. In the hibiscus growing area larger thermal energy stations are only at Niala, El Obeid, Umm Ruwaba and as mentioned before in the area of Wad Medani.

4.2 Transport and distances

In Appendix II a schematical pattern of the Sudanese transport system is given together with the distances of the main towns.

The Sudanese railway lines are coming from Wadi Halfa or Port Sudan in the North going through Khartoum to Sennar into the industrial area and from there to the West through Erharad, Kosti, El Obeid, Babanousa to Nyala, and from Babanousa into the South to Wau. A further railway line is comming from Port Sudan going to Kassala at the East frontier to Ethiopia and then going to Sennar. The railroad system of 4.784 km was constructed in the beginning of this century and is with some exceptions still workable. The amount of cars and engines which can still be used at present is low, because many of the equipment is broken. Presently, the railway trains are running very slowly, because of very bad served rails and very old diesel engines. Therefore, it takes more than two days for a train to go from Khartoum to Babanousa and more than four days to go from Port Sudan to Babanousa. The velocity of the trains is between 35 and 50 km per hour. Most of the engines are of United States type or German type diesels.

There exist an increasing network of motorways from Khartoum to the North and to Port Sudan, as well as to Sennar, El Obeid, En Nahud and El Fasher have been built in the last 15 years. These ways exist of asphaltic concrete. Down to the South and at the area of Babanousa the roads do not have any asphaltic coats. The long distance goods trafic is more and more transferred to the roads which at present take more than double the tonnage of the transportation by the railroad.

Transportation by riverboats is only used between Kosti on the White Nile to Khartoum.

As there are no figures for transportation cost and time by rail and by car available, no economic judgement can be given at present. A comparison of the shipment distances for materials and products for several alternative karkadeh production places are shown in Table 7. With the exception of the calyces shipment from the growing areas to the factory for all other mentioned production places the transport ways are of shorter distance.

Table 7

Comparison of the transportation ways for the various production places

Material	Location from	to	possible way for transportation	distance km	remarks
fuel	Port Sudan	Babanousa	rail	1938	
		El Obeid			) no necessary
		Kosti			) electric energy
		Wad Medani			) available
spare parts	Port Sudan	Babanousa	rail	1938	) slowly shipment
packaging materials		El Obeid	rail	1518	) because of slow
equipment		Kosti	rail	1211	) rail
			asphalt coated road	1239	
		Wad Medani	rail	961	
			asphalt coated road	1010	
maintenance and service from foreign countries	Khartoum	Babanousa	rail	1129	inopportune
		El Obeid	rail	689	)
			part.asphalt coated road	615	) comparatively
		Kosti	asphalt coated road	312	) easy to reach
		Wad Medani	rail	174	)
			asphalt coated road	187	)
dried calyces	South Dafur area	Babanousa	uncoated roads	200-600	) transportation
			rail		) depends on the
		El Obeid	uncoated roads	400-700	) local situation
			rail		)

Table 7 (continued)

Material	Location from	to	possible way for transportation	distance km	remarks
dried calyces	North Kordufan area	Babanousa		20-200	)
		El Obeid		20-400	)
		Kosti	uncoated roads	40-700	)
					) transportation way
	Central State	Kosti	asphalt coated road	20-200	) depends on the
	El Markazia		uncoated roads		) local situation
			rail		)
		Wad Medani	asphalt coated road	20-200	)
			uncoated road		
			rail		
Karkadeh powder	Babanousa	Port Sudan	rail	1938	
	El Obeid	Port Sudan	rail	1518	
	Kosti	Khartoum	asphalt coated road	312	
	Wad Medani	Khartoum	rail	174	
			asphalt coated road	187	

The advantage of the alternative production places w.r.t. the transport distances and therefore also to transport cost and time is evident.

4.3 Workshops and mechanical services

Larger workshops for construction and preparing of spare parts for production equipment exist only at Khartoum. But even these workshops will not be able to produce sophisticated mechanical spare parts in steel and therefore spare parts for production equipment as it is used for the karkadeh production have to be imported via Port Sudan and Khartoum.

4.4 Education and skill of the population

Most people of the younger generation particularly in the large towns and villages are well-educated at schools by governmental law. An increasing number of young people takes the opportunity to have a university education at the three or four universities in the country. Mechanical and agricultural engineers as well as biologists and scientists in chemistry and food technology have a comparatively good education in comparison to European and North American standards. The skill of workers particularly within the older generation is somewhat less, but because of the natural intelligence and the passionated behaviour of the Arab and Numidian people many industrial work is often carried out in an amazing short period of time. Nevertheless, much better training of a higher number of people in the whole population is necessary to have available a sufficient number of skilled workers for a high sophisticated fruit technology as it is for the production of karkadeh powder.

5. Strategy for the karkadeh production

Within the scope of this project several discussions were held with the product development managers of the larger United States and European fruit and drinks companies. A unanimous statement was obtained in all the discussions, that the use of karkadeh powder for the drink and beverage industry could be a great challenge for the food industry in

South America and Asia. In many cases there are already recipes for product compositions and manufacturing concepts available. And even for the European market an increasing demand for karkadeh drinks is predicted. Recently settled joint ventures between Nestlé and CocaCola offer a worldwide market potential for new types of drinks and beverages including karkadeh drinks for the different local areas.

Nevertheless, a strong reluctancy for any marketing activities was expressed with reference to the fact that no sufficient karkadeh powder material is continuously available at present. No risks will be taken by the large food companies for product development and marketing activities including the development of packages, distribution and storage tests for a product of which the raw material is not available continuously or does show large quality changes. In comparison of karkadeh powder from China, Indonesia and India it is known at the development departments of the large food industry that Sudanese karkadeh is the best quality, but the available amounts far too low and therefore the presently available material is used mainly for test production and very small local markets.

This implies that an increasing future demand for Sudanese karkadeh powder is a realistic fact, which should encourage the Sudanese farmers in the rain areas as well as in the water-irrigated areas for a larger cultivation of hibiscus sabdariffa and a more careful harvesting of the calyces. There is a great chance for the Sudan to become the most important karkadeh producing country in the world within the next five to ten years.

5.1 Marketing strategy

The above mentioned expected increase of the local karkadeh use as beverage as well as the intended export of karkadeh requires in principle not only a more systematic cultivation of hibiscus sabdariffa at the irregated areas, but also a more intensive cultivation of the crop at those areas where there is sufficient rain in normal years. Therefore cultivation programmes have to be set up to grow hibiscus sabdariffa as a major crop in Sudan and detailed harvesting instructions and drying procedures have to be followed by the farmers.

5.1.1 Export market

The world-market price for karkadeh calyces as well as for powder is directly related to the quality of the product with regard to colour and flavour. To acquire the highest assets in the Sudanes export business the production of karkadeh powder of high quality should be favoured instead of the export of hibiscus calyces as a raw material. The export of powder instead of calyces raw material will increase the maintained foreign currency on his best up to a 10-fold amount. But a price of that of 6 times of the calyces can be obtained on a realistic basis. The market potential for export is already at present in the order of about 100 tons per year and might grow under the explained requirements of constant quality to several 100 tons/year.

Hibiscus sabdariffa plants growing at the irrigated areas do generate calyces of inferior quality w.r.t. colour and flavour in comparison with those grown at the natural rain areas. Cultivation of the grop at irrigated areas is nearly independent of the weathering conditions during the growing of the plants and the flowering at the natural rain areas deviates strongly from to year according to the amount of rain. This means, karkadeh of high quality from the North and South Kordofan and Darfur State is of variable availability from year to year.

High cost for product development, marketing, and distribution in the potential export market will only be invested by the large beverage industry, if sufficient raw material for a karkadeh drink production is available for a period of several years. Therefore, a steady availability of karkadeh powder as raw material of constant quality is the basic requirement for the use of the product in the large European and American beverage industry.

This problem of the differeing availability of karkadeh calyces of high quality in the Sudan could only be solved if a surplus production is stored in good years and used in years with less production. This means, that either the calyces or the produced powder will have to be stored very carefully under optimal storage conditions which have to be developed experimentally.

5.1.2 Local market

Production of karkadeh powder for the local market is nearly exclusive for the Sudanese drink and beverage industry. The Sudanese drink industry exists of several small factories in comparison to the European and American ones, needs less material and is not bound strongly to a constant quality. Therefore, products prepared from raw material of the irrigated areas and smaller lots of raw materials grown elsewhere in Sudan, should be used for this purpose. An amount of 50 tons/year of powder material will be sufficient for about 10 million drinks. This should be the first target for the local production. To preserve flavour and colour in the powder as much as possible until the used for drinks, storage in big polypropylene bags of 5 kg content should be the most effective production for sale.

5.2 Investment strategy

5.2.1 Local investments and activities

Any activity in the field of the karkadeh production in Sudan depends on a systematic cultivation of hibiscus sabdariffa, insufficient availability of calyces as raw material will hamper any long-term investment of a promising karkadeh technology for the future.

For the local activities the following strategy is recommended:

1. Intensivication of the cultivation of hibiscus sabdariffa in North and South Kordofan area and the South Darfur area and in the irrigated area of the Central State (El Markazia).

2. Instruction of the farmers about optimal harvesting and drying procedure for the hibiscus calyces.

3. Organization of the collection and transportation of raw materials to the powder factories.

4. Installation of electrical energy at the two selected new production places and preparation of the ground to build up new factories.

5. Set up workshops near to the new factories, where spareparts can be stored and mechanical equipment can be repaired.

6. Training of a sufficient number of engineers and staff an the Babanousa factory to run the new factories.

5.2.2 Foreign investments

Factory equipment for a powder technology is a very expensive matter and cannot be accomplished by the Sudanese domestic economy without foreign investors. To install a useful and effective karkadeh powder technology, a three-step investment programme is recommended.

1st step:

Minimum regeneration of the Babanousa factory to guarantee a small interim production until the new factories have been installed (see page 26, Table 2). The Babanousa factory should also be used in the next future as a training centre for the education and training of the engineers and factory workers in the new factories.

Simultously investors have to be gained for sponsoring the set-up of the recommended new factories.

2nd step:

Installation of new factories should be provided at places which fulfil the under 5.3 mentioned requirements.
The factory needs to exist of three main separate workshop halls, one containing the continuous extraction, cleaning and evaporating equipment. Another one the spray-dryer and packaging station. All other equipment, energy converter, steam generator, colling system and storage tanks, may be installed in a third separate hall. A list of the necessary main equipment is given in Table 8.

Table 8

List of equipment to be replaced at Babanousa factory for longer productivity

Engineering operation	Type of equipment	Manufacturer	Investment cost
Steam generation	Automatic steam generator S 20 1 ton/h	Th. Loos GmbH Nürnbergerstr. 73 D-91710 Gunzenhausen	75.000
Extract clarifying	Decanter centrifuge NX 409	Alfa-Laval Food Engineering	112.000
Storage of extract	Storage and feeding tanks	BMA Braunschweigische Maschinenanstalt AG Am Alten Bahnhof 5 D-38122 Braunschweig	60.000
Air drying	Ammonia cooling system	elsewhere	125.000
Extract concentration	Down-draft evaporator SP 28	Niro A/S Gladsoxevej 305 DK-2860 Seeborg, Danmark	100.000
Packaging	Packaging and scaling automate	elsewhere	15.000
Spray-drying unit	Rotary atomizer B 6	Niro A/S	95.000
Maintenance	Tubes and pipes	elsewhere	40.000
		US-$	622.000

The capacity of the new factory should be about 40-60 tons of powder per year at a working time of about 200 days with the future target to enlarge the production capacity by adding a second or third production line in the later future without total change of the basic installation of the factory equipment.

5.3 Possible locations for investments

To start a new more realistic karkadeh powder production from hibiscus calycees in Sudan, three conditions have to be fulfilled for the production places.

1. The production place should be not far away from the main growing areas.

2. The electrical energy should be available either from thermal energy stations or from the electrical network in the Sudan.

3. The production place should be situated in an area with surface-coated roads and railway connection for easy and quick material shipment, and which can easily be reached by normal transportation conditions under service engineers from Europe and/or United States. - At present none of the companies supplying technological equipment for the powder production are willing and able to send service engineers to places which cannot be reached in short times. As a consequence the whole service activity, which is an important point within the undisturbed production, cannot be carried out under economical conditions.

5.3.1 Babanousa

From the avove mentioned requirements Babanousa fulfills only very few aspects. The main disadvantage for a factory at Babanousa is that it is far away from the more industrialized area of the central state. Electrical energy can only be obtained by the factory's own diesels. Any material for maintenance packaging spare parts and service have to be shipped on a long distance by a slow running rail. No surface-coated roads are available in the Babanousa area.

Because of the desolate state of the production facilities mentioned in Part I of this Report, an improved future karkadeh production at Babanousa, which would include the replacement of the large spray-drying equipment and an installation of a new diesel, cannot be lend realism.

To keep alive the karkadeh powder production in the Sudan for the present time only the already mentioned minimum restoration (Part I, page 26) will be justified.

5.3.2 Alternative places

Taking into account the above mentioned requirements two new places for a set-up of a small powder factory in the Sudan can be recommended for the first step. The first one is **El Obeid** in the Kordofan State, which is connected with a railroad, a surfaced-coated road, an airport, and a thermal power station for electricity. The other one is **Kosti and/or Wad Medani**, which also has a connection to the railroad and a surface-coated highway to Khartoum and is connected to the Sudanese electricity network and can easily be reached from Khartoum. Both cities are not too far away from the irrigated hibiscus growing areas and fulfil the above mentioned requirements satisfactory.

If karkadeh plant cultivation in the upper Nile State (see page 35) area prove successful, Malakal Town become a place for karkadeh processing. This choice is supported by the fact that special considerations is given to Southern Sudan in the ten year development plan which started this year 1992. The powder produced in Malakal, bearing in mind the condition above, could be transported to Juba for local use and also for export to Uganda, Kenya and Ethiopia. But this will only be of interest for the later future.

5.4 Comparison of investment and production cost

Leaving the technological problems of an over-dimensioned factory equipment out of consideration the Babanousa factory could be run for the next 10 years without the problem of a breakdown of the equipment, by an investment volume according to the before mentioned investment list of 937.550 US-$ (Part I, Table 2 and 3, page 26 and 28). The investment volume for a new factory at one of the alternative places, as given in Table 8, page 65, is in the order of 622.000 US-$.
From Table 1 on page 25 the production cost for the powder production at the Babanousa factory in 1991 to 1992 it is clearly seen that only fuel and maintenance besides the raw material costs are of significant influence. Under the assumption that these figures are correct for the future, production cost at alternative places are less because of cheaper energy and smaller transport cost. This would not be of high relevance. The installation of a new factory at one of the alternative places would also have the further advantage, that in future times the production equipment could be much easier enlarged for a traditional production by the installation of further spray-drying and evaporation units without exchange of the available other equipment.

Too less information about the real production and transportation cost in Sudan are available. Therefore an exact judgement for any alternative production place is not possible. But an estimation on a relative scale of the economic efficiency for Babanousa and the alternative places can be carried out as follows:

In Table 9 the absolute and relative figures are given for the total effort to be spent at the different production places. The figures are taken from the before mentioned Tables of this Report. The relative effort necessary for investment, transport distances, availability of electrical energy and of the production rate for the different places are calculated by taking the value for Babanousa as 1.

The relative effort value is obtained by either dividing the effort figures of Babanousa by the figure of the alternative places or by estimating the effort (e.g. electrical energy). The relation for the calculation of the total relative effort rate is given on page 70.

The figures for Kosti and Wad Medani cannot directly compared to those of Babanousa, because a factory at both these places would only pick up raw material from the irrigated areas. But the total effort rate do clearly show the advantage of any alternative factory place in comparison to Babanousa. Even if the capital expenditure of US-$ 262.000 for a short-term restoration of the Babanousa factory is taken into account, the total effort rate is still better for the alternative places.

The last column of Table 9 shows the effort rate which should be as low as possible for a higher economic efficiency.

Table 9

Comparison of investment and production cost for different production places in the Sudan

Place	Capital Expenditure for factory investment '000 US-$	Productivity to/year	Transport Distance km raw material	material maintenance	Electric Energy available	Total Effort Rate (rel.) *)	
Babanousa	938	40	NK 20-200 SD 200-600	1.200-1.900	no		
rel. effort	1	1	1	1	1	4	
El Obeid	620 + 262	40-60	NK 20-400 SD 400-700	700-1.500	yes		
rel. effort	0,66 / 0,94	1,5	1 - 2 2 - 1,16	0,58 - 0,79	0,7	2,37 2,42	2,55 2,61
Kosti	620 + 262	40-60	CS 20-200	300-1.200	yes		
rel. effort	0,66 / 0,94	1,5	1	0,25 - 0,63	0,7	1,87	2,05
Wad Medani	620 + 262	40-60	CS 20-200	200-1.000	yes		
rel. effort	0,66 / 0,94	1,5	1	0,17 - 0,53	0,7	1,81	1,99

*) Total effort rate (rel.) = $\frac{\text{Capital expenditure + transport distance + electric energy cost}}{\text{Productivity}}$

NK = North Kordofan; SD = South Darfur; CS = Central State

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Appendix I

Fig. 1 :   total view of the factory

Fig. 2 : leaching equipment

Fig. 3: inside of the leaching equipment

Fig. 4 :   outlet of the leaching vessel

Fig. 5 :   sieve filtration station

Fig. 6 : storage tanks before centrifugation

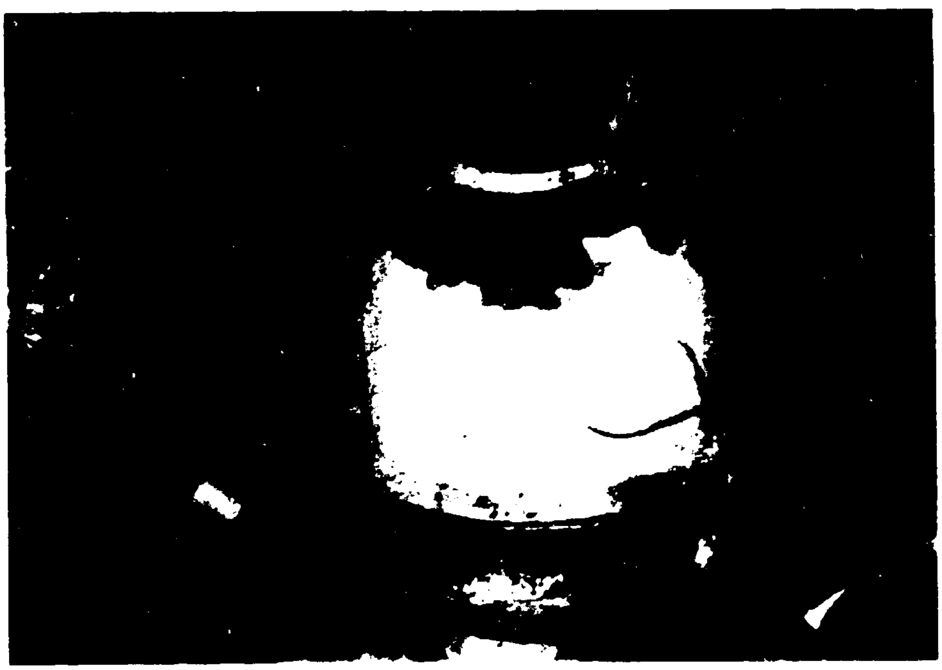

Fig. 7 : milk centrifuge, destroyed head

Fig. 8 :   milk centrifuge with repaired head

Fig. 9 :   storage tank after centrifugation

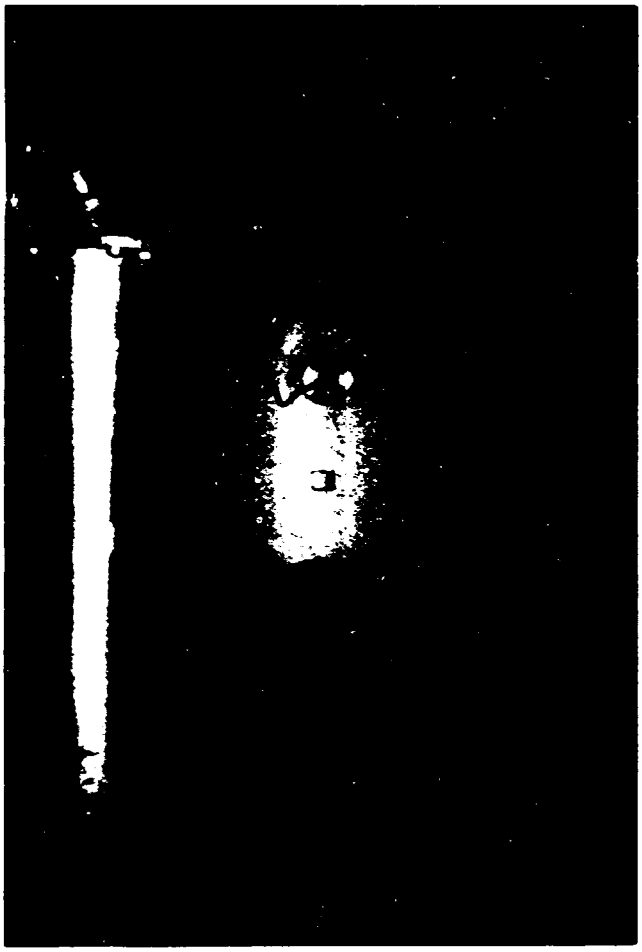

Fig. 10 : feeder tank for concentration

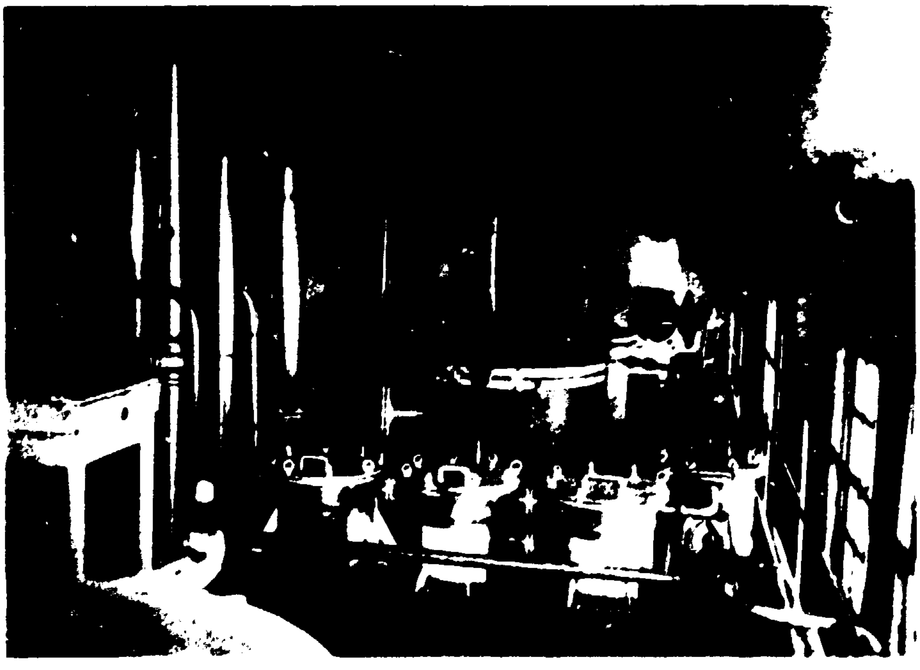

Fig. 11 : vacuum concentration equipment

Fig. 12 : feeder tank for spray drier

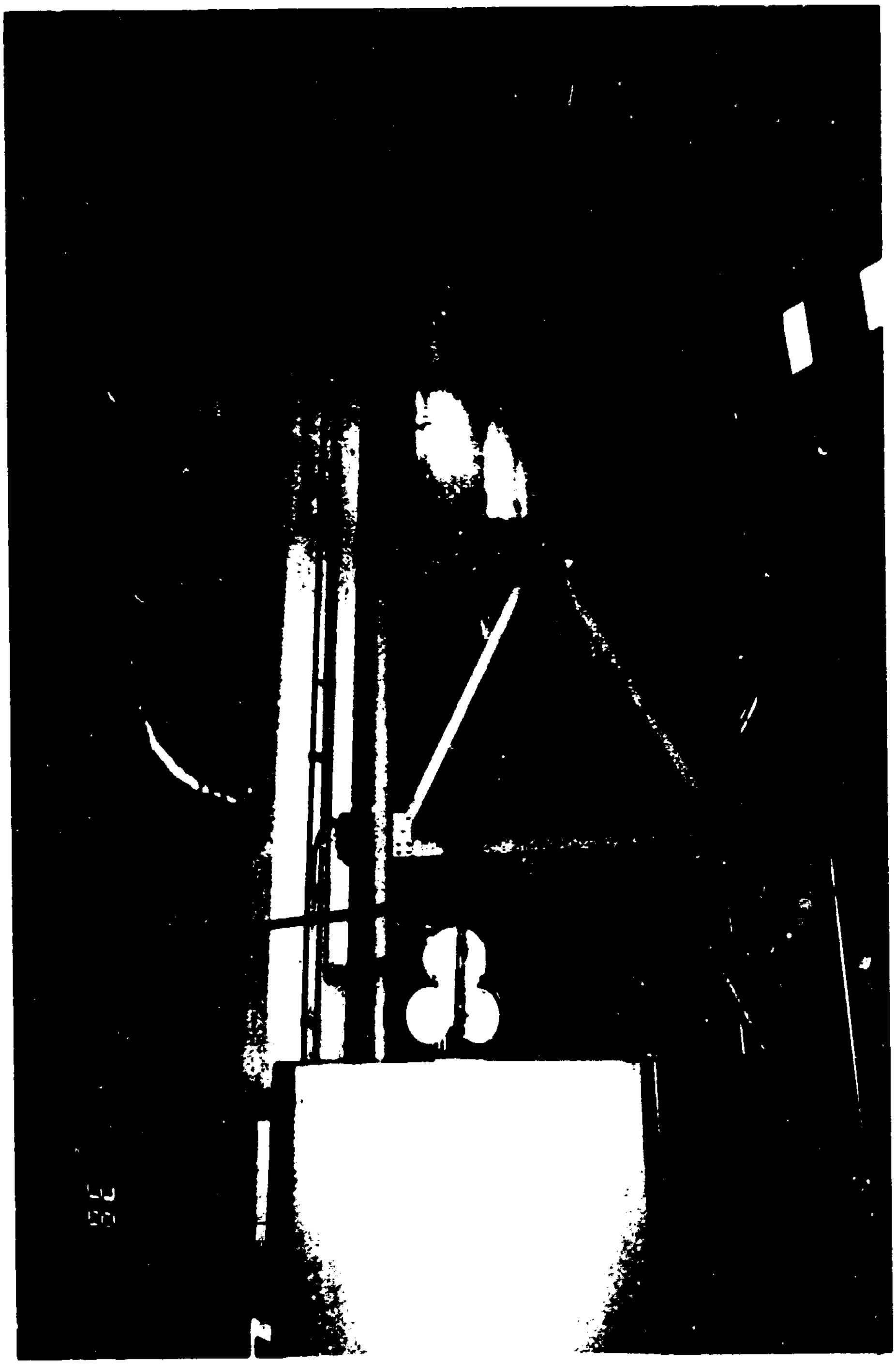

Fig. 13 : spray drier, total view

Fig. 14: inside [illegible]er, top and
atomizing unit

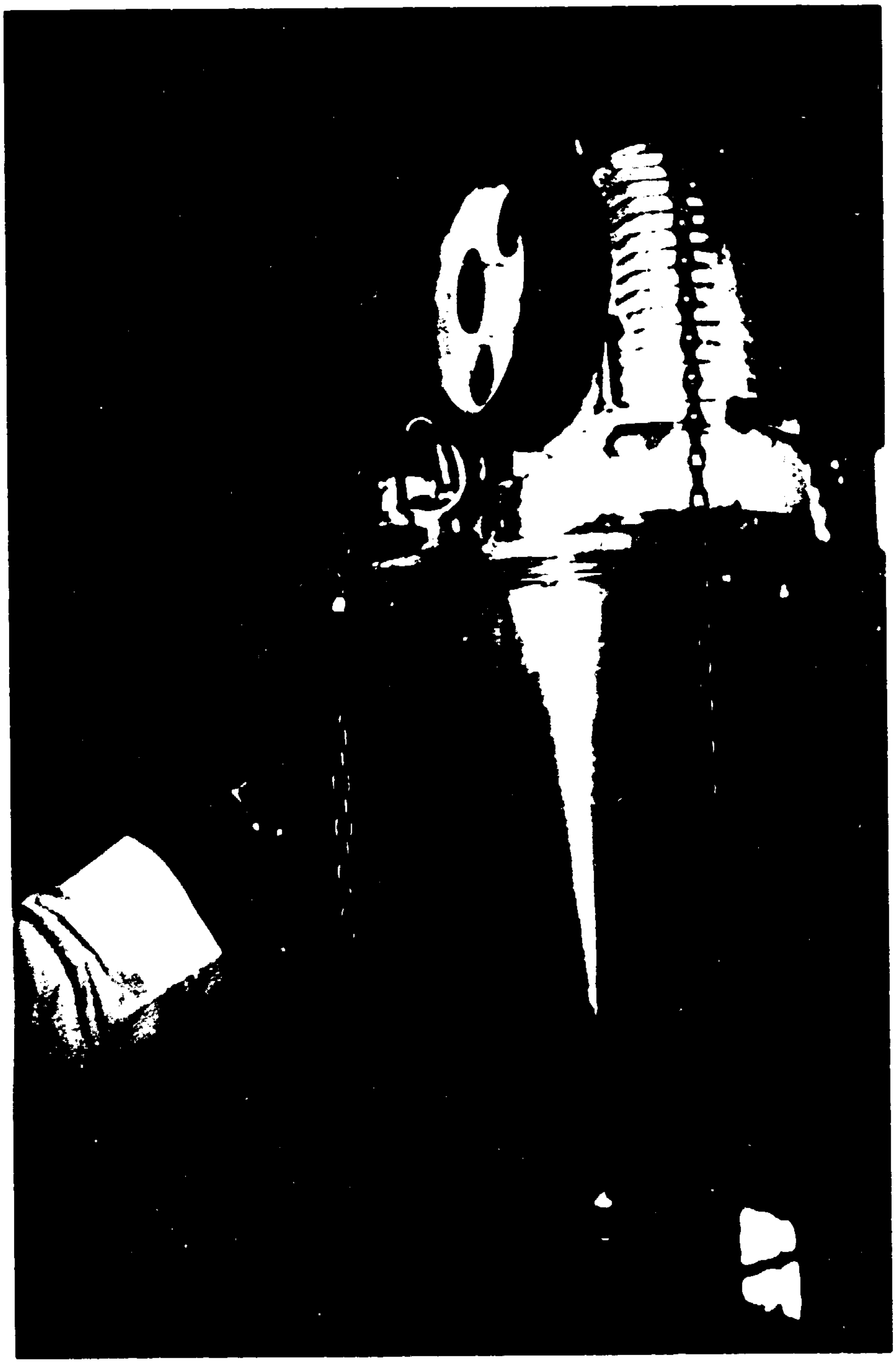

Fig. 15 : atomizer unit dislocated
from the drier

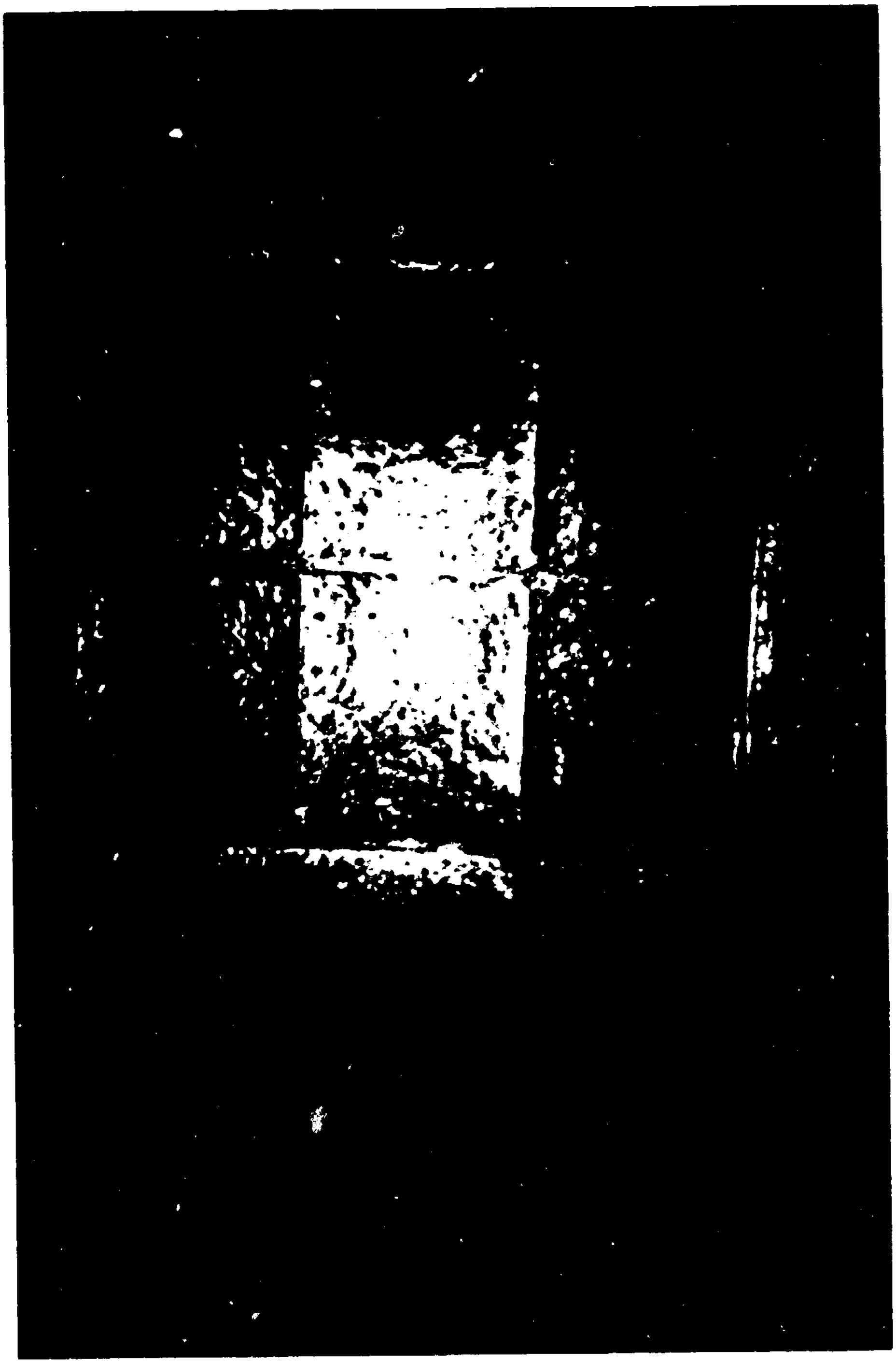

Fig. 16 : inner surface of the spray drier destroyed by mechanical cleaning

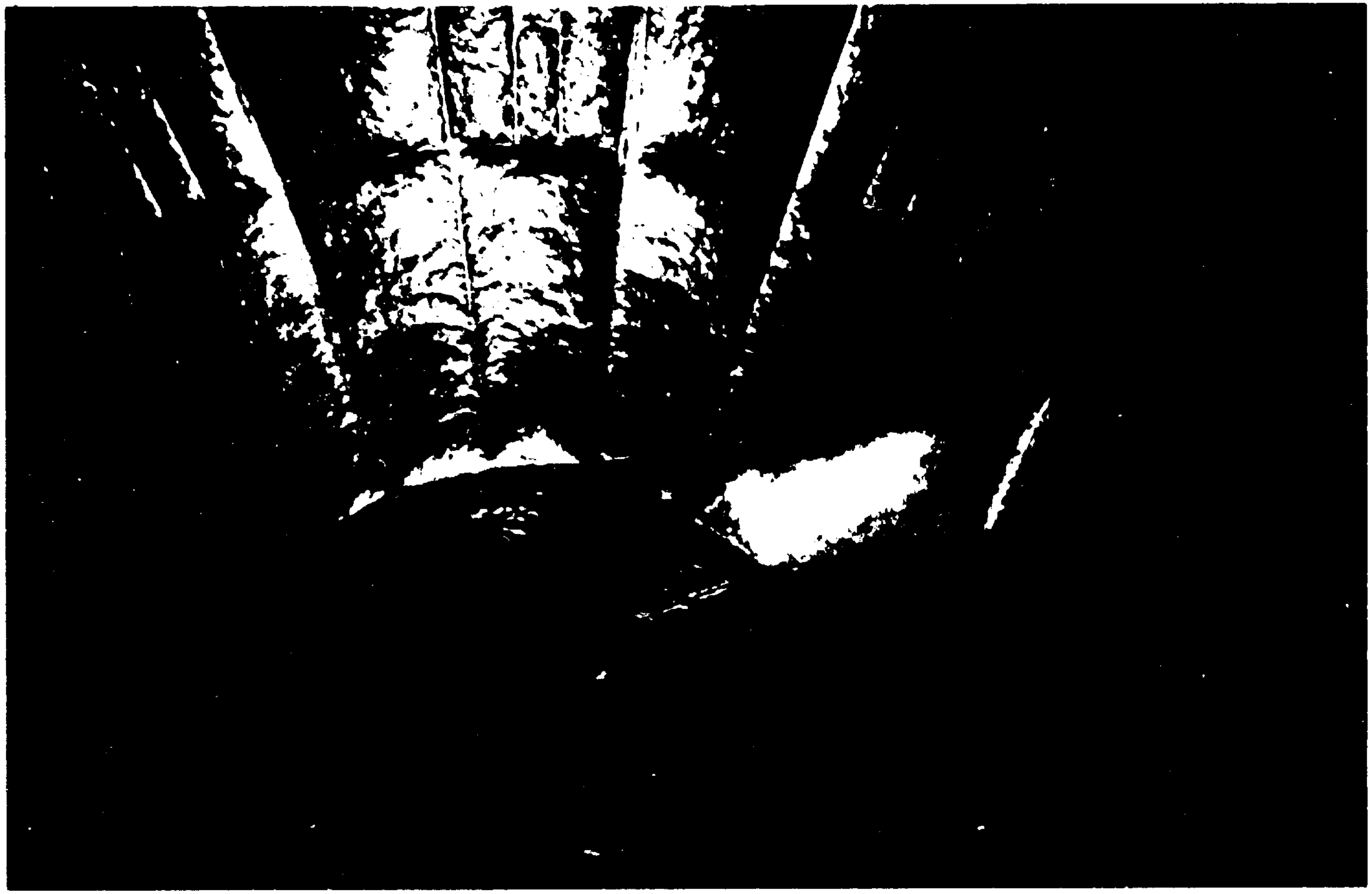

Fig. 17 : bottom and air outlet of innerside of the spray drier

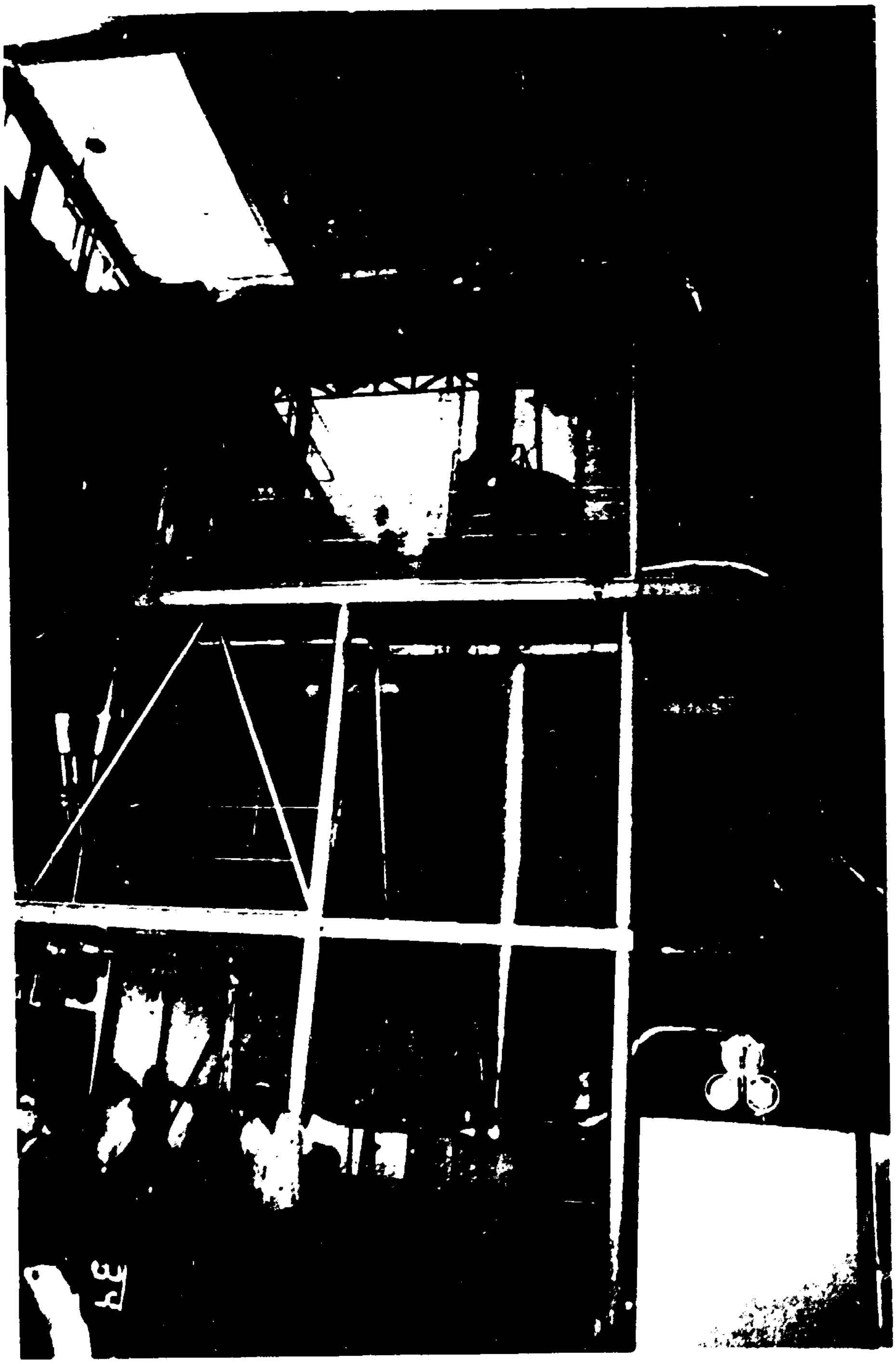

Fig. 18 : cyclone for dust separation

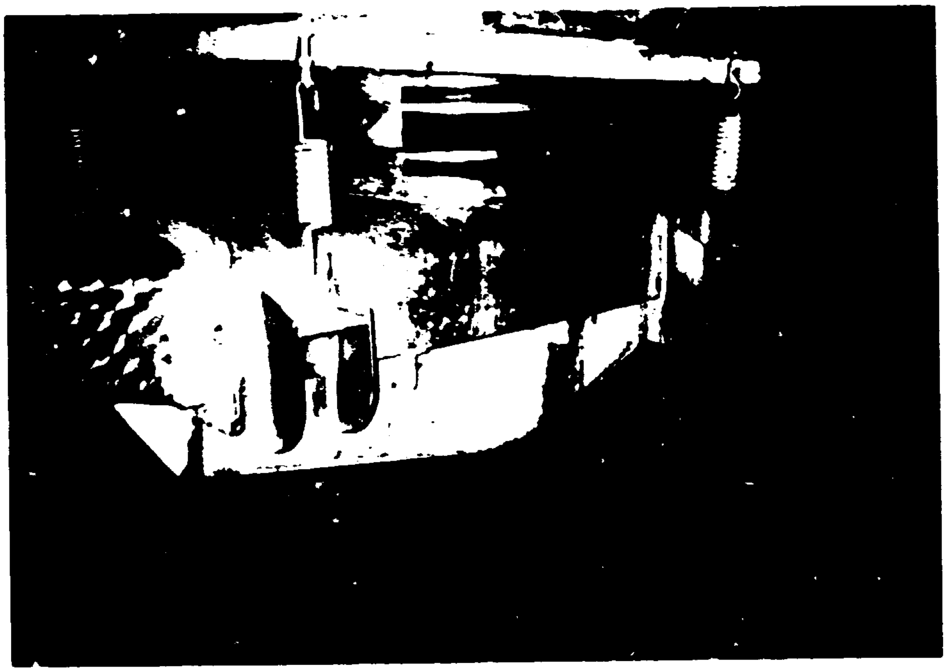

Fig. 19 : outlet of spray drier
with vibration riddle

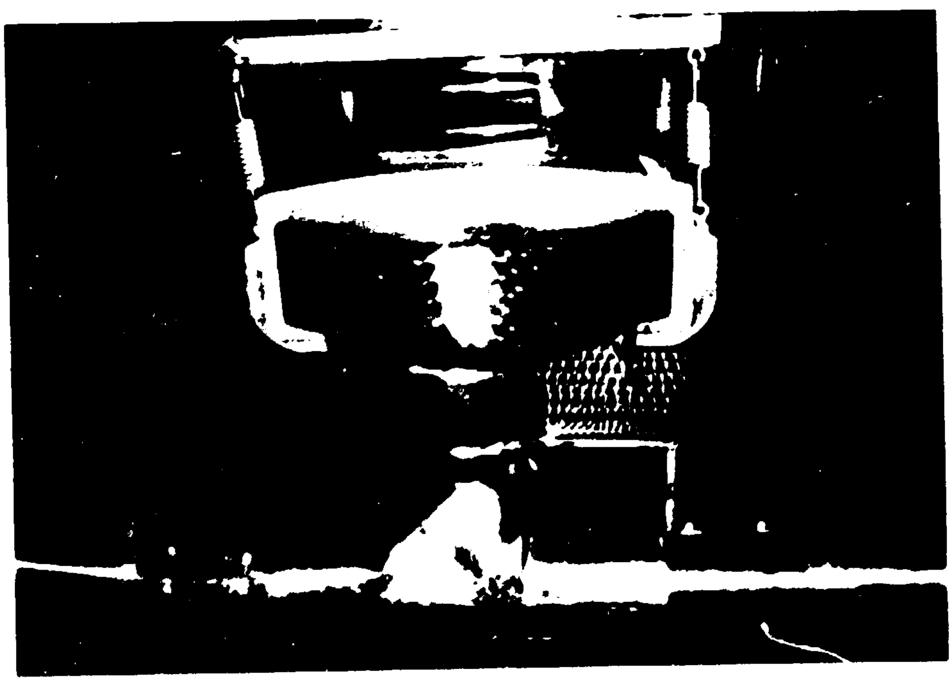

Fig. 20 : air inlet for cooling and
transportation of product

Fig. 21 :   air drier (condensing system)

Fig. 22 : pipe for powder transportation to the filling station

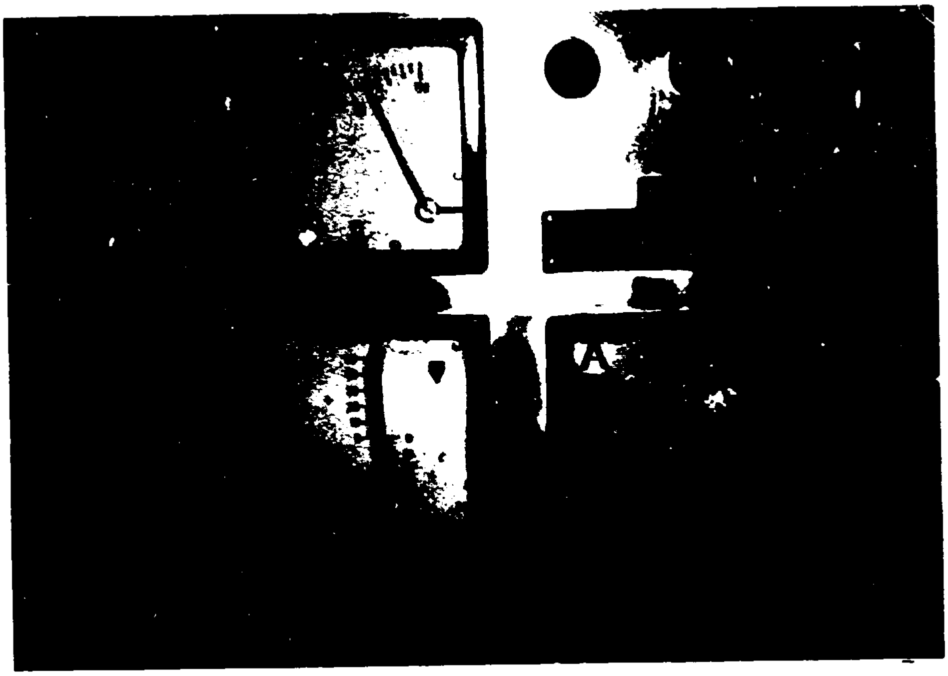

Fig. 23 : detail view of the steering panel of the spray drier

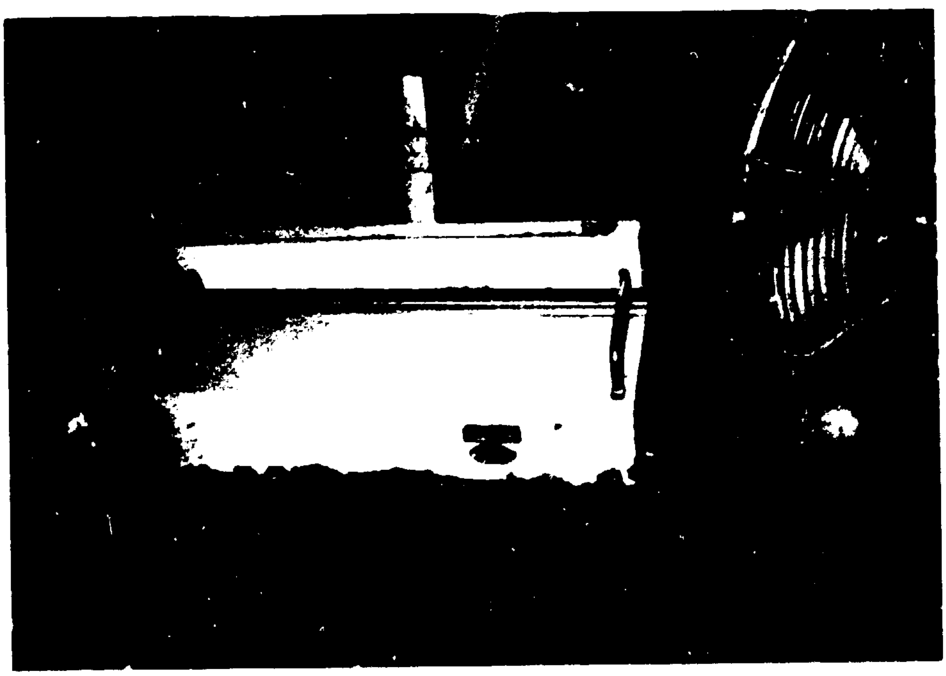

Fig. 24 : plastic bag sealing equipment

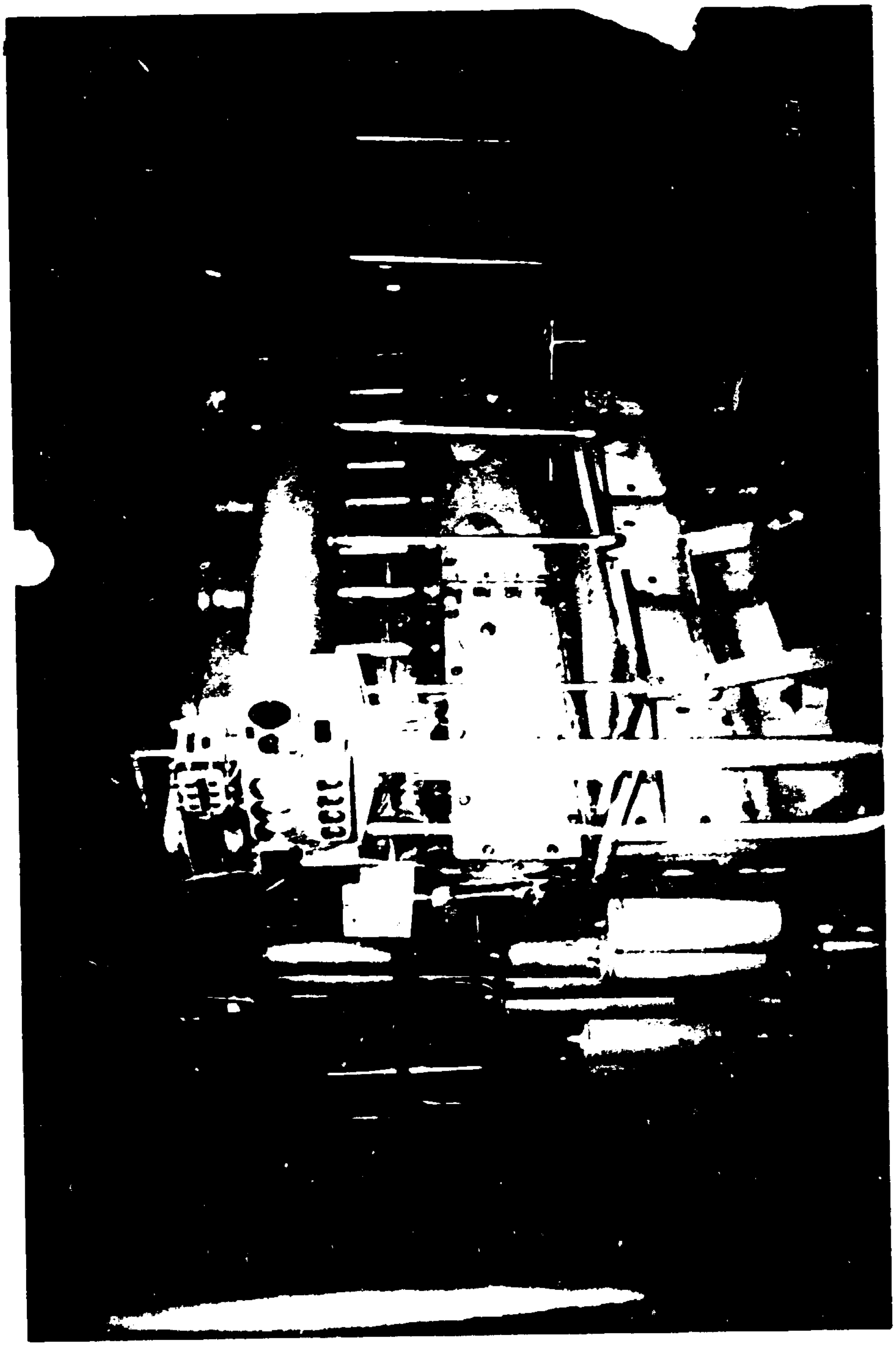

Fig. 25 : diesel generator

Fig. 26 : steam generator No. 2

Fig. 27 : steam generator No. 3
(rotted fire chamber)

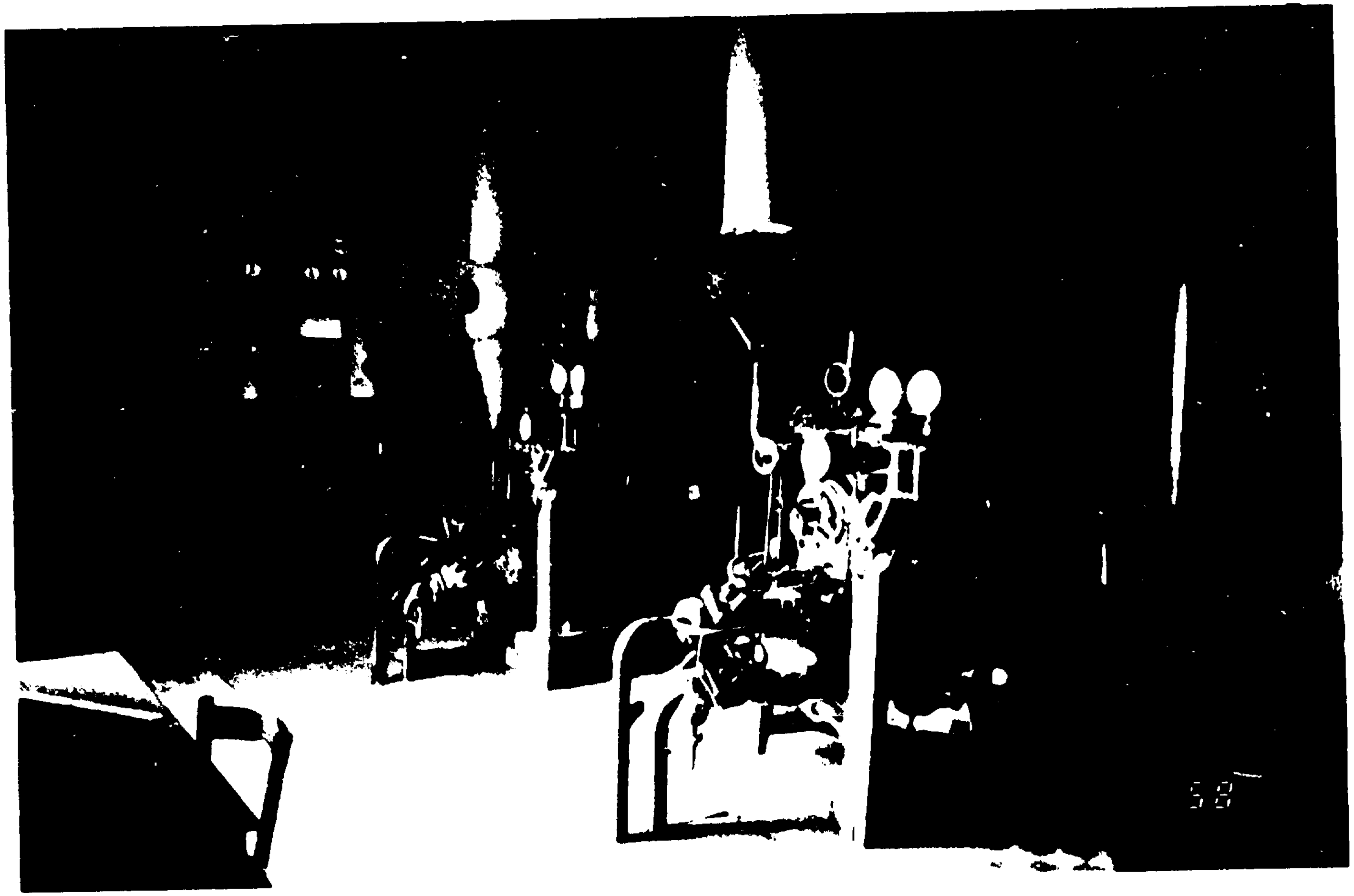

Fig. 28 : compressor for the ammonia cooling system

Fig. 29 : pumping-station in the ammonia compressor hall

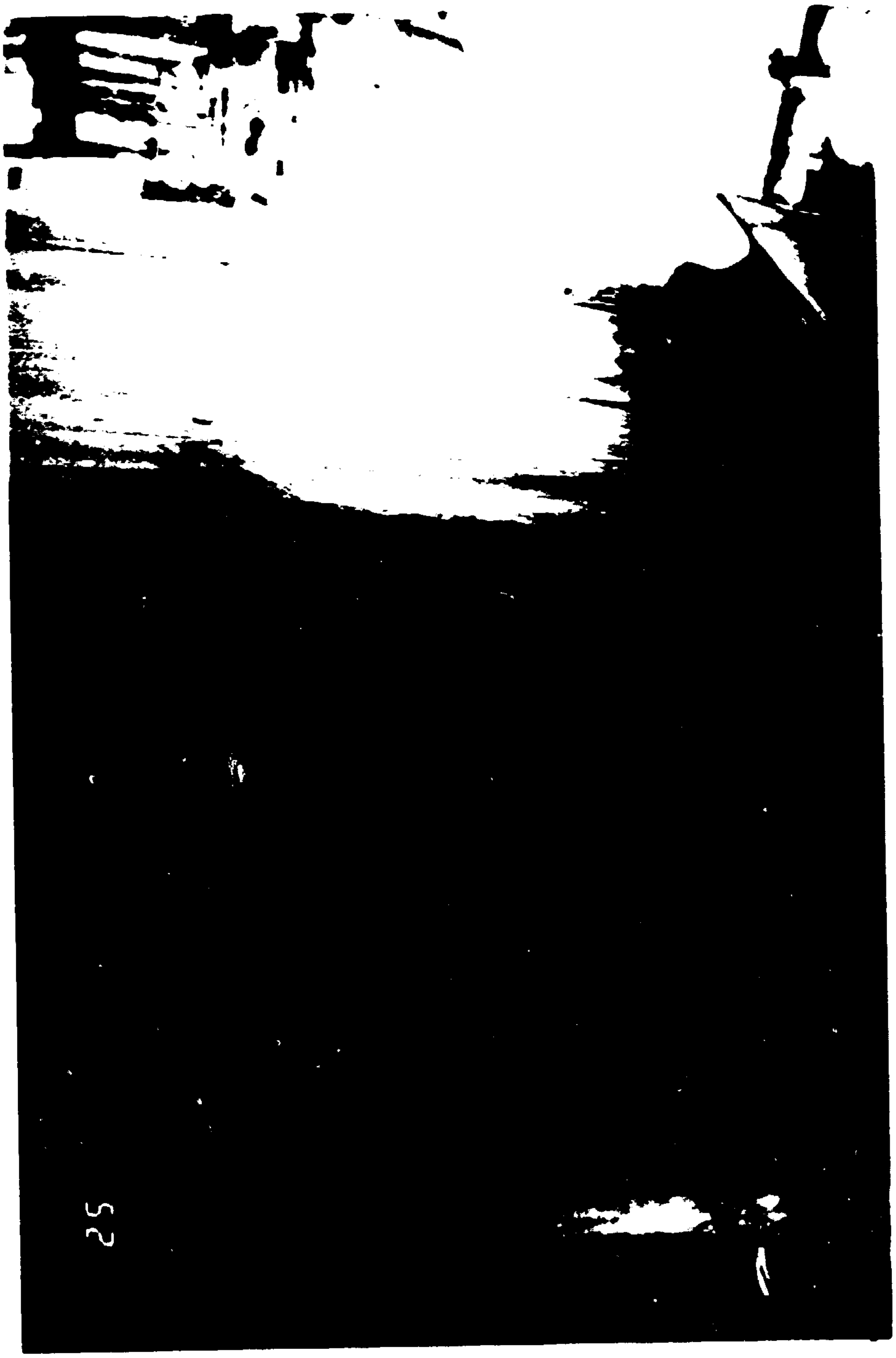

Fig. 30 : brine cooling transfer unit
(ammonia system)

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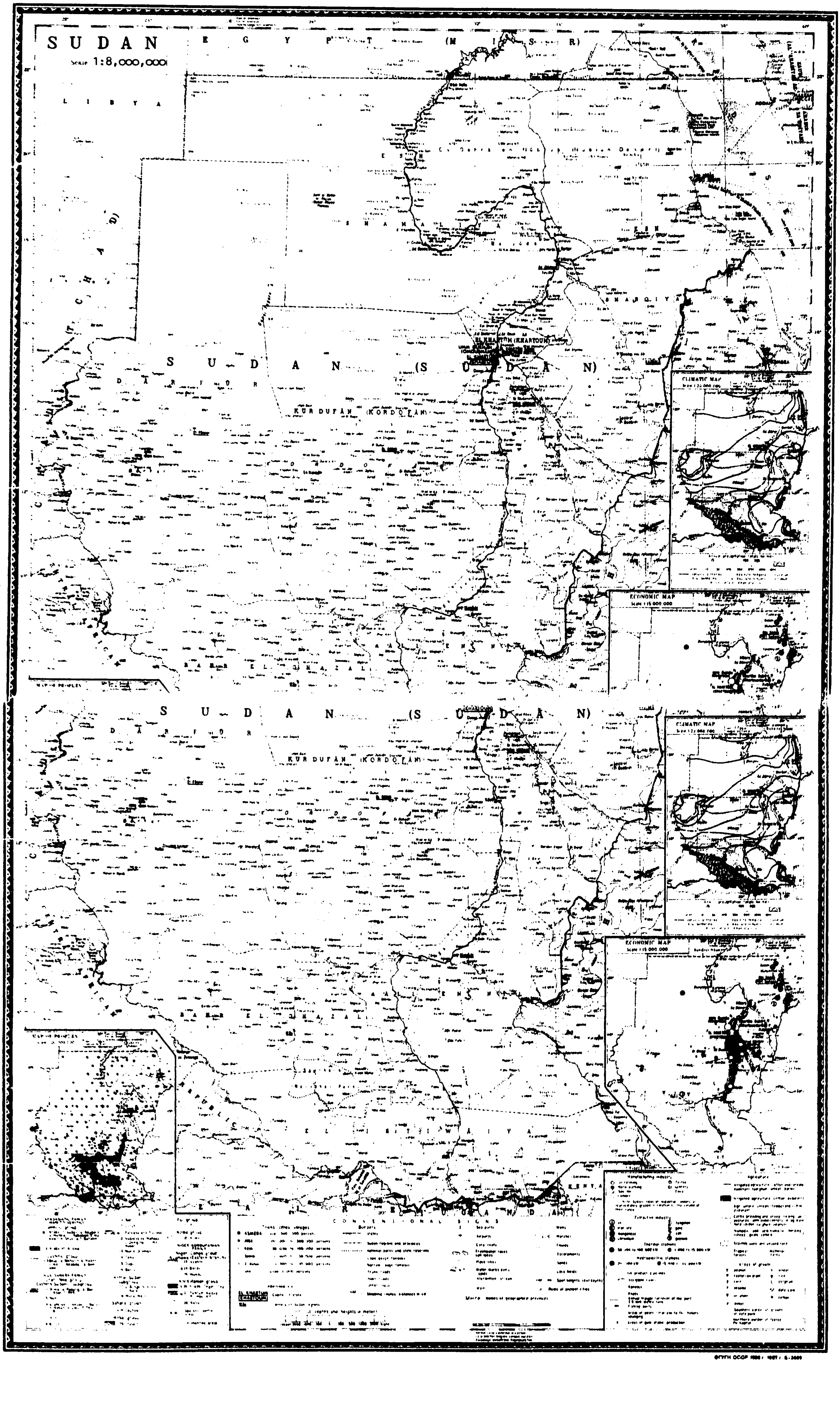
Appendix II

SECTION 1



SECTION 2

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Sudanese transport system and distances