

ON THE TECHNOLOGY OF A BEET SUGAR FACTORY,
FOR WORKING UP THE PRODUCE OF FIVE HUN-
DRED ACRES OF BEET.

By J. BARNARD.

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“In tracing the history of any great enterprise, it will rarely appear that success has been attained all at once, but in most instances the progress gained has been slow and gradual; and it has generally been found to be a work of time to wear down prejudices, alter the course of habitual thought and practice, as well as to overcome that *vis inertix* which is opposed to all innovation and change. The cultivation of the White or Silesian Beet, with its many attendant advantages in relation to agriculture, and as a sugar-producing root, has proved no exception to this ordinary experience. In support of this, it may be well, before passing on to the particular object of this paper, to draw attention to what has been done towards the establishment of the important industry now under consideration.

“In 1868, a Select Committee of the House of Assembly, inquiring into the best means of encouraging manufactures, reported in favour of a subsidy of £500 being paid to the producer of every 500 tons of sugar manufactured from beetroot, under certain conditions; and so impressed were the committee with the great advantages to be derived from its introduction, that they added the recommendation to re-print an excellent treatise by Arnold Baruchson, ‘for the information and guidance of the colonists.’

“The Government promptly carried these suggestions into effect, by printing and widely circulating throughout the community an abridgement of Baruchson’s pamphlet; and they also, in the succeeding session, introduced and passed a measure to encourage this among other manufactures, which enacted that ‘there should be paid to the person or company who first manufactures, to the satisfaction of the Governor-in-Council, 200 tons of good marketable sugar in any one year from beet or other product grown in Tasmania, the sum of £2,000.’

“Several able leading articles have also, from time to time, appeared in *The Mercury* newspaper, urging upon public attention the special importance of cultivating the sugar-beet.

“The little share that I have had in the same direction, I may now be permitted to mention, without, I hope, any imputation of undue egotism.

“In June, 1869, after my return from Sydney, I read a short paper before the Royal Society, describing the simple and inexpensive, if somewhat rude, process which was adopted by a

settler in the interior of New South Wales for extracting the sugar for his household from this invaluable root.

"In August following I supplemented that paper by another communication giving some account of a cheap American machine for making beet-sugar upon a somewhat larger scale, but still within moderate limits. At the same time I furnished some statistics, affording a sound basis for the encouragement of all practical agriculturists.

"Having cleared my way by these few preliminary remarks, I now advance a step further, and place before the Royal Society the requisite data for the establishment of a sugar factory, calculated to work 150,000lbs. of beetroot per 24 hours, during a campaign of 100 days, and corresponding to the average product of the cultivation of 500 acres in beets. The scope of this paper may be described as the technology of the manufacture, with its estimated cost of buildings and machinery, and working expenses, together with the probable results to be annually realized, derived from the most recent and reliable publication on the subject.*

"1. *Production of steam.*—Beetroot sugar works consume a large amount of steam for driving engines, which propel root-washers, hydraulic pumps, and presses, pulpers, water pumps, centrifugals, &c. Steam also conveys the juice and syrups from one place in the building to another, and is the agent used for evaporating and boiling them. The steam department of a 500 acre beetroot sugar factory comprises three steam boilers of 40 h.p. each, with two internal pipes and one flue; two steam drums, with fittings complete; and one 4 h.p. donkey engine, driving two feed pumps. The total cost of the appliances for the production of steam is stated at £925.

"2. *Washing and Pulping the Beets and Extracting the Juice.*—Operations, in Tasmania, should be commenced early in April, when steam should be got up in the boilers to 40 or 45 lbs. pressure, and the beets should be regularly carted in. An exact account should be kept of each load entering the works, and of every pound of beet consumed. The beets as they are brought in are placed in piles alongside of the beetroot washer, which is a long cylindrical drum revolving in an iron tank, furnished below with a man-hole door, for allowing it to be occasionally cleared out; the refuse being carted off as manure. The proper speed for a root-washer is from 20 to 30 revolutions per minute. The more water employed in washing the beets the better, but the supply of both roots and water must be regular. On leaving the root-washer, the beets are pitched

* The work referred to is entitled "On the manufacture of beetroot sugar in England and Ireland. By William Crookes, F.R.S., editor of the Chemical News.—Longmans, 1870.

into the jaws of the pulper, where they are seized between revolving cylinders armed with knife blades, which speedily reduce them to fragments. These fragments pass into the pulper proper, to which consists of a double revolving drum, driven by belting; and the speed of this drum is 600 to 700 revolutions per minute. The pulp is received in front of the pulper in a small reservoir. The next stage is extracting the juice from the pulp by hydraulic presses worked by steam power, and is at once simple, easily managed, and efficient. For this purpose the pulp is put into wool bags, 33 inches deep by 22 inches broad, in a quantity not to exceed, when slightly flattened, the thickness of a finger. These bags, or sacks, are piled up one over the other, separated by sheet iron trays, and, after some preliminary pressure, are transferred to the hydraulic presses, where the remainder of the juice is squeezed out.

“The cake obtained after this pressure is used as fodder for cattle, or in the manufacture of brandy and vinegar, as well as for the manufacture of paper, for which it is increasingly in demand.

“The total cost of the machinery and implements employed in the washing, pulping, and pressing department to work 150,000 lbs. of beet per 24 hours is stated to be £1,967.

“3. *The Woollen Sacks.*—From 900 to 1,000 sacks are sent to the washing machine every six hours; and the price of a sack varies from 2s. to 3s. The first cost of a full set of them for a 500-acre factory is £400. About 2,000 trays are required, costing about £200; and the price of a sack-washing machine and connections is £20; making a total under this head of £620.

“4. *Defecation of the Juice.*—After the liquid product has been collected into a special reservoir, there are various impurities to be eliminated, some of which can be removed before crystallisation of the sugar by the combined action of heat and the use of lime. This operation is known as defecation of the juice, when a certain portion of the sugar combines with some of the lime used, forming the saccharate of lime; and from this saccharate the sugar has to be freed by the action of carbonic acid gas, which, having a greater affinity for the lime, combines with it, forming insoluble carbonate of lime, while it liberates the combined sugar. This process is called the “carbonatation” of the juice. Defecation is effected in a batch of open, circular, round-bottomed pans, made of copper, into which the liquor, after being conveyed from the juice reservoir, into an upright iron boiler, called a “monte-jus” (literally mount juice), is then passed into the defecating pans, when milk of lime is poured into the warm juice, and well stirred into it.

“The defecating operator must always be a man of experience, as much must be left to his empirical judgment.

“The total cost for the defecating department of a 500-acre factory is given at £295.

“5. *The scums of Defecation.*—The scums formed during the process of defecation of the beetroot juice, being rich in saccharine matter, must be made to give up as much of their valuable contents as possible; and this is effected by collecting them into a special reservoir, and the action of powerful presses, followed by other minor processes.

“The “dead” scums constitute a valuable fertiliser, rich in nitrogen and lime, and are hoarded with care for sale to the farmers.

“The total cost of the “scum” department of a 500-acre factory would be £134.

“6. *Carbonatation.*—This process is the saturation of the defecated beetroot juice by means of carbonic acid gas, which may be effected in a simple, easy, and cheap manner by the combustion of charcoal. The combined defecated and scum juices are conveyed into carbonatation pans, and the carbonic acid is passed through the liquid. When the “foaming” has ceased, the carbonatated juice is run into large receivers, to settle, after which the juice is ready for the filters.

“The deposit formed during carbonatation is a valuable manure, which must not be lost or wasted.

“The total cost for the carbonatation department of a 500-acre factory is stated at £632.

“7. *Filtration and concentration of the juice.*—Is the next process after leaving the carbonatation pans, and usually takes place twice before crystalized sugar is produced. The first filtration is that of the carbonatated juice, the second is this juice after evaporation until it has become a thin “syrup.” Evaporating pans were formerly simple contrivances, and consisted of open boilers; but these have now given way to the more perfect appliances known as the “triple-effect vacuum pans.”

“The total cost of the filtering department is £595; and of the concentration and boiling department of a 500-acre factory is given at £2,300.

“8. *Bone-black, or animal charcoal.*—Is a very important item in the manufacture of beet sugar. The average quantity needed is 20 per cent. of the quantity of beets, by weight, worked up every 24 hours. A factory consuming 150,000lbs. of beetroot per diem, would thus need 30,000lbs. of bone-black. The residue from the bone-black washer is collected in cisterns, where it deposits itself as fine mud, and constitutes a highly valuable fertilizer.

“The cost of the bone-black department of a sugar factory, working 150,000lbs. of beets, every 24 hours, is estimated at £257.

“9. *Crystallization*.—The syrup boiled to a consistency of from 40 to 42deg. of Baume’s areometer, is distributed into iron forms or crystallizers of a capacity of about 12 gallons each. These are left quiet for 18 or 20 hours in a room, the temperature of which is kept at 95deg. F.; and in from 5 to 8 days the sugar is “made.” The contents of the forms are next emptied into “centrifugal turbines,” revolving drums, the outer surface of which is covered with metallic tissue, through the meshes of which the syrups flow, by the action of the centrifugal force, while the crystals of sugar are retained within. These centrifugals are of various construction, but the velocity of their circumference must not be inferior to from 160 to 180 feet per second.

“In a very short space of time the sugar (first product) is ready to be scooped out from the inside of the centrifugals. Then follow other processes for securing the second and third qualities; the residue from the third sugar is molasses, and is collected into cisterns for the distiller’s use.

“The cost of the crystallization department is £760.

“To the foregoing estimates must be added piping and cocks, £750; vats, £60; various tools, £200; packing and unpacking of machinery, £400; besides freight and other expenses on the whole apparatus, the total weight of which is estimated to be about 200 tons.

“*Water supply*.—Perhaps the most important consideration in the choice of a locality for a beetroot sugar establishment is an abundance of water, as will be seen from the following estimate of the quantity required per hour for the daily washing of 150,000 lbs. of beets; viz. :—

	lbs.
For the supply of the steam generator	3,000
Washing and pulping	6,000
Defecation	1,000
Milk of lime	100
Filtration	4,000
Bone-black washing	6,000
Concentration of juice.....	73,190
Boiling	19,900

113,190

or 1882 cubic feet, which is equal to a delivery of 32·5 lbs. per second, or about half a cubic foot.

“*Labour and general estimates*.—With some few exceptions no skilled labour is required in new beetroot sugar works, as most of the operations are of a simple mechanical nature.

The only skilled hands really needed are an engineer, an hydraulic pump man, a defecator, a sugar boiler, and a bone-black burner.

“Based upon a campaign of 100 working days, the following is the general estimate given of the cost of labour for a factory upon the scale mentioned. The work is continuous day and night, being divided into two shifts; and the average daily rate of wages is taken at 4s., but a higher rate of pay is, of course, given to the skilled labour. The various processes, with the cost of each, are as under:—

1. <i>Washing and pulping</i> .—Carriage and washing of the beets, 14 men, 2 shifts for 24 hours, 2,800 days' labour, at 4s.....	£ 560
Press Department, 28 men, 2 shifts per 24 hours, 5,600 days, at 4s.....	1,120
Sack washing and darning, 8 women, 2 shifts, 1,600 days, at 4s.....	320
2. <i>Defecation</i> .—8 men per 24 hours, 800 days' labour, at 4s.	160
3. <i>Scums</i> .—6 men per 24 hours, 600 days, at 4s.	140
4. <i>Carbonatation</i> —	
250 days, at 4s.	50
Monte-jus.....	40
Carbonic acid gas (preparation of)	40
5. <i>Filtration</i> .—3 men every 24 hours, at 4s.	60
6. <i>Concentration</i> .—Two men, every 24 hours	80
7. <i>Boiling</i> .—Two men, every 24 hours	80
8. <i>Crystallizations and Centrifugals</i> —1,500 days' labour, at 4s.	300
9. <i>Generation of Steam</i> .—Two shifts of 3 men, 600 days, at 4s.	120
10. <i>Breaking and Packing</i> .—Five men, at 4s. per day ...	100
11. <i>Men in the Yards, &c.</i> —Five men at 4s.....	100
12. <i>Management</i> —	
One general superintendent and two overseers	800
Bookkeeper and clerk.....	320
13.— <i>Extras</i> —	
Carpenter, plumber, and smiths (3 months)	300
Extra pay to skilled labour	500

General cost of labour for one year's campaign..... £5,190

“The quantity of coal consumed by such an establishment would average 600 tons, which, at 20s., would cost £600.

“The bone-black, 30,000lbs., would cost, for the first outlay, at 2½d. per lb., £312, but in succeeding years would only amount to replacing waste.

“The lime used would amount to 4,500 bushels, and cost about £280.

“The cost of 15,000,000lbs. of beet root to be worked up into sugar would be, at 12s. per ton, £4,500.

ANNUAL EXPENSES

“Summing up the above, the yearly expenses would be—

	£
Labour	5,190
Coal	600
Bone-black (waste)	100
Lime	280
Purchase of beet roots	4,500
Add 20 per cent. for incidentals	2,100
	£12,620
To which has to be added taxes, and insurance, computed at	400
Interest on capital invested	960
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Making a grand total of	£13,980

FIRST COSTS.

“The first outlay for the establishment of machinery, buildings, &c., may be summed up as follows:—

Production of steam	925
Washing and pulping	1,967
Defecation	295
Scum	134
Sacks, trays, sack-washing	620
Carbonatation	632
Filtration	595
Evaporation of juice	2,300
Crystallization and turbines	760
Bone-black department	257
Pipes and cocks	750
Packing and unpacking	400
Tubs and tanks.....	60
Brickwork	500
Sundries and tools	400
Carriage of 200 tons of machinery, &c.	250
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	£10,845

“Adding £2,000 for the erection of the works, and £312 for first cost of bone-black, we have the sum of £13,157 needed for the first establishment of a manufactory of sugar from beet roots for the produce grown on 500 acres of ground, and which ought to produce at least 1,200,000 lbs. of raw sugar.

“By the statistics for 1871, the quantity of sugar imported into Tasmania for that year, was 3,737 tons, (or 8,359,880 lbs.) for a population of 101,785, giving an average consumption annually of 82 lbs. for each person.

REALISATION.

“The products to be realised in the foregoing example of a sugar manufactory would be as follows:—

Sugar from 15,000,000 lbs. beet at 8 per cent. of sugar, the sugar being sold at 24s. per cwt., 2½d. per lb., 600 tons	£ 14,400
2,700,000 lbs. pulp, at ½d. per lb.	5,620
5,000 gallons molasses, at 1s. per gallon	250
Residues, as fertilizers	200
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Total	£20,470
Deducting annual expenses and interest as above.....	13,980
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Leaves net annual profit	£6,490
or 31·7 per cent.	

There is every reason to believe that, with careful management, the quantity of sugar obtained will range as high as 10 per cent. instead of 8 per cent., taken as the basis of the foregoing computations. In such a case, the net income would be £24,170, and the net annual profit £10,090, or 41·2 per cent.

“Such is a mere outline from the elaborate specifications and estimates given by Mr. Crookes in his admirable work; and so cogent are the facts and figures detailed, as to fully justify the conviction that a Beet-root Sugar Factory upon the scale of magnitude set out would prove to be a grand commercial success.”