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Economic and Environmental Benefits of the Best Available Technique Application in a Food Processing Plant

Frantisek Bozek, Pavel Budinsky, Ignac Hoza, Alexandr Bozek, Magdalena Naplavova

***Abstract*—**A cleaner production project was implemented in a bakery. The project is based on the substitution of the best available technique for an obsolete leaven production technology. The new technology enables production of durable, high-quality leavens. Moreover, 25% of flour as the original raw material can be replaced by pastry from the previous day production which has not been sold. That pastry was previously disposed in a waste incineration plant. Besides the environmental benefits resulting from less waste, lower consumption of energy, reduction of sewage waters quantity and floury dustiness there are also significant economic benefits. Payback period of investment was calculated with help of static method of financial analysis about 2.6 years, using dynamic method 3.5 years and an internal rate of return more than 29%. The supposed annual average profit after taxationin the second year of operation was incompliance with the real profit.

***Keywords*—**Bakery, best available technology, cleaner production, costs, economic benefit, efficiency, energy, environmental benefit, investment, savings.

I. Introduction

At present prime attention is paid to minimizing and utilizing of biodegradable waste as a significant type of waste [1]-[4]. Pastry production is a typical example, because it processes raw materials which are subject to rapid degradation as well as products which are valueless once they lose their freshness [5], [6].

There are many ways how to deal with the produce solid waste resulting from the production of bakery [7]. Non-consumed pastry is commonly utilized in agriculture as feed. Utilization in large-scale breeding is problematic, though. Effective breeding of livestock is based on prepared, optimum fodder rations. The addition of non-consumed pastry is not considered in such cases. That is why it is necessary to seek out the possibility of use of non-consumed pastry by private farmers and small breeders. Regular demand is not guaranteed by these target groups. In case of bad estimate of demand for pastry a larger amount of non-consumed pastry and bakery products remain to be disposed of [8].

One of the effective ways as regards of cleaner production is reusing of waste in production, allowing especially the implementation of best available techniques (BAT) [9].

F. Bozek is with the College of Business and Hotel Management, 9 Bosonozska, 625 00 Brno, Czech Republic (phone: +420 973 443 170; e-mail: frantisek.bozek@unob.cz).

P. Budinsky is with the College of Business and Hotel Management, 9 Bosonozska, 625 00 Brno, Czech Republic (phone: +420 224 431 000; e-mail: pavel.budinsky@fnmotol.cz).

I. Hoza is with the College of Business and Hotel Management, 9 Bosonozska, 625 00 Brno, Czech Republic (phone: +420 732 681 457; e-mail: hoza@hotskolabrno.cz).

A. Bozek is with the Faculty of Mechanical Engineering, Brno University of Technology, 2 Technicka, 616 69 Brno, Czech Republic (phone: +420 602 828 688, e-mail: A.bzk@unob.cz).

M. Naplavova is with the College of Business and Hotel Management, 9 Bosonozska, 625 00 Brno, Czech Republic (phone: +420 973 442 097; e-mail: naplavovam@gmail.com).

II. Analysis of Current State

Bread is a typical product of bakeries and its production is technologically divided into handicraft production and mechanized production [9], [10].

During mechanized production dough is produced continually from wheat and rye flour with addition of durable rye leavens, solutions of salt and yeast, caraway and drinking water in a masticator [11], [12]. Dough goes to a graduation machine through a conveyer. Required weight of dough is separated and formed into a shape of bread roll on a rolling machine. The semi-product is put into a scuttle with a special device. The scuttle has got a fabric lining and is in a tray-type proofer. After proofing, bread is automatically removed onto a metal baking belt of a continuous oven heated by natural gas. Baked bread is cooled by nozzles with drinking water [13].

Handicraft production is quite different. It is necessary to process dough with higher fermentation efficiency which results in looser dough [11]. Dough is prepared from the same types of flour in kneading-troughs. Masticating is carried out with machines. Time and speed of masticating depend on the properties of flours. Dough matures in larger amount and then it is separated in a vacuum parting machine and rolled in a rolling machine. After that a pancake is rolled on a special device. The pancake is twisted into the form of bread roll with help of grating. Semi-products are caught into floury scuttles which are put into carts to proof in proofers. Proofed pieces of dough are tipped on a setting belt of a multi-story oven and automatically sent into the baking process. High temperature and humidity during baking result in considerable product volume with required moisture, taste and durability [13].

Waste especially in the form of non-consumed pastry results from the product itself. Pastry from the previous day is unsalable due to limited durability and changed sensorial properties linked to that [14]-[16]. Internal recycling can be an effective solution to the problem of non-consumed pastry as a typical measure of cleaner production [8], [17], [18].

Originally 1.12×10^5 kg year^{-1} of produced pastry remained non-consumed, out of which 7.7×10^4 kg year^{-1} were used as feed, because the organization manages its own outlet where stale pastry has been offered without being declared waste. The remaining amount of 3.5×10^4 kg year^{-1} of non-consumed pastry was incinerated in the municipal waste incineration plant [13]. The company has met the legal regulation [19] which enables the energetic utilization of waste in case the material cannot be utilized. However, the bakery management considered this way of disposing stale pastry to be inefficient. The incineration of non-consumed pastry has not been reasonable from the economic viewpoint either, because the price for the incineration varied from 35 to 45 USD per ton of waste.

III. Applied Methods

The detailed input-output analysis was used for the determination of material and energy flows before and after the introduction of BAT, needed to quantify the economic and environmental effects [20].

The methods of Cost-Benefit Analysis and financial analysis became the basis for quantification of the economic effects after implementation of BAT in the process of bread production [21]. The total operating costs associated with the introduction of the BAT, both variable and fixed was identified in the first phase of the process. Thereafter other financial (interests) and the environmental (charges for environmental pollution) costs were analyzed. Subsequently revenues respecting the operational, environmental and other costs of the bakery production before and after the implementation of the BAT were determined and savings from the differences calculated.

Payback period and present value of investment, discounted cash flow and internal rate of return were applied from financial analysis methods for the calculation of economic effects of the BAT implementation [21].

IV. Outcomes and Discussion

The possibility of applying internal recycling together with the evaluation of economic and environmental benefits quantification was verified in the bakery operation. The bakery featured medium enterprise with 197 employees and an annual turnover of about 5.4×10^6 USD, situated in South Moravia region of the Czech Republic [13]. The best available technology (BAT) for the production of durable leavens was installed in above mentioned company. This technology enables quality fermentation process having the parameters comparable to ideal classical leaven. In contrast to other dough leaven processes approximately 25% of dough can be substituted for non-dispatched wheat-rye bread which has got extremely positive effects on fermentation. Due to longer fermentation time and high water content there is wheat-rye bread and wheat pastry of high quality, longer durability and bigger volume with the savings of additives, especially yeast, fat and sugar. At the same time the product has got more distinctive taste and aroma [5], [6].

A. Description of the Installed Technology

The proposed line consists of the following complex of equipment:

a) Leaven making machine for making clear fermentation culture;
b) Leaven making machine equipped with a proportioning pump as well as a device for crushing pastry and weighing on tenzometers;
c) Ripening tanks with the stirring of leaven;
d) Leaven distribution systems from leaven making machines to ripening tanks and from the ripening tanks to masticators;
e) Transport of flour and leaven into fermentation machines;
f) Waterdozers adding water into fermentation machines and a masticator;
g) Control system and its check.

Production and the repeating of basic operation are carried out in the fermentation machine. Production of final leaven is under way in the machinery which has a hard bread self-crushing device. Containers for leaven ripening and storing at a temperature of a bakery have automated system of the dosing of leaven into dough according to a selected technology of leaven and dough production process control.

Durability of leaven, guaranteed by a producer to be up to 7 days, is important for the optimum course of leaven preparation process. Preparation of leaven with a durability of approximately 0.5 hour had been carried out before the above mentioned technology was implemented. After this time period lactic fermentation changed to alcohol fermentation and if the process was not stopped by adding flour the whole batch could not be used anymore and the whole process had to be repeated.

B. Economic and Environmental Benefits

Total investment in the new technology was $IC \approx 7.59\times10^4$ USD. Installation of the new technology was held in the first year of the project and was completed in the second month of the second year. The innovated line for the bread production was triggered into production in the third month of the same year. Economic and environmental benefits achieved after implementing BAT are evident from Tables I-III, total savings from Table IV.

Generation and allocation of company profit and cash flow after the mentioned investment is shown in Table V. It holds for such a situation when machinery was obsolete, needed to be exchanged and depreciation of machines from investment costs was DM = 16.7% [22]. Profit tax rate was calculated to be PTR =31% [22], loan rate LR = 3.15% per year and average annual inflation AAI = 2.80% [23].

TABLE I
PRODUCTION PROCESS EXPENSES AND SAVINGS

Type of expenses	Primary expenses (USD $year^{-1}$)	Expenses after BAT implementation (USD $year^{-1}$)	Savings (difference) (USD $year^{-1}$)
Waste collection, separation and storage costs	2 595	2 595	-
Waste transport costs	194	-	194
Waste disposal costs	1 409	-	1 409
"End of pipe" technologies operating costs	-	-	-
Other expenses	-	-	-
Total	4 198	2 595	1 603

TABLE II
EXPANSES AND SAVINGS REGARDING SOLID WASTE LIQUIDATION

Type of expenses	Primary expenses (USD $year^{-1}$)	Expenses after BAT implementation (USD $year^{-1}$)	Savings (difference) (USD $year^{-1}$)
Waste collection, separation and storage costs	2 595	2 595	-
Waste transport costs	194	-	194
Waste disposal costs	1 409	-	1 409
"End of pipe" technologies operating costs	-	-	-
Other expenses	-	-	-
Total	4 198	2 595	1 603

TABLE III
AIR POLLUTION CHARGES SAVINGS

Charge factors	Primary amount ($year^{-1}$)	Amount after BAT introduction ($year^{-1}$)	Primary charges (USD $year^{-1}$)	Charges after BAT implementation (USD $year^{-1}$)	Savings (USD $year^{-1}$)
Municipal solid waste	-	-	-	-	-
Other waste	-	-	-	-	-
Hazardous waste	-	-	-	-	-
Waters	-	-	-	-	-
Air	-	-	-	-	-
Soil	-	-	-	-	-
Power [a)]	217.478 GJ	203.228 GJ	3 172	2 965	207
Total	-	-	3 172	2 965	207

a) Pollution charge is 14.6 USD GJ^{-1} under the assumption that the thermal energy is generated from black coal and charges for solid emissions, SO_2, NO_x and CO are summed. The calculation of power generation charge assumed there was 33% efficiency during the generation of electric power from thermal power, i.e. 44.2 USD GJ_{el}^{-1}, after conversion 159.1 USD MW^{-1}, when 1 kJ = 3.6 W.

TABLE IV
TOTAL ECONOMIC AND ENVIRONMENTAL BENEFITS AFTER IMPLEMENTING OF BAT

Types of savings	Amount of savings
Total investment (USD)	75 873
Production process savings (USD $year^{-1}$)	29 706
Wastes savings (USD $year^{-1}$)	1 603
Sum of production process and waste savings (USD $year^{-1}$)	31 309
The proportion of annual savings to total value of investment	4.13×10^{-1}
Air pollution charges savings (USD $year^{-1}$)	207
The proportion of annual pollution charges savings to total value of investment	2.73×10^{-3}
Total savings (USD $year^{-1}$)	31 516

TABLE V
GENERATION AND ALLOCATION OF PROFIT AND CASH FLOW AFTER THE BAT IMPLEMENTATION

Type of item	Year 1	2	3	4	5	6	7
Total investment costs (USD)	75 873	-	-	-	-	-	-
Costs of adjustment BAT (USD)	-	-	-	250	-	265	-
Principal business loan (USD)	-	75 873	60 653	42 564	23 905	4 658	-
Revenues (USD)	-	26 999	33 306	34 238	35 197	36 182	37 195
Depreciation of machines (USD)	-	12 671	12 671	12 671	12 671	12 671	12 671
Interest on business loan (USD)	2 390	2 390	1 911	1 341	753	147	-
Gross profit (USD)	-	11 938	18 724	19 976	21 773	23 099	24 524
Profit tax (USD)	-	3 701	5 804	6 193	6 750	7 161	7 602
Profit after taxation (USD)	-	8 237	12 920	13 783	15 023	15 938	16 922
Back-payment (USD)	-	20 000	20 000	20 000	20 000	4 805	-
Cash flow (USD)	- 2 390	20 908	25 591	26 454	27 694	28 609	29 593

TABLE VI
CUMULATED NET PRESENT VALUE OF INVESTMENT IN INDIVIDUAL YEARS

Year	IC (USD)	IC_a [a)] (USD)	IC_R [b)] (USD)	$CF_{(t)}$ (USD)	$(1 + IDR)^{t-1}$	$DCF_{(t)}$ (USD)	$CNPVI_{(t)}$ (USD)
1	75 873	-	-	-	1.00000	- 78 263	- 78 263
2	-	-	-	20 908	1.06175	19 692	- 58 571
3	-	-	-	25 591	1.12731	22 701	- 35 870
4	-	250	-	26 454	1.19692	22 102	- 13 768
5	-	-	-	27 694	1.27083	21 792	8 024
6	-	265	-	28 609	1.34931	21 203	29 227
7	-	-	-	29 593	1.43263	20 656	49 883
8	-	-	7 220	21 402	1.52109	14 070	63 953
9	-	-	-	27 122	1.61502	16 794	80 747
10	-	290	-	27 682	1.71475	16 143	96 890
11	-	-	-	4 777	1.82063	2 624	99 14

a) IC_a means adjustment costs of the technology line
b) IC_R denotes repair costs of the technology line

Payback period of investment $PP \approx 2.56$ years and it has been counted according to the refer (1), where IC means the amount of investment and $CF_{(t)}$ is the cash flow of revenues in the year $t = 7$ when the investment is paid back.

$$PP = \frac{IC}{CF_{(t)}} \tag{1}$$

Dynamic method of the financial analysis takes into account the fact that the value of financial means is changed in dependence on the time. Thus, the discounted cash flow $DCF_{(t)}$ in t-year can be calculated according to (2) in which IDR represents internal discount rate, symbols $CF_{(t)}$ and t have the same meaning as in (1) and $t \in \langle 1; 11 \rangle \wedge t \in N$ and N is the symbol for the set of all natural numbers.

$$DCF_{(t)} = \frac{CF_{(t)}}{\left(1 + \frac{IDR}{100}\right)^{t-1}} \tag{2}$$

Internal discount rate $IDR = 6.175\%$ has been determined with help of (3):

$$IDR = ADR + AAI + BRP \tag{3}$$

where $ADR = 1.375\%$ denotes average discount rate of the Czech national bank, $AAI = 2.8\%$ average annual inflation and $BRP = 2.00\%$ risk surcharge in the time of commencement of production at the upgraded line.

The discounted cash flow $DCF_{(t = 7)} \approx 2.07\times10^4$ USD in the year when the loan has been repaid how it can be seen in Table VI.

When using a dynamic method it can be found out that the mentioned investment will be profitable in the fourth year of operation namely amount approximately 8.02×10^3 USD. Total revenue of the investment during its service life which is 9 years exceeds the amount of 9.95×10^4 USD. Calculation was made with help of (4) and (5), where $CNPVCF_{(t)}$ is a cumulated net present value of cash flow in t-year when internal discount rate $IDR = 6.175\%$. $CNPVI_{(t)}$ means cumulated present value of investment (project) in t-year and $t \in \langle 1; 11 \rangle \wedge t \in N$, $CF_{(t)}$ cash flow from a particular investment in t-year and IC the amount of investment.

$$CNPVCF_{(t)} = \sum_{t=1}^{n} \frac{CF_{(t)}}{\left(1 + \frac{IDR}{100}\right)^{t-1}} \tag{4}$$

$$CNPVI_{(t)} = CNPVCF_{(t)} - IC \tag{5}$$

The amounts of cumulated net present value of the investment $CNPVI_{(t)}$ in individual t-years as well as other necessary data are shown in Table VI.

Under assumption that the service life $s = 9$ years of investment, i.e. in this case $t \in \langle 1; 11 \rangle \wedge t \in N \wedge n = 11$, the internal rate of return IRR was calculated to be roughly 29.2% with use of (6). As the analytic solution of (6) is difficult the approximation method was applied in compliance with (7), where S_1 represents a cumulated net present value of cash flow in a year of investment service life, i_1 an appraised interest rate for which $S_1 > 0$, S_2 is an analogical value of cash flow, when i_2 is an interest rate for which $S_2 < 0$, and it holds that $i_2 > i_1$ and sums of S_1 and S_2 are sufficiently close to zero.

$$\sum_{t=1}^{n} \frac{CF_{(t)}}{\left(1 + \frac{IDR}{100}\right)^{t-1}} - IC = 0 \tag{6}$$

$$IRR = 100 \times \left\{ i_1 + \left[S_1 \times (S_1 - S_2)^{-1} \right] \times (i_2 - i_1) \right\} \tag{7}$$

V. CONCLUSION

Economic and environmental benefits resulting from the implementation cleaner production methodology and best available techniques in food industry have been clearly proved on the example of a bakery. It has been based on the substitution of an obsolete leaven production technology by the best available technology enabling production of durable, high-quality leaven as well as utilization of non-consumed pastry which has not been sold elsewhere due to bad estimate of demand. The implementation of technology required investment costs amounting approximately to 7.59×10^4 USD and resulted in positive economic and environmental benefits not only for the company itself, but also for the society.

Based on the company performance before the implementation of technology the payback period of the investment has been assessed to be circa 2 years and 7 months in case a static method was applied and roughly 3 years and 6 months in case a dynamic method was applied. The supposed company annual average profit after taxation is approximately 1.82×10^4 USD. The internal rate of return is more than 29% under the assumption that the service life of installed machinery is 9 years. Company total net profit from the sale of pastry in the second year after the measure of BAT is introduced was roughly 1.46×10^4 USD as compared with the calculated profit after taxation of 1.29×10^4USD and it corresponds with the above mentioned assumptions.

The environmental benefits were also achieved by the implementation of the measures (BAT). They are represented mainly by the substitution of non-consumed pastry for flour with in the production process and a significant reduction of energy consumption. The reduced energy consumption has resulted in the reduced environmental burden caused by emissions the value of which expressed in the form of economic indicator makes approximately 207 USD of social savings each year. Parallel to these effects it was reduced drinking water consumption, thus the production of sewage water, waste disposal and transport costs and dustiness of environment.

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