CHAPTER 6

ENVIRONMENTAL IMPACTS OF IMPROVED TECHNOLOGY FOR PROCESSING GOLDEN BROWN DRIED LONGAN FLESH

Production of golden brown dried longan flesh in Tambon Makhuea Chae for market began about 25 – 30 years ago. At the beginning, the drying operation was based on traditional folk method with the use of wood fueled cooking stove to dry at low heat the peeled and pitted longan fruits which were laid on bamboo-wicker tray placed over the stove. Later, an improved system for longan drying was introduced involving the use of oven built according to the local knowledge. The oven is a galvanized iron open chamber with multiple shelves for placing the drying trays to enable the production of more output in one time operation. It is heated by external burning of longan fuel wood; and the heat is transmitted through a connective iron tube into the oven which is installed with a number of electric fans working to circulate the heat.

There are a number of disadvantages of this conventional oven and one of them is the leakage of heat from the opened front that causes the use of unnecessarily large volume of fuel wood as well as the physical discomfort for the oven attendant. Furthermore, the galvanized iron used as oven walls cannot prevent the thermal leakage. Meanwhile, this type of oven needs intensive labor input for feeding fuel wood and regulating the temperature as well as switching the trays in alternation to assure the right color and texture of the dried fruits. Therefore, attempts have been made to overcome the afore-mentioned shortcomings by developing alternative model of oven to increase the fuel wood input use efficiency and lessen the dependence on human input in controlling the physical quality of dried longan. Finally, a modified version of the conventional styled oven or an improved technology was developed and has been adopted for use to certain extent. The improved technology is featured by the replacement of galvanized iron by insulating material to assure heat containment and the installation of cavity door to prevent heat dissipation as well as the use of thermostat to regulate the fanning speed to draw the external burning heat into the oven. From the 2011 survey, there were only four GDL processors that used the improved ovens. However, the relevant hard data exist enough to enable the analysis on the environmental implications as well as the efficiency of improved technology from the reduction in fuel wood use, and the cost saving in terms of labor and electricity inputs. This chapter reveals the characteristics of GDL processors, efficiency comparison analysis between two groups of sampled GDL processors and efficiency analysis by meta-frontier concept as the following sections.

6.1 Socio-economic characteristics of sampled GDL processors

The investigation on general socio-economic characteristics of 48 sampled golden brown dried longan processing households was undertaken to gain an insight into the difference in their production behavior, with the details in the following sub-topics.

6.1.1 General characteristics of GDL processors

The majority of sampled GDL processors (20 individuals or 41.64 %) were in 41 – 50 years old age group (Table 6.1). The second largest age group was 51

- 60 years old comprising 15 processors or 31.25 % of the total. Only two samples (4.17 %) each were in the under 30 years old and over 60 years old age groups.

Table 6.1 Characteristics of GDL processors

Description			**Gender**		**Total**
			male	**female**	
Age	under 30	number	2	0	2
		percentage	4.17	0.00	4.17
	30-40 years	number	5	4	9
		percentage	10.42	8.33	18.75
	41-50 years	number	12	8	20
		percentage	25.00	16.67	41.67
	51-60 years	number	7	8	15
		percentage	14.58	16.67	31.25
	over 60 years	number	0	2	2
		percentage	0.00	4.17	4.17
Education	primary school	number	15	18	33
		percentage	31.25	37.5	68.75
	secondary school	number	6	3	9
		percentage	12.5	6.25	18.75
	high school/technical school	number	1	1	2
		percentage	2.08	2.08	4.17
	diploma /vocational college	number	1	0	1
		percentage	2.08	0.00	2.08
	bachelor’s degree	number	2	0	2
		percentage	4.17	0.00	4.17
	master’s degree	number	1	0	1
		percentage	2.08	0.00	2.08
Total		number	**26**	**22**	**48**
		percentage	**54.17**	**45.83**	**100**

Source: Survey, 2012

Most of the processors (33 individuals or 68.75 %) completed primary education. Nine (18.75 %) out of the total samples finished secondary education while the remaining two (4.17 %) each attained high school or vocational school certificates and university degrees. Altogether 37 processors (77.1 %) obtained loans for working capital from two sources while 8 (16.7 %) did so from only one source (Tables 6.2). Their most popular credit sources were the Bank for Agriculture and Agricultural Cooperatives (BAAC) and the Village Fund (VF) as these two financial institutions usually allow the small scaled producers or manufacturers to get an easy access to loans at lower interest rates than those of other credit providers, which is the fundamental organizational objective and mission of both BAAC and VF.

6.1.2 The GDL features of processing among the sampled processors.

1) Drying ovens

Two types of drying oven were used: conventional design and improved version. The existing ovens were ready for drying in-season as well as off-season longan fruits. In the previous natural longan season, a total 44 processors used the conventional ovens and 34 out of which each used one oven while the remaining 10 each used two ovens. There were four processors that each used one improved oven during the same season. Apparently, there was an underutilization of the drying facilities as the number of processors owing two ovens was 25 and that of those owing one oven was 20. The examination on the relationship between oven availability and utilization indicated, based on the value of Pearson chi-square at 99.0 % confident level, that the number of ovens in operation varied with the number of available ovens in the past longan season thus implying the use of the available facilities to the full capacity. The available ovens were underutilized in 2011 natural longan season because the higher price of fresh longan in comparison to prices in previous years and the unattractive dried longan price had discouraged GDL processors from increasing production capacity. Some processors even lowered their output level to avoid the risk from high production costs.

2) Length of longan drying operation

Longan drying is a non-stop operation until the raw materials are not available. It was common among the majority 36 processors (75 %) to run the longan drying operation for 30 days' duration. The next most common length of operation was 20 days among nine processors (18.75 %). The types of oven either conventional or improved appeared to have nothing to do with the length of longan drying operation. The optimal drying season should last 30 days because the best longan fruits will come from the 30 days' length in the middle of 30 – 45 days' harvesting season when the mature fruits are large, with good weight and relatively sweeter taste. Naturally, longan output becomes lower at the end of harvesting season while its price gets higher and at the same time the degree of fruit sweetness declines, and all these factors cause a higher cost of longan drying per oven. Therefore, the appropriate length of longan drying operation is 30 days (Table 6.4).

Table 6.2 Loan source of GDL processors

Source	Borrower		Non-borrower	
	number	percentage	number	percentage
Bank for Agriculture and Agricultural Cooperatives	42	87.50	6	12.50
Village Fund	33	68.75	15	31.25
Commercial bank	7	14.58	41	85.42
SME Bank	9	18.75	39	81.25
Relatives	1	2.08	47	97.92

Source: Survey, 2012

Table 6.3 Use of drying ovens

Type of drying oven				Existing ovens			Total
				1	2	3	
Operating ovens	Improved	**1**	number	1	2	1	4
			percentage	25.00	50.00	25.00	100.00
		2	number	0	0	0	0
			percentage	0.00	0.00	0.00	0.00
	Conventional	**1**	number	19	13	2	34
			percentage	55.88	38.24	5.88	100.00
		2	number	0	10	0	10
			percentage	0.00	100.00	0.00	100.00
Pearson Chi-Square = 11.621***				Asymp. Sig. (2-sided) =0.003			
Likelihood Ratio = 15.476***				Asymp. Sig. (2-sided) = 0.000			
Linear-by-Linear Association=4.386**				Asymp. Sig. (2-sided)=0.036			

Source: Survey, 2012

Table 6.4 Length of longan drying operation

Length of longan drying operation		Oven type		Total
		improved	conventional	
20 days	number	0	9	9
	percentage	0.00	20.45	18.75
25 days	number	0	1	1
	percentage	0.00	2.27	2.08
30 days	number	4	32	36
	percentage	100.00	72.73	75.00
40 days	number	0	1	1
	percentage	0.00	2.27	2.08
60 days	number	0	1	1
	percentage	0.00	2.27	2.08
Total	number	**4**	**44**	**48**
	percentage	**8.33**	**91.67**	**100.00**

Source: Survey, 2012

3) Statistical difference between the two technologies in use of factor inputs

The tests of statistical difference between the two technologies in various aspects (Table 6.5) indicated that fuel wood consumption differed at 99 % significant level (p = 0.005), labor input and electricity cost differed at 90 % significant level (p = 0.067 and p = 0.056, respectively), while the fresh longan raw material cost and the output value or the total revenue were not different statistically between the use of conventional oven and that of improved oven. As the consumption of fuel wood and electricity and the use of labor input in the case of improved oven are lower and differ statistically significantly in comparison with conventional oven, the use of improved oven will ensure cost efficiency of the longan drying enterprises. The saving of production cost or the gain in cost efficiency is the consequence of modification of the conventional oven design with the additions of insulating material, steel cavity door, and thermostat to prevent heat dissipation and regulate the heating temperature. Meanwhile, the raw material input level had no relationship with the technological level.

6.2 Efficiency comparison between two groups of sampled GDL processors

The comparison was performed in reference to the group frontiers. This study found the average technical efficiency of conventional oven users to be 0.944 with the lowest efficiency score of 0.777 (Table 6.6). Specifically, in this group, there were 12 processors (27.27 %) operating on the group frontier while 32 other processors (72.73 %) working below the frontier line. All four processors using improved oven apparently were operating on the group frontier thus were fully technically efficient.

Table 6.5 Summary statistics of data on firms processing golden dried longan

Variable	Conventional technology 44 observations	Improved technology 4 observations	Mann-Whitney U test	Pooled data 48 observations
Output (total revenue)				
mean(baht)	24,548	33,323	Mann-Whitney=55.00 ρ value=0.218	25,278
st.dev	3,955	13,362		5,631
max(baht)	37,200	48,248		48,248
min(baht)	16,975	19,074		16,975
Input1(fresh longan)				
mean(baht)	17,686	22,550	Mann-Whitney=70.00 ρ value=0.495	18,091
st.dev	2,492	7,709		3,364
max(baht)	23,400	31,391		31,391
min(baht)	12,015	15,712		12,015
Input2(labor)				
mean(baht)	4,108	5,839	Mann-Whitney=39.00* ρ value=0.067	4,252
st.dev	515	2,151		878
max(baht)	6,351	8,346		8,346
min(baht)	3,270	3,848		3,270
Input3(fuel)				
mean(kg)	739	546	Mann Whitney=14.50*** ρ value=0.005	722
st.dev	136	29		140
max(kg)	1,041	573		1,041
min(kg)	525	505		505
Input4(electricity payment)				
mean(baht)	179	130	Mann Whitney=37.50* ρ value=0.056	175
st.dev	56	14		55
max(baht)	300	150		300
min(baht)	100	120		100

Source: Survey, 2012

Note ***sig at 0.01 level for 2-tailed test

* sig at 0.10 level for 2-tailed test

Table 6.6 Technical efficiency scores of GDL processors using different oven types

Oven type		Observations		Average efficiency score
		efficient (TE=1)	inefficient (TE<1)	
Improved	number	4	0	1.0
	percentage	100	0	
Conventional	number	12	32	0.944
	percentage	27.27	72.73	

Source: Survey, 2012

By group comparison, the average efficiency score of processors using improved oven was 1.0 while that of those using conventional oven was 0.997 indicating the relative inefficiency of the latter group. However, the knowledge about technical efficiency from input – output relationship is not fully meaningful unless other contributing factors are understood. The following investigation is an attempt to establish the relationship between technical efficiency and other production environments and conditions.

1) Borrowed capital and efficiency

Generally, the GDL processors have to get loans for use as working capital or even for fixed factor investment. It was found from this study that three out of four efficient processors using improved oven each borrowed more than 250,000 baht while 12 (85.71 %) out of the 14 efficient processors in the conventional oven group each made borrowing in various ranges between 50,001 and over 250,000 baht. Meanwhile, the majority 14 inefficient processors in the conventional oven group each borrowed 50,001 – 100,000 baht for working capital (Table 6.7). The Pearson chi-square value of 13.521, for analyzing the relationship between efficiency scores and the amount of borrowed capital at 99 % statistically significant level, clearly reflects that borrowing can impair efficiency. This is because the large working capital from loans can enable the processors to pay for production process and technological improvements as well as pay for the extremely high daily expenses involving the purchase of fresh longan, the employment of peeling and pitting labors, fuel wood cost, transportation cost, payment for oven attendant, as well as the provision of food and drinking water for the processing labors. In other words, the small sized loans cannot allow some processors to improve their production process and technology in a short span of time.

However, there are three processors having small capital borrowing size (50,001 - 100,000 baht) that are efficient because all three have established a good management system involving the control of drying oven attendants, the control of payment for peeling and pitting labors, and the use of quality raw materials (fresh longan fruit grading). They thus can become efficient despite the low loan use levels.

Table 6.7 Efficiency score and capital borrowing size

Oven type			Capital borrowing size					Total
			50,001 - 100,000 baht	100,001 - 150,000 baht	150,001 - 200,000 baht	200,001 - 250,000 baht	> 250,000 baht	
Improved	inefficient	number	0	0	0	0	0	0
		percentage	0.00	0.00	0.00	0.00	0.00	0.00
	efficient	number	0	0	0	1	3	4
		percentage	0.00	0.00	0.00	25.0	75.0	100.0
Conventional	inefficient	number	14	8	6	0	2	30
		percentage	46.77	26.76	20.0	0.00	6.77	100.0
	efficient	number	3	3	3	3	2	14
		percentage	21.43	21.43	21.43	21.43	14.29	100.0
Pearson Chi-Square = 13.521***					Asymp. Sig. (2-sided) =0.009			
Likelihood Ratio = 14.942***					Asymp. Sig. (2-sided) = 0.005			
Linear-by-Linear Association=9.975***					Asymp. Sig. (2-sided)=0.002			

Source: Survey, 2012

2) Processors' experience and efficiency

Experience was found to explain production efficiency. Specifically, GDL processors having high or many years experience in the drying operation were relatively more capable of improving their production process and productivity to achieve greater technical efficiency. Of all processors, 27.08 % also regarded as inefficient were in the 6 – 10 years experience group while 12.50 % also recognized as efficient were in the 11 -15 years experience group. The inspection based on oven type revealed that the conventional oven users had relatively shorter working experience and the majority of them or 29.55 % had 6 – 10 years experience while 75 % of the improved oven users had 11 - 15 years experience. It should be noted that those improved oven users had prior experience from using the conventional oven, were familiar with the problems and weakness of the conventional oven, and had the knowledge about comparative costs and returns. All these experiences and knowledge have contributed to their high technical efficiency. This is supported by the Pearson chi-square = 22.886 at 90 % statistically significant level for the test of relationship between experience and efficiency (Table 6.8)

Meanwhile, eight conventional oven users with 11 -15 years' experience and those two with 16 – 20 years' experience appeared to be technically inefficient. However, the survey data revealed that these processors had recognized the importance of oven improvement but they have to take into account the money they need for the investment and the length of time needed for the modification and improvement of the drying oven; and quite probably they will do it in the following crop year.

Table 6.8 GDL processing experience, oven type, and technical efficiency

Length of GDL processing experience		Conventional ovens		Improved ovens		Total	
		inefficient (TE<1)	efficient (TE=1)	inefficient (TE<1)	efficient (TE=1)	inefficient (TE<1)	efficient (TE=1)
Under 5 years	number	9	3	0	0	9	3
	percentage	20.45	6.82	0.00	0.00	18.75	6.25
6-10 years	number	13	4	0	0	13	4
	percentage	29.55	9.09	0.00	0.00	27.08	8.33
11-15 years	number	8	3	0	3	8	6
	percentage	18.18	6.82	0.00	75.00	16.67	12.50
16-20 years	number	2	1	0	1	2	2
	percentage	4.55	2.27	0.00	25.00	4.17	4.17
21-25 years	number	0	1	0	0	0	1
	percentage	0.00	2.27	0.00	0.00	0.00	2.08
Total	number	32	12	0	4	32	16
	percentage	72.73	27.27	0.00	100.00	66.67	33.33
Pearson Chi-Square = 22.886*				Asymp. Sig. (2-sided) =0.087			
Likelihood Ratio = 27.303**				Asymp. Sig. (2-sided) = 0.026			
Linear-by-Linear Association=3.586**				Asymp. Sig. (2-sided)=0.050			

Source: Survey, 2012

3) Problem of input slacks among GDL processors

In the conventional oven users group, 16 processors (36.36 %) used best practice input – output combinations meaning that they did not use any input excessively (Table 6.9). Fifteen processors (34.09 %) should cut down the use of one input, 11 (25.00 %) should reduce the level of two inputs, and the other two (4.55 %) should try to manage to minimize three inputs. The most critical and most common excess input was fuel wood, to which the majority of conventional oven users must pay attention but so far they had neglected to manage the use to improve the efficiency. Most processors habitually did not pay heed to oven temperature but constantly fed the fuel wood for burning despite the existing high oven temperature.

Furthermore, the absence of temperature monitoring and regulating device can be a factor causing input slack. Meanwhile, the problem of input slacks was not present in the group of processors using improved oven as the improvements in oven features in fact were made to minimize fuel wood consumption.

Table 6.9 Input slacks of GDL processors

Input slack	Conventional ovens		Improved ovens		Total	
	number	percentage	number	percentage	number	percentage
No input slack	16	36.36	4	100.00	20	41.67
1 input slack	15	34.09	0	0	15	31.25
2 input slacks	11	25.00	0	0	11	22.92
3 input slacks	2	4.55	0	0	2	4.17
4 input slacks	0	0.00	0	0	0	0.00
Total	**44**	**100**	**4**	**100**	**48**	**100**

Source: Survey, 2012

Excess input definitely has the implication on production cost and net revenue of the enterprise. Those GDL processors having three input slacks obviously incurred higher costs for fresh longan fruits, labor, and energy than the other groups. As evident from Table 6.10, they spent 20,310 baht for fresh longan and 5,020 baht for peeling and pitting labor per oven operation, used 867 kg of fuel wood per oven, and paid averagely 210 baht electricity cost per oven per day. In the other extreme case, those processors with no input slack spent 17,499 baht and 4,233 baht per oven for fresh longan and labor respectively, used 617 kg of fuel wood per oven, and paid on the average 162 baht per oven per day for electricity input. On the revenue side,

Table 6.10 Revenue and input expenses classified by input slack category.

Input slack category		Total revenue (baht/oven)	Fresh longan value (baht/oven)	Labor cost for peeling and pitting (baht/oven)	Fuel wood consumption (kg/oven)	Electricity cost (baht/oven)
None	Mean	27,326	17,449	4,233	617	162
	Std. Deviation	8,077	4,539	1,224	93	59
	Minimum	16,975	12,015	3,270	505	100
	Maximum	48,248	31,391	8,346	833	300
One input slack	Mean	25,057	18,289	4,158	739	175
	Std. Deviation	2,476	1,768	360	96	53
	Minimum	21,560	15,457	3,750	550	120
	Maximum	30,135	22,500	4,973	833	300
Two input slacks	Mean	25,097	18,585	4,274	866	191
	Std. Deviation	3,143	2,548	342	119	35
	Minimum	20,125	15,437	4,000	595	120
	Maximum	32,400	23,400	4,908	1,041	250
Three input slacks	Mean	25,341	20,310	5,020	867	210
	Std. Deviation	7,532	3,266	1,881	47	127
	Minimum	22,000	18,000	3,690	833	120
	Maximum	32,653	22,619	6,351	900	300
Total	Mean	25,279	18,091	4,252	723	175
	Std. Deviation	5,631	3,365	879	141	55
	Minimum	16,975	12,015	3,270	505	100
	Maximum	48,248	31,391	8,346	1,041	300

Source: Survey, 2012

the average processor with no input slack earned 27,326 baht per oven, 1,985 baht more than the average earning at 25,341 baht per oven of the processors with three input slacks. The excessive use of inputs can be attributable to the processor's negligence to assess production cost and oven capacity, their practice according to experience, as well as their lack of attention to oversee all stages of processing operation. The appropriate control over the use of inputs can help reduce input use as well as money input to the technically feasible level.

In the consideration of input slack differentials among various processors using conventional oven and improved alternative, it was found none of the improved oven users had input slack because all of them were already operating at the efficient input – output combinations. However, the processors using conventional oven encountered different situations from none to four input slacks which need to be handled differently. Based on information in Table 6.11, there are possibilities to eliminate input slack(s) without affecting the existing output levels as described below.

(1) Fresh longan fruits: Ten (22.73 %) of all processors using conventional oven can possibly save the money for buying fresh longan by 861.96 baht per oven on average while the processor no. 22 might be able to save the cost up to 1,474.37 baht level and the processor no. 11 being in the least inefficient position should manage to save by 470.82 baht per oven. The possibility depends on the price and fruit weight of fresh longan which keep varying from early to late harvesting season. Experienced processors with knowledge and skill will arrange for the longan buying and drying activities to take place during appropriate time to get longan at relatively low prices, with good quality and fruit weight, and consequently a high economic return. Thus the lack of knowledge and experience on the part of longan drying operators may result in the problem of input slack.

Table 6.11 Number of processors having the input slacks

Firms	Technology	TE*	Input slacks			
			Fresh longan value(baht/ oven)	Labor cost for peeling and pitting(baht/ oven)	Fuel wood consumption (kg/oven)	Electricity cost (baht/oven)
1	Improved	1.000	-	-	-	-
2	Improved	1.000	-	-	-	-
3	Improved	1.000	-	-	-	-
4	Improved	1.000	-	-	-	-
5	Conventional	1.000	-	-	-	-
6	Conventional	1.000	-	-	-	-
7	Conventional	1.000	-	-	-	-
8	Conventional	0.980	-	385.21	-	-
9	Conventional	1.000	-	-	-	-
10	Conventional	0.976	-	413.94	26.39	-
11	Conventional	0.980	470.82	900.76	292.1	-
12	Conventional	0.920	-	-	-	-
13	Conventional	0.919	-	-	-	-
14	Conventional	0.863	1110.70	-	-	-
15	Conventional	0.992	869.77	-	-	-
16	Conventional	1.000	-	-	-	-
17	Conventional	0.942	-	-	44.73	-
18	Conventional	0.948	620.71	-	-	-
19	Conventional	0.954	1002.49	-	80.03	153.74
20	Conventional	1.000	-	-	-	-
21	Conventional	1.000	-	-	-	-
22	Conventional	0.889	1474.37	-	235.43	-
23	Conventional	0.856	-	-	29.99	-
24	Conventional	1.000	-	-	-	-
25	Conventional	0.894	-	-	42.29	-
26	Conventional	0.908	-	-	-	31.59
27	Conventional	0.857	-	-	-	37.54
28	Conventional	0.842	-	-	172.54	38.97
29	Conventional	0.989	-	-	187.65	79.63
30	Conventional	0.884	-	-	55.75	28.17
31	Conventional	0.988	-	-	156.89	-
32	Conventional	1.000	-	-	-	-
33	Conventional	0.893	-	-	104.	-
34	Conventional	0.997	727.58	-	-	-
35	Conventional	0.808	1029.95	-	-	-
36	Conventional	0.892	-	-	68.11	27.06
37	Conventional	0.777	736.82	-	18.88	-
38	Conventional	0.970	-	-	-	-

Table 6.11 (Continued)

Firms	Technology	TE*	Input slacks			
			Fresh longan value(baht/ oven)	Labor cost for peeling and pitting(baht/ oven)	Fuel wood consumption (kg/oven)	Electricity cost (baht/oven)
39	Conventional	0.910	-	-	28.84	52.41
40	Conventional	0.850	576.38	-	166.55	-
41	Conventional	1.000	-	-	-	-
42	Conventional	0.884	-	-	-	-
43	Conventional	0.897	-	-	8.64	24.31
44	Conventional	1.000	-	-	-	-
45	Conventional	0.900	-	-	10.53	24.31
46	Conventional	1.000	-	-	-	-
47	Conventional	0.985	-	-	186.68	-
48	Conventional	0.988	-	-	84.18	-
average			861.96	566.64	100.04	49.78
Number of processors having the input slacks			10	3	20	10
percentage			22.73	6.82	45.45	22.73

Source: Survey, 2012

(2) Labor cost for peeling and pitting longan fruits: Three or 6.82 % of the conventional oven users should cut down this cost by averagely 566.64 baht per oven. The processor no. 11 should try the hardest to save as far as 900.76 baht while the processor no. 8 should at least reduce the cost by 385.21 baht per oven. The excess use of labors was the least common situation compared to the use of other inputs probably because the wage was paid on the longan flesh weight basis. A fixed daily wage rate may open an opportunity for some labors not to work to full capacity but the payment by piecework or kilograms of longan flesh will be an incentive for labors to produce more outputs.

(3) Fuel wood consumption (kg per oven): This input was most commonly used excessively. Twenty of all conventional oven users or 45.45 % should cut down fuel wood consumption by 100.04 kg per oven on the average to save 120 baht fuel wood cost per oven as the price of one kg fuel wood was 1.20 baht.

The processor no. 22, the most inefficient fuel wood user should try to reduce the input use by 235.43 kg per oven to save 282.51 baht cost. Meanwhile the processor no. 43 should have no difficulty cutting down fuel wood consumption by 8.64 kg per oven and saving 10.36 baht cost per oven. The main cause of this input slack was the habitual practice of those processors using conventional oven to keep feeding fuel wood for burning without paying attention to the oven temperature. The recommended practice is stopping burning fuel wood about half an hour before finishing the drying operation because the heat in the oven will remain enough for further reducing the longan flesh moisture. Another likely reason giving rise to excess input situation is the practice by the oven attendant, generally an unskilled labor, of feeding fuel wood for burning without considering whether or not there is a waste of resource or sometime doing so to expedite the drying process so as to shorten the working hours.

(4) Electricity cost (baht/oven): Ten or 22.73 % of all conventional oven users should reduce the electricity cost by roughly 50 baht per oven on the average. The processor no. 19 currently paying the most should attempt to reduce by 153.74 baht level while those processors nos. 43 and 45 should reduce by 24.31 baht per oven. This input slack occurred because no automatic temperature control device was installed in the conventional oven making it necessary to keep the fans working continuingly for heat circulation or to control the fan speed by human labor and thus causing high consumption of electricity input.

The relationship between processors having no input slack and their efficiency level is positively established at 99.0 % statistically significant level by Pearson's chi-square = 33.60 (Table 6.12), meaning that those processors with no input slack were operating efficiently on the production frontier; particularly all processors using improved oven while having no input slack were producing highly efficient on the frontier. Four conventional oven users namely processors nos. 12, 13, 38 and 42 with no input slack appeared to be operating inefficiently below the frontier line with the efficiency scores of 0.920, 0.919, 0.970, and 0.884, respectively (Table 6.11). Their inefficiency was mainly caused by problems in the management system such as the poor quality control over the off-grade longan fruit raw material resulting in low quality dried longan output and hence lower return per oven compared to the average return per oven of all conventional oven users, and the use of unskilled labors in peeling and pitting operation resulting in damage in longan flesh. The four processors attained rather low return per oven at 24,000, 22,320, 26,875, and 20,350 baht/oven, respectively or averagely 23,536.25 baht/oven compared to the 24,548 baht/oven average level of all conventional oven users, and the 33,323 baht/oven level of improved oven users (Table 6.5).

4) Returns to scale of GDL processors

Analysis of returns to scale is crucial for appropriate allocation of resources by the GDL processors as it explains what happens when the scale of production increases. Chronologically, a firm will operate in three different stages of returns to scale namely increasing returns to scale: IRS, constant returns to scale: CRS, and decreasing returns to scale: DRS. The present study found the majority 39 GDL processors, or 81.25 % of the total were experiencing increasing returns to scale, while eight (16.67 %) processors were operating in the output range of constant returns to scale, and only one processor (2.08 %) had decreasing returns to scale in GDL production (Table 6.13). As IRS indicates the increase in output more than the proportional change in all inputs, the processors operating in this range should take the advantage of increasing output returns by increasing fresh longan raw material which must be accompanied by the increase in labor input for peeling and pitting, as well as the increase in the length of drying season or alternatively in the number of drying ovens. Meanwhile, they have to take into consideration the need to save fuel cost and the ongoing input and output prices because the returns to scale explain only the physical input – output relationship not the economic returns. By the same token, processors in DRS range should lower the raw material volume, employ fewer peeling and pitting labors, shorten the drying season or reduce the number of drying ovens, while trying to save fuel wood and electricity costs. Those processors facing CRS can maintain their existing input – output combinations as output will change at the same rate as the proportional change in input usage unless there is a change in cost or price variable.

Table 6.12 Relationship between efficiency and none input slack

			Input slacks				Total
			None	1	2	3	
Improved ovens	inefficiency	number	0	0	0	0	0
		percentage	0.0	0.0	0.0	0.0	0.0
	efficiency	number	4	0	0	0	4
		percentage	100.0	0.0	0.0	0.0	100.0
Conventional ovens	inefficiency	number	4	15	11	2	32
		percentage	12.5	46.9	34.4	6.2	100.0
	efficiency	number	12	0	0	0	12
		percentage	100.0	0.0	0.0	0.0	100.00
Total	inefficiency	number	4	15	11	2	32
		percentage	12.5	46.9	34.4	6.2	100.0
	efficiency	number	16	0	0	0	16
		percentage	100.0	0.0	0.0	0.0	100.0
Pearson Chi-Square = 33.600***				Asymp. Sig. (2-sided) =0.000			
Likelihood Ratio = 41.089***				Asymp. Sig. (2-sided) = 0.000			
Linear-by-Linear Association=23.525***				Asymp. Sig. (2-sided)=0.000			

Note ***sig at 0.01 level for 2-tailed test

By comparison, the majority three of the four improved oven users were operating in the CRS output range suggesting that the adoption of improved technology can enable the attainment of appropriate input – output combinations while as many as 38 conventional oven users were facing IRS and they should increase their output levels either by adopting new technology or enlarging their inputs proportionally. The chi-square value = 7.788 calculated for testing the relationship between efficiency and returns to scale at 95 % statistically significant level suggests that the GDL processors who used conventional oven remain able to increase input levels to get more outputs and improve their production efficiency.

Table 6.13 Production returns to scale of GDL processors

Oven type			Returns to scale			Total
			DRS	CRS	IRS	
Improved	inefficiency	number	0	0	0	0
		percentage	0	0	0	0
	efficiency	number	0	3	1	4
		percentage	0	75	25	100
Conventional	inefficiency	number	1	2	29	32
		percentage	2.27	4.55	65.91	72.73
	efficiency	number	0	3	9	12
		percentage	0.00	6.82	20.45	27.27
Total	inefficiency	number	1	2	29	32
		percentage	2.08	4.17	60.42	66.67
	efficiency	number	0	6	10	16
		percentage	0.00	12.50	20.83	33.33
Pearson Chi-Square = 7.788**				Asymp. Sig. (2-sided) =0.020		
Likelihood Ratio = 7.705**				Asymp. Sig. (2-sided) = 0.021		
Linear-by-Linear Association=3.160*				Asymp. Sig. (2-sided)=0.075		

Source: Survey, 2012

6.3 Efficiency analysis by meta-frontier concept

Meta-frontier concept was proposed for comparative efficiency analysis of heterogeneous groups (Battese et al., 2004). Thus it is appropriate for application in analyzing the technical efficiency of different technologies; and in the case of GDL processing, the different technologies are represented by conventional oven and improved oven. Before constructing a meta-frontier, it is necessary to perform a test to assure whether statistically significant difference exists between the different variable sets. The present study adopted the Mann-Whitney U test(Pereira and Leslie, 2010) which is generally used for comparing two independent groups, each containing at least 30 samples. Thus it took a non-parametric test approach (Sala-Garrido et al., 2011) because in this study there are only two groups of samples which are not normally distributed. The null and alternative hypotheses for testing are:

H_0: $TE_i=TE_c$

H_1: $TE_i \neq TE_c$

The result of Mann-Whitney U test (28.00) at 95 % statistically significant level ($p = 0.021$) as shown in Table 6.14 indicated that a meta-frontier exists between conventional and improved technologies. Previously, the group frontier analysis revealed the average technical efficiency of processors in the conventional technology group was 0.944 with the poorest performer having the technical efficiency score of 0.777 (Table 6.15 and Figure 6.1). Fourteen processors (31.81 %) were operating on the group frontier while the other 30 (68.19 %) attained below the frontier. Relative to the meta-frontier constructed to envelop both groups' production frontier, the average technical efficiency of processors using conventional oven became 0.939 with the poorest performer having the technical efficient score of 0.777 while 12 processors (27.27 %) were found to operate on the grand frontier and the other 32 (72.73 %) were regarded as inefficient.

Table 6.14 Test for different technical efficiency between 2 groups

Groups	Observations	Mean	Std. Dev	Mann-Whitney U test	$\rho - Value$
-Improved Technology(TE_i)	4	1.000	0.000	28.00**	0.021
-Conventional Technology(TE_c)	44	0.944	0.062		

Source: Survey, 2012

Note **sig at 0.05 level for 2-tailed test

Table 6.15 Technical efficiency and Meta-technology ratio

Groups	Mean	Std. Dev	Maximum	Minimum	Dried longan efficiency (%)
Conventional technology					
Group Efficiency(TEk)	0.944	0.062	1.000	0.777	31.81
Meta-frontier Efficiency (TE)	0.939	0.062	1.000	0.777	25.00
MTRk(TGR)	0.997	0.012	1.000	0.919	
Improved technology					
Group Efficiency(TEk)	1.000	0.000	1.000	1.000	100.0
Meta-frontier Efficiency (TE)	1.000	0.000	1.000	1.000	100.0
MTRk(TGR)	1.000	0.000	1.000	1.000	

Source: Survey, 2012

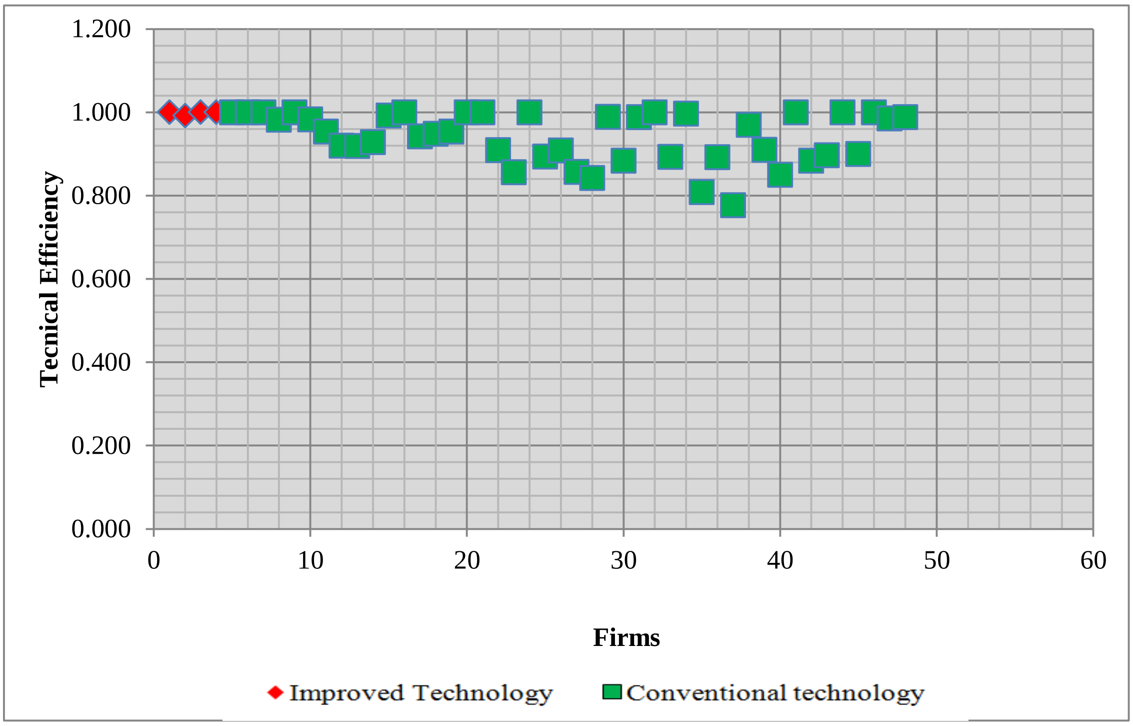

Figure 6.1 Meta-frontier of 48 firms.

As the processors using improved oven all had shown to have technical efficiency score of 1.00, they were also fully technically efficient with respect to the meta-frontier. Thus the two groups combined gave the number of efficient processors, who were operating on the meta-frontier, to be 16 or 31.2 % (Figure 6.1). The other 32 processors using conventional oven now constitute 68.8 % of all samples under study remained inefficient relative to the meta-frontier and the poorest performer still had the technical efficiency score of 0.777. The meta-technology ratio of the conventional technology group was calculated at 0.997 indicating the 99.5 % efficiency in input use while the corresponding figure of the improved technology group was 1.00 demonstrating the full efficiency in input use. It can be concluded that there is a 0.5 % difference in the efficiency between the two groups under the same input sets and the meta-frontier.

Table 6.16 Total revenue, cost, and economic returns of 2 groups on average

Revenue, cost and returns	Conventional technology 44 observations	Improved technology 4 observations
Total revenue (baht/oven)	24,548.00	33,323.00
Cost		
1.Fresh longan (baht/oven)	17,686.00	22,550.00
2.Labor cost (baht/oven)	4,108.00	5,839.00
3.Fuel (baht/oven)	886.80	655.20
4.Electricity cost (baht/oven)	179.00	130.00
Total cost	22,859.80	29,174.20
Returns(baht/oven)	1,688.20	4,148.80

Source: Survey, 2012

Among all conventional oven users, 12 GDL processors in this group or 27.27 % were found to operate on the frontier line (Figure 6.1). The underlying reason for their efficiency was their adoption of good input use management system including the grading system on the fresh longan fruits as raw material input, and the control over the performance of peeling and pitting labors. This had enabled them to operate efficiently on the frontier line just like those processors using improved technology.

6.4 Summary

The results from meta-frontier analysis revealed the existence of quite small efficiency gap between the conventional technology and the improved technology which incorporates the elements of insulating material, cavity door, and thermostat. However, by comparing the input levels per unit output, it was found that the input use efficiency of the improved technology group was relatively higher at statistically significant level in terms of fuel wood, labor, and electricity cost. By means of partial budgeting evaluation, the change to improved technology will involve an investment of 27,050 baht per oven for modification works (detail is in appendix table 6). The modified features will enable the improved oven to consume less fuel wood from the average level of 739 kg per conventional oven for 14 hours or one day drying operation down to 546 kg level (reduce 26.12%) for the exactly same operation. Therefore, the conventional oven used 193 kg excess fuel wood per day. Given the fuel wood price at 1.20 baht per kg (2011 price), the investment for improving the oven taking into account the fuel wood cost saving will have 116 days or two years and 26 days payback period (based on 45 days drying operation in each longan season). The improved technology not only enhances the technical efficiency of GDL processors due to fuel wood saving but also helps lower the carbon dioxide emissions to the atmosphere from fuel wood burning. If all golden brown dried longan processors that have a combined number of 305 ovens adopt the use of improved ovens; then in total for one longan drying season or 45 days, fuel wood consumption can be reduced by 59,475 kg per day, expenses can be saved by 71,370 baht per day, and carbon dioxide emissions can be lowered by 100,070 kg per day (Lu et al., 2009; MacCarty et al., 2008). Furthermore, all GDL processors after the change to use improved ovens will enjoy greater private economic returns from various cost savings.

The comparison in terms of economic returns to GDL processing between conventional oven user and improved oven user groups revealed that the improved oven users generally incurred relatively higher costs for raw material and peeling and pitting labors (Table 6.16) but lower for fuel and electricity. However, the gross revenue on the average of the improved oven user group was much higher than that of conventional oven user group making the average economic return per oven to the former group 2,460.60 baht more than that to the latter group (4,148.80 vs 1,688.20 baht/oven). Therefore, it can be concluded that the technological elements in the improved version of longan drying oven help not only enhance the production efficiency but also reduce the fuel and electricity costs, enabling the shorter pay-back period for investment in getting improved oven for GDL processing.