Optimizing the Winery Operational Scheduling under the Requirement of CO_2 Emission Reduction: A Case Study of Hualien Tourism Winery

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***Abstract*—In this study we use the methods of linear programming model and carbon tax to explore the optimal production of winemaking industry. During the winemaking processes, we must use electricity, fuel oil, and steam, as major energy. The final productions are wine product, wastewater, lees, and CO_2, etc. Different process modes will produce different energy consumption, thus providing a possibility in CO_2 reduction. In the text first we establish the linear programming model, and then under the goal of profit maximization, we explore the carbon tax and the interrelationship caused by changes in energy consumption and the CO_2 reduction. The results show that under different carbon tax levels and operational changes in production schedules that will change the usage of energy and thus reduce the total CO_2 emissions [1]. Carbon tax can trigger the effect of CO_2 reduction. When carbon reduction cost is equal to the taxable cost, the tax effect of CO_2 reduction will result. It shows that profit and loss balance point is the best carbon tax price [2], finally we also analyze the CO_2 inventory policy of winery during the period 2006-2016, the main sources of greenhouse gas emissions were fuel oil, and wastewater.**

***Index Terms*—wine- making process, linear programming, carbon tax**

I. Introduction

In Taiwan we are currently facing serious air pollution problems. China ranks first in the world for carbon dioxide emissions and has announced the "National Carbon Emission Trading Market Construction Scheme." Compared to the international market, Taiwan's emissions trading market is small. It may not be able to produce effective carbon prices or be a driving incentive for reduction. In other words, the effect of emissions trading may not be better than the collection of carbon tax [3]. Therefore, in this study we have used linear programming, carbon tax, and inventory of energy-saving & carbon emissions to explore optimal production in the winemaking industry.

In the first part of this study, the linear programming model of the winemaking industry is established. Second, assuming the goal of minimizing costs and maximizing profits, we discuss the influence of changes to energy consumption and the decrease of CO_2 due to the levying of carbon taxation on the cost [4]. By using cluster analysis, we explore the energy consumption during the winemaking process and analyze the implementation of the greenhouse gas inventory measures then we analyze and compare the sources of greenhouse gas emissions at the winery during 2006-2016 [5].

A. Energy Consumption and Greenhouse Gas Emissions in the Wine Industry

The beginning of Taiwan's winemaking industry was in1947, Tobacco and alcohol bureau was established then changed the name into Taiwan Tobacco & Liquor Corporation - TTL in 2002 July. Rice wine is the most traditional, the largest and the most representative of wine products in Taiwan. In Winery there are five categories and 11 kinds of alcoholic products, in this study we choose 7 kinds of rice wine products as research objects, the different of product with different process and CO_2 emission, the process of winemaking is as follows:

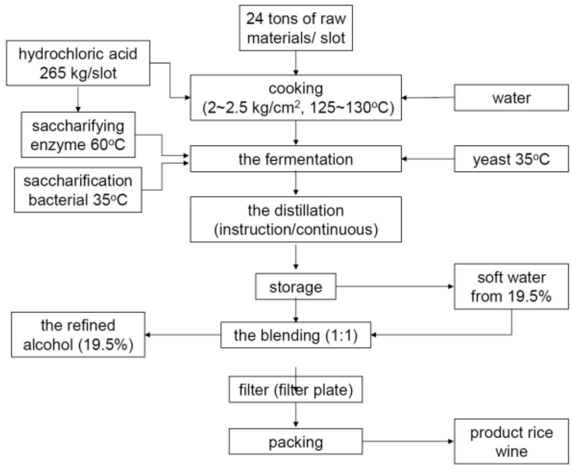

Figure 1. Rice wine-making process

B. Energy Consumption in Industry

Domestic energy consumption in the industrial sector is the largest, it accounts for about 37.1% of the total

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consumption of energy, and the proportion will change with the adjustment of industrial structure. Fig. 2 was the historical statistics of domestic energy supply and demand situation. According to statistics, in 2016 the supply of imported crude oil and petroleum products had been accounting for 48.9% of total supply. The wine-making industry must use heavy oil as a fuel for energy use and emissions CO_2, The environmental problems caused by the GHS are deteriorating now. How to improve our economic development and protect the environment becomes a common challenge.

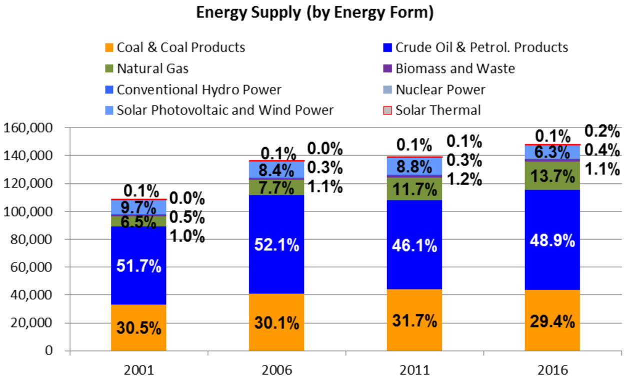

Figure 2. Taiwan's energy supply structure (energy)

C. Analysis of Greenhouse gas Emissions 2006-2016 in Winery

Analysis of the types of greenhouse gas emissions from 2006 to 2016, as shown in Fig. 3, the source of CO_2 emissions were fixed fuel oil as the main source, followed by wastewater, process emissions, electricity and outsourcing.

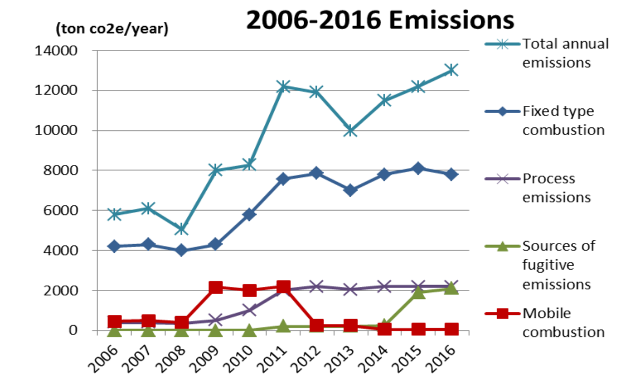

Figure 3. Analysis of greenhouse gas emissions 2006-2016

In Taiwan, our greenhouse gas reduction targets are to achieve greenhouse gas emissions reductions for 2025 carbon dioxide emissions and encourage energy-intensive industries to use the best energy efficient technology (BAT) to effectively manage energy and improve efficiently, especially in industries that must seek the most efficiency use of energy, that is, the minimum CO_2 emissions operation, to pursuit profit maximization. Through the data analysis, the winery from 2006 to 2016, the source of greenhouse gas emissions, with fixed fuel oil as the main source, the results of greenhouse gas inventory shows that CO_2 emission has been improving year by year.

II. Linear Programming Model of Wine Industry

By the model of the linear programming, first we set carbon tax prices, by CO_2 taxation mechanism to analyze changes in the production scheduling process and energy usage, then under the goal of maximizing profit, to explore the interaction between changes in production scheduling and CO_2 emissions reductions [6].

A. The Goal of the Linear Programming Model for Wine Industry

The goal of the linear planning model of wine Industry is the combination of output interest, input cost and carbon cost, expression in monetary terms; the energy goal is to minimize energy input, in terms of quantity or currency; the environmental goal is to minimize CO_2 emissions by quantity .Therefore, there are three targets of the linear planning model, they are economy, energy and environmental protection. Since the purpose is to produce in the production process of obtaining the maximum profit, however, profit is the value of the product portfolio produced in the production process and the cost invested in the manufacturing process, therefore in this text; we must consider minimizing CO_2 emissions the environmental objectives. The following shows the concept of wine industry; its targets are as follows:

1. Economic target: Optimize the allocation of resources, the pursuit of the maximization of production value.

2. Energy Target: Fixed capital investment, the pursuit of the minimum energy supply

3. Environmental target: The pursuits of optimal profit conditions, CO_2 emissions are minimized. The mathematical formula can be measured in monetary units.

B. Establishment of Linear Programming Model for Wine Industry

Linear programming can be mathematically expressed as follows:

$$\underset{a_i \ldots a_M}{\text{maximize}} \quad \sum_{i=1}^{M} P_i a_i - \sum_{i=1}^{M} C_i a_i - \sum_{i=1}^{M} E_i a_i - Pc \sum_{i=1}^{M} Q_i a_i$$

subject to

$$a_i >= 0, \quad i = 1, \ldots, M.$$

$$\sum_{i=1}^{M} a_i \le CAP$$

$$a_i \le \bar{a}_i, \quad i = 1, \ldots, M.$$

$$\sum_{i=1}^{M} Q_i a_i \le CO2$$

Where M is 7, i.e. 7 products.

a_i means the quantity of product i produced in one month.

P_i means the price of product i

C_i means the cost of product i

E_i means the energy consumption(water, fuel, and electricity) of product i

P_C means the carbon tax.

Q_i means the co2 emission of product i

CAP means total quantity limitation

$\bar{a}_i$ means the limitation quantity of product i

$CO2$ means limitation of co2 emission

eq(1) means each quantity of product i should be positive.

eq(2) means total quantity should less than total quantity limitation.

eq(3) means the quantity of product i should not larger than the limitation of it.

eq(4) means the emission should not larget than limitation of co2 emission.

C. *Unit Energy Consumption Setting and Cluster Analysis*

Based on the unit energy consumption characteristics of rice wine manufacturing process, in this study, we use the method of cluster analysis. The purpose of this is to attribute the energy consumption of the process with different characteristics to analyze the change of production capacity of low-energy cluster process and the relation of CO_2 reduction, we use specific energy consumption (SEC), which can be defined as a physical measure of the proportion of energy consumption in production activities to produce inputs or outputs, they are expressed in SEC as follows:

$$SEC\ i = \frac{Ei}{mi}$$ there

SEC i: product / unit i energy consumption;
E i: product / ingredient energy consumption;
M i: product / output of ingredient / ingredient rate.

Using the above calculation method of unit energy consumption (SEC), we can get the numerical value of the energy consumption of each process unit, and divide the energy consumption into unit heat energy produced by fuel, steam and electricity. The data source of unit energy consumption analysis is based on the indicators of energy supplies declared by the wine producers in the annual. As the operating process changes; the usage of energy is also changing. Under different carbon tax, the total energy consumption is also different, when un-taxed, there is the highest amount of emissions, after carbon tax is levied, in order to reduce the emission of CO_2, and the production structure will be operated in the direction of low energy consumption to reduce the total energy consumption so as to reduce the emission of CO_2.

TABLE I. UNIT ENERGY INPUT AND CLUSTER CHARACTERISTICS UNIT: /MONTH

Name of product	CO_2 emission	Fuel oil Ton/month	Electricity Kwh/month	Water (steam) Ton/month	Cluster characteristics
Red label rice cooking wine (0.6L)	129.09	3457.97	23.50	3432.66	high
Red label pure rice cooking wine(0.6L)	1.40	37.50	0.25	36.77	low
Super red label rice wine (0.3L)	142.44	3818.65	25.94	3,788.18	high
Super red label pure rice wine (0.3L)	143.01	3830.92	26.02	3800.44	high
Super red label pure rice wine (0.6L)	23.43	672.85	4.28	625.234	medium
Red label rice wine water (0.6L)	18.55	497.13	3.35	490.38	medium
Gift box(wine)	2.73	73.28	0.50	73.55	low

III. FUEL CONSUMPTION OF RICE WINEMAKING

Using the above calculation method of unit energy consumption (SEC), we can get the numerical value of the energy consumption of each process, and divide the energy consumption into unit heat energy produced by fuel, steam and unit energy used by electricity [7]. The data source of unit energy consumption analysis is based on the indicators of energy supplies declared by the wine producers in the annual report of ITRI manufacturing energy users, including energy consumption per unit of heat (steam and fuel) and unit electricity energy.

A. *Rice Wine Revenue and Costs in 2017*

After levying a carbon tax, due to the increase in the carbon tax cost, to reduce the CO_2 emission cost, the industry will reduce the fixed costs and the operating costs through the reduction of fuel consumption and the adjustment of operating costs. The total cost will increase due to the taxable cost of CO_2 emissions; however, as the carbon tax level increases, the ratio of fixed costs and operating costs, total costs will decrease slightly. The practice of energy conservation and carbon reduction can be achieved through the levy of carbon tax. The method of reducing CO_2 emissions can be achieved by raising the selling price of the product and thus reducing the demand for rice wine, or by reducing the profit of winery and directly suppressing the production of the wine industry. However, the price of rice wine must be considered consumer’s acceptance, on the other hand, to raise the cost of wine industry operators, we must consider the impact of high costs on the industry's competitiveness in the free market. In other words, raising the carbon tax level, although conducive to CO_2 emission reductions, however, once the cost has been raised to a certain level, the absence of related measures will significantly increase the overall production cost of the industry will be unfavorable to the competitiveness of the wine industry.

TABLE II. RICE WINE TOTAL REVENUE AND COSTS 2017

Item	Quantity	Total revenue		Costs	
		Amount USD/year	Total revenue %	Amount USD/year	Total cost %

Red label rice cooking wine (0.6L)	34,736.16	3627765.90	8.64	2636769.60	12.65
Red label pure rice cooking wine(0.6L)	444.96	79389.77	0.19	41756.56	0.20
Super red label rice wine (0.3L)	41,955.12	14813077	35.30	7499834.40	35.99
Super red label pure rice wine (0.3L)	40,453.20	15870234	37.82	73290013	35.16
Super red label pure rice wine (0.6L)	6,325.99	2379750.70	5.67	849456.38	4.08
Red label rice wine water (0.6L)	6,038.80	1193966.00	2.85	321638.48	1.54

B. Empirical Results and Analysis

The data analysis is to illustrate the source of research data, MATLAB simulation software and the CVX module are used to solve the problems of linear programming model [8], this study simulated changes in production based on whether the carbon taxation was levied or not and the carbon taxation levied. Under the basic situation of maximizing the target of economic benefits and minimizing the target of energy consumption, the research model obtains the production benefits, total energy consumption, total CO_2 emissions, in this case, CO_2 is not set as a total emission constrain, so this study uses this as a CO_2 tax constrain under the carbon taxation. The CO_2 emission constrains obtained from solving the basic situation and the environmental targets in the objective function are brought into the research model [9]. The result of solving each carbon tax level and basic situation as shown in Table III under different carbon taxation levels. In addition, the setting of carbon taxation , we adopt the observation index of the literature, taking into consideration the current actual carbon taxation transaction prices and setting them at six levels of 10, 30, 60, 90, 120,150, USD / metric ton CO_2. It is used to construct the linear programming model of wine industry, as a taxation and different carbon taxation standards under the empirical simulation basis and analyzes the impact of changes in energy consumption and CO_2 reduction caused by the levy of the carbon taxation. The results under different carbon tax levels.

TABLE III. COST CHANGES AT DIFFERENT LEVELS OF CARBON TAXATION

CO_2 price ,us /MT	**0**	**10**	**30**	**60**	**90**	**120**	**150**
Cost increase USD/month							
total cost	7,819,397	9,257,434	12,133,507	16,447,617	20,761,727	25,075,837	29,389,947
Fixed costs	7,819,397	7,819,397	7,819,397	7,819,397	7,819,397	7,819,397	7,819,397
CO_2 total costs	-	1,438,037	4,314,110	8,628,220	12,942,330	17,256,440	21,570,550
Operating cost	100	84	64	48	38	31	27
CO_2 tax costs	-	16	36	52	62	69	73

TABLE IV. THE RESULTS UNDER DIFFERENT CARBON TAX LEVELS

CO_2 price ,USD /MT	**0**	**10**	**30**	**60**	**90**	**120**	**150**
CO_2 emission, MT/year							
Total CO_2	7957.17	7949.19	7748.17	7626.97	7614.63	7424.13	7273.54
Fuel oil	6490.11	6487.92	6312.18	6193.00	6176.67	5937.89	5896.96
electricity	1006.41	1002.76	989.70	985.00	991.27	1054.18	947.67
TTL red label rice cooking wine	129.09	129.08	124.20	116.86	123.73	106.45	114.67
TTL red label pure rice cooking wine	1.40	1.38	0.96	1.44	1.36	1.21	1.35
0.3L TTL super red label rice wine	142.44	140.95	136.94	146.69	138.09	123.35	136.85
0.3L TTL super red label pure rice wine	143.01	142.49	140.64	139.97	140.86	159.08	134.67
0.6L TTL super red label pure rice wine	23.43	23.19	22.53	24.14	22.72	20.29	22.51
TTL red label rice wine water	18.558	18.70	18.34	17.20	17.24	18.82	16.29
Wine gift box	2.73	2.72	2.68	2.67	2.69	2.86	2.57

C. Analysis of the Tax Effect

In terms of cost-effectiveness, when CO_2 reduces emissions costs equal to the carbon tax costs, we get the best carbon tax. At this point, the cost of investing in CO_2 to reduce emissions will equal the amount of CO_2 levied tax cost, in other words, the relative CO_2 emission at this time is the emission at the optimal production level, and when reducing CO_2 emissions costs lower than the cost of tax, the wine industry will try its best to reduce CO_2 emissions, however, when the cost of reducing emissions is higher than the cost of tax, wine industry will adopt a strategy of preferring to pay carbon tax to save costs ,that is to say, after the CO_2 tax, whether the wine industry will substantially reduce its carbon emissions it determine whether the taxable cost of CO_2 has already exceeded the CO_2 emission reduction costs .When CO_2's taxable costs are lower, it is less likely to commit itself to carbon reduction because carbon tax is beneficial to the industry [10].

TABLE V. THE CARBON TAXATION EFFECT UNDER DIFFERENT CARBON TAXES

CO_2 price ,USD /MT	**10**	**30**	**60**	**90**	**120**	**150**
CO_2 reduction						
MT/month	23	576	910	944	1468	1884
%	0.10	2.63	4.15	4.31	6.70	8.59
Profit and loss costs, USD/MT-CO_2	9.36	26.26	56.67	83.57	110.81	130.20
CO_2 tax effect						
USD/MT-CO_2	0.63	3.734	3.32	6.42	9.18	19.80
The ratio of carbon (%)	6.38	12.44	5.54	7.13	7.65	13.20

Changing in production may reduce energy consumption costs because of a reduction in energy usage; however, due to the newly increased high cost of tax and the decrease of output value and the increase of the taxable cost due to the decrease of output, the production benefit after tax has been reduced substainly.

IV. CONCLUSION

In this study, we make use of the linear programming model to explore a complicated winemaking process we compare changes in CO_2 emissions when the carbon tax is not levied and the carbon tax is levied. The research goals are to minimize the demand for energy usage, to minimize CO_2 emission requirements and pursuit of maximizing production value. The process of simulation is first to simulate the situation of carbon tax which has not been levied as a basic situation, and then to calculate the total emission of CO_2 under the basic situation as the discharge constrain, finally, under the different levying standards of carbon tax, to simulate a variety of circumstances.

The results show that:

1. The winemaking industry under different carbon tax levels, the producer will undergo to change production schedules, they have changed the structure of their energy usage towards lower-carbon production that will reduce the usage of energy and thus reduce the total CO_2 emissions.

2. As a result of carbon tax levies, wine industries are also under pressure to reduce their total costs, the higher the levy of carbon tax, the greater the effect of carbon reduction. However, when the carbon tax is too high, the high cost of tax barriers will occur and the output of the study with the final demand of each product, the carbon reduction effect is limited.

3. In terms of cost, the levy of carbon tax can trigger the effect of CO_2 reduction. When wine industry's carbon reduction cost is equal to the taxable cost, the carbon tax effect of CO_2 reduction will result. The profit and loss balance point is the best carbon tax level. If the carbon tax level is greater than the best tax rate at the P & L balance, there is an incentive to force the industry to make a mandatory reduction.

After levying carbon tax, the results show that when the cost of tax is greater than the cost of reducing CO_2 emissions, wine industry will change the operational strategy to achieve CO_2 emission reduction, and get the tax effect due to the levy of carbon tax. The results show that when CO_2 taxable price:

(1) At 30 US $ / metric ton - CO_2, the available carbon reduction effect is 2.63%, the tax effect is 3.74 US $ / metric ton- CO_2.

(2) At US $ 90 / metric ton - CO_2, the carbon reduction effect is 4.31% and the tax effect is US $ 6.43 / metric ton- CO_2.

(3) At US $150 / metric ton - CO_2 carbon reduction effect is 8.59% and tax effect of US $ 19.80 / metric ton - CO_2 However, due to the output constraint of the final demand, the CO_2 reduction space for the wine making process that will limit the structure will be less than 10%.

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