WASTE BIOMASS IN TURKEY AND SOLAR DRYING AS A NEW ALTERNATIVE FOR ITS UTILIZATION AS FEED

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ABSTRACT

Sources of waste biomass in Turkey were classified in this study. The amounts belonging to the items of the classification were estimated. The current use of these wastes were discussed and it was suggested that the best way to recycle nutritious wastes was using them as feed. Since some of these wastes are high in moisture, it is essential to protect them against bacterial spoilage by drying. Drying, on the other hand, is an energy intensive process. The economical feasibility as well as the ecological benefit of drying wastes by burning fuels is questionable. An economical solution at least for countries with abundant solar insolation would be the use of solar energy for drying.Various methods of solar drying of food wastes were examined. Open air as well as forced air drying gave bacteriologically inadequate products. Therefore, solar boiler dryers, working at 105°C, were constructed. To prevent the observed temperatures higher than 105°C at the later stages, drying was conducted in two stages. While sterilization and removal of most of the water were achieved by boiling in the solar boiler dryer at the first day, open air drying at the second day allowed to obtain a light brown colored product with trace amounts of bacteria and mold. The energy efficiency for vaporization was 85%. Heat losses of the whole dryer due to

reflection, convection, and radiation were calculated to be 13%, 7%, and 20%, respectively.

Suitability of the material obtained, as animal feed, was tested on broiler chickens. The results indicated that soybean meal protein in broiler diets, can be replaced by the protein of this product up to 40% without any reduction of the weight gain of the birds.

TÜRKİYE'DE ATIK BİYOMAS POTANSİYELİ VE BUNUN HAYVAN YEMİ OLARAK DEĞERLENDİRİLMESİ İÇİN ALTERNATİF BİR YÖNTEM: GÜNEŞ ENERJİSİ İLE KURUTMA

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ÖZET

Bu çalışmada, Türkiye'deki atık biyomas kaynakları sınıflandırılmış ve atık miktarları belirlenmiştir. Bunların şimdiki kullanımları hakkında bilgi verilerek besin değeri yüksek olan atıkları geri kazanmada en iyi yolun, hayvan yemi olarak kullanmları olduğu kararına varılmıştır. Atıkların bazılarının nem yüzdesi yüksek olduğundan, bakteriyel bozulmaya karşı korumak için kurutmak gerekir. Ancak kurutma fazla enerji gerektiren bir işlem olduğu için, en azından güneşlenmenin yoğun olduğu ülkelerde kurutmada güneş enerjisinden yararlanmak ekonomik olabilir.

Gıda atıklarını güneşle kurutmanın çeşitli metodları incelendi. Açıkta kurutma ve hava ile kurutma sonucunda bakteriyolojik açıdan uygun olmayan ürünler elde edildi. Bu yüzden, 105^{o}C de çalışan solar kaynatmalı kurutucular geliştirildi. Kurutma işlemi sürerken 105^{o}C,nin üzerine çıkıldığı gözlenmiş ve bu yüzden kurutma işlemi iki aşamada tamamlanmıştır. Bu yöntemle, birinci gün yeterli sterilizasyon sağlanarak suyun büyük bir kısmı atılmış, ikinci gün açıkta kurutmaya devam edilarak, bakteri ve küf içermeyen, açık kahverengi bir ürün elde edilmiştir. Suyun buharalştırılmasında

kullanılan enerji verimi yüzde 85'tir. Kurutucunun yansıma, taşınma ve ışıma ısı kayıpları sırası ile yüzde 13, 7 ve 20 olarak hesaplanmıştır.

Elde edilen ürünün, hayvan yemi olarak uygunluğunu incelemek üzere etlik piliçler üzerinde yedi haftalık bir deneme yapılmıştır. Bu denemenin sonuçlarına dayanarak, etlik piliç rasyonlarında, soya küspesi proteinin yüzde 40'ının bu üründen karşılanabileceği sonucuna varılmıştır.

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I. INTRODUCTION

Biomass is defined as renewable organic matter produced by photosynthesis. It can be in the form of trees, crops, aquatic plants, animals, and organic wastes of different kinds. Biomass is used as sources of food, feed, raw material for fiber industry, and energy.

Due to the prevailing geographical and meteorological conditions, Turkey is very suitable for forestry and agriculture. Having versatile land and solar insolation, Turkey should have high potential of biomass production. A comparison of the expected biomass capacity and the estimated actual biomass production in Turkey was made in Chapter II. This comparison showed that the biomass production in Turkey is much below the expected yield. The reasons of low biomass production and the ways to increase it were discussed. On the other hand, attempts should be done on efficient utilization of actual biomass in hand. This can be achieved by reusing the waste biomass, namely; all kinds of agricultural and forestry wastes, as well as domestic and industrial organic wastes. Generally, waste biomass is burned or discarded. In both cases, the result is environmental pollution. Therefore, interest to find new processes for utilization of these wastes will not only provide a gain in economical value but also a decrease in pollution.

Accordingly, the objective of this study is to explore alternatives and new methods of using waste biomass efficiently depending on the kind. To start with, sources of waste biomass were classified and the amounts of them were estimated. The current use of these wastes were summarized also in Chapter II. Alternative ways of utilizing waste biomass were inspected and discussed in Chapter III and it was suggested that the most economical way to recycle these wastes was to use them as feed especially if they have nutritious value. Since the possibility of bacterial spoilage of the wastes is high, it is essential to dry and sterilize while processing them. Although drying is an energy intensive process and therefore regarded as expensive, the use of solar energy in a cheap way diminishes this burden. This would be an economical solution at least for countries with abundant solar insolation.

Solar drying of food wastes from the university restaurant were examined. Since open air-drying and forced air drying experiments gave bacteriologically inadequate products, the new low-cost "solar boiler-dryer, working at 105°C, was designed and constructed. The details and results of solar drying experiments are discussed in Chapter IV.

The dried food wastes for five successive days were mixed and suitability of the material, as animal feed, was tested on broiler chickens in the experiments of which the details and discussions are presented in Chapter V.

II. BIOMASS POTENTIAL OF TURKEY AND ESTIMATION OF THE AMOUNT OF WASTE BIOMASS

2.1. Introduction

2.1.1. Ecosystems and Carbon Cycle

Living organisms, plants, animals and microorganisms, cannot function isolated. They can survive as part of an ecosystem, where material is cycled between them. The ecosystem is defined as being composed of the biological community and the physical environment. The borders of the ecosystem are chosen such that there are no feedback effects from the environment to the ecosystem. All ecosystems have similar building blocks: primary producers, consumers, decomposers and nutrient reservoirs. The basic processes in ecosystem are material cycles and the flow and dissipation of energy [1].

Carbon makes up less than 1 percent of our planet, but it is the key element for life on earth. Plants, animals, microorganisms, foods and humanbody are all based on compounds of this versatile element-and carbon compounds in the atmosphere make the planet warm enough for life to evolve. Plants are the major source behind the global carbon cycle. Through photosynthesis, they convert carbon dioxide into carbohydrates that form their stems, trunks, leaves, and roots (Fig. 2.1.1). By fixing carbon in this way the plants themselves grow, and then carbon enters the food chains as animals eat the plants [2].

Both plants and algae are able to make their own organic food by photosynthesis, converting solar energy into chemical energy in carbohydrate molecules. Organisms that can make their own food are known as autotrophs. All other organisms, termed heterotrophs, rely on finding their food ready-made as sugars or other carbon compounds made by green plants. Once plants

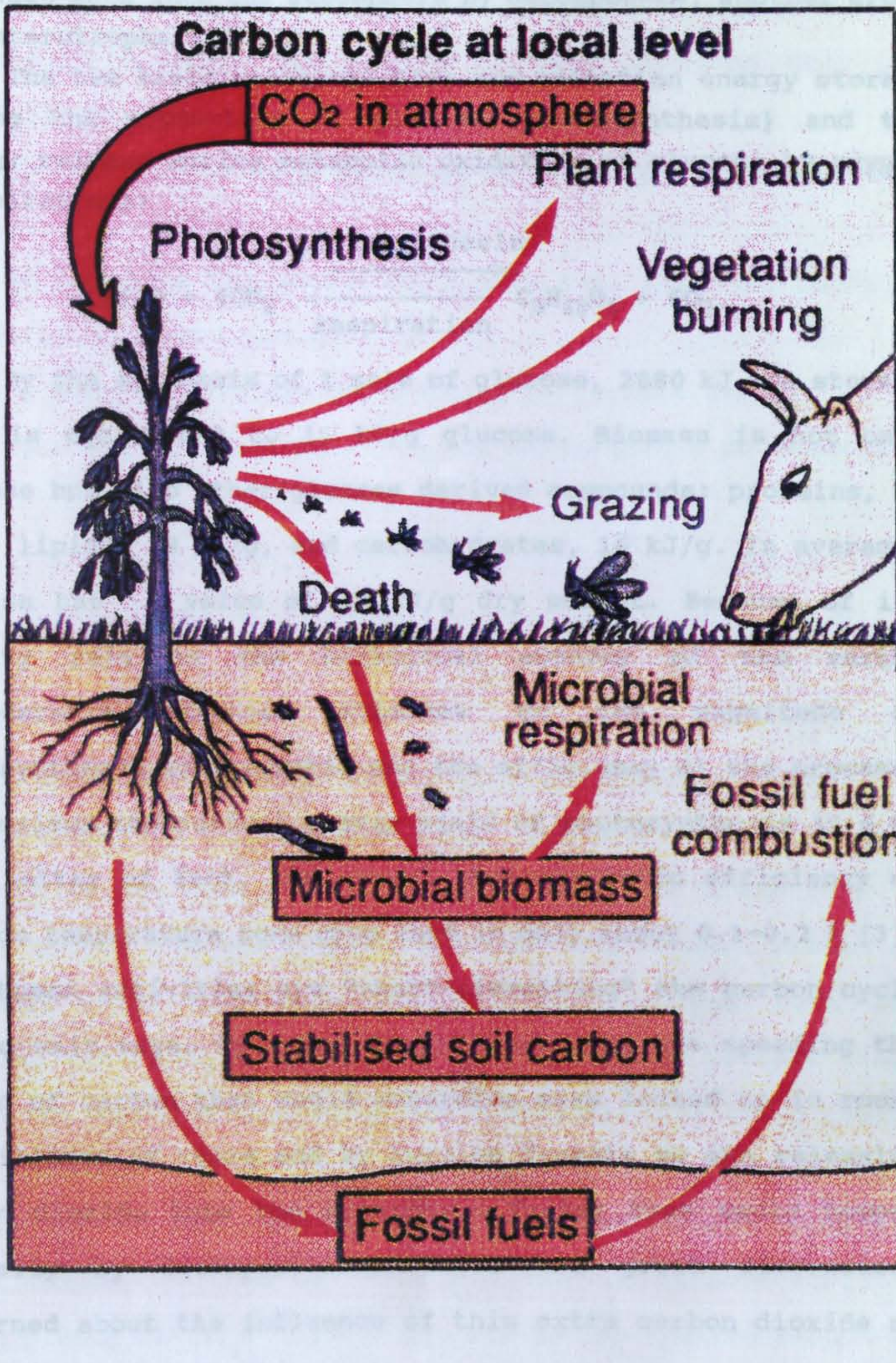


FIGURE 2.1.1. Products and processes of photosynthesis [2].

and animals die, the carbon they have stored is normally released back into the atmosphere by decomposers, another group of heterotrophs [2].

The two basic processes here are radiation energy storage during the production of glucose (photosynthesis) and the energy release during metabolic oxidation of glucose by oxygen (respiration):

$$6H_2O + 6CO_2 \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

By the synthesis of 1 mole of glucose, 2880 kJ are stored. This is equivalent to 16 kJ/g glucose. Biomass is not only glucose but also other glucose derived compounds: proteins, 21 kJ/g, lipids, 38 kJ/g, and carbohydrates, 16 kJ/g. In average, biomass has a value of 20 kJ/g dry weight. Because of its primary role in the biological economy of the earth, considerable interest attaches to the magnitude of photosynthesis in the world and the efficiency of the process. The maximum theoretical energy yield of photosynthesis is 6 %. As a matter of fact, the annual photosynthetic efficiency of average temperature zone crop land is only about 0.1-0.2 % [3].

Human activities are "short-circuiting" the carbon cycle in two main ways. By using fossil fuels, we are speeding the return of carbon that would otherwise stay locked up in rocks for millions of years and by burning forests we are releasing carbon dioxide into the atmosphere faster than would happen naturally by decomposition. There are great discussions concerned about the influence of this extra carbon dioxide on the Earth's climate through the greenhouse effect.

Burning vegetation plays an important part in the global carbon cycle. Many people in developing countries use wood or agricultural wastes as fuel, furthermore both forests and grasslands are burned to create land for farming. Unlike forests, grasslands can recover quickly provided they are carefully managed [2].

Methods suggested in order to overcome this burden include [2]:

a) decrease the amount of fossil fuel used and increase the efficiency of burning,

b) stop or slow the destruction of forests and

c) encourage reforestation and revegetation in general.

2.1.2. Importance of Biomass

Biomass is defined as renewable organic matter produced by photosynthesis, a mechanism that converts solar energy, directly in the case of plants. Biomass can be in the form of trees, crops, aquatic plants, animals, and organic wastes of different kinds. Biomass is used as sources of food, feed, raw material for fiber industry, and energy. At the present time, due to the economic conditions and availability of cheap fossil fuels, biomass is predominantly cultivated all around the world as a source of food. Thought is being given to extending the use of biomass so that every part of the harvestable portions of the plants can be utilized [4]. Due to the limited amount of fossil fuels, biomass should also be considered as a renewable energy source in near future with crops specifically cultivated on energy farms for their fuel content. Fuel crops could be conventional annual crops, fast growing plants or even multiplicant communities [5].

Apart from its economical importance mentioned above, biomass has positive influence on the feed back of the ecosystems and on environmental pollution; like preventing soil erosion, balancing carbon content in the atmosphere, etc. Replacing fossil fuels by biomass energy may be the most cost-effective response to greenhouse effect. Modern biomass fuels that are in use already include substitutes for liquid fuels such as petroleum, and the wood or agricultural wastes that many small power stations now use. Advanced biomass technologies could eventually take over from coal and oil as a major energy source all over the world, without distorting the natural flows of the carbon cycle [2].

2.2. Biomass Potential of Turkey

2.2.1. Theoretical Capacity

Turkey has a surface area of 77.945 Mha with yearly average total solar radiation distribution ranging from 12 to 19 MJ/m^2 per day [6]. Due to the prevailing geographical and meteorological conditions, Turkey is very suitable for forestry and agriculture. The distribution surface area of Turkey by use is given in Table 2.2.1.

TABLE 2.2.1. Distribution of Total Area of Turkey according to Utilization [7].

USE	AREA (hectare)
AGRICULTURAL AREA	27 699 003
FORESTS	23 468 463
GRASSLANDS	21 745 690
OTHER (Marsh, river beds, rocks, etc.)	3 360 248
WATER SURFACES	1 102 396
RESIDENTIAL AREA	569 400
TOTAL AREA	77 945 200

As it is evident from Table 2.2.1, the sum of the agricultural areas, grasslands and forests constitute 93.6 % of the total area of Turkey. Having such a versatile land and high solar insolation, Turkey should have high potential of biomass production. The expected biomass capacity can be approximated by using the world average biomass yields given in Table 2.2.2.

TABLE 2.2.2. Biomass Yields of some Ecosystems [1,4].

Ecosystem	g/m^2year
Forests	800
Agricultural Areas	650
Grasslands	800
Marsh	3000

Taking the values in Tables 2.2.1 and 2.2.2 into consideration, the annual average biomass yields of forests, agricultural areas, and grasslands are estimated as 188 million tons, 180 million tons, and 174 million tons per year, respectively, adding up to 542 million tons of dry biomass per year (Table 2.2.3).

Further, we estimated the yearly actual biomass production in Turkey by using the data for the production of agriculture, grasslands and forestry. For agricultural areas, we took the total production of all agricultural products in one year, given by Turkish State institute of Statistics in 1989 [8] which is approximately equal to 34 million tons/year. The yield of dry biomass on grasslands range from 70 to 200 g/m^2 per year

[9], depending on the characteristics of different types of lands. Considering the ratios of different quality grasslands, the production of biomass from grasslands on a yearly basis was calculated to be 16 million tons. It has been reported that each year 24 million tons of wood is cut from the forests in one year [10]. On the other hand the authorities claim that the illegal wood cuttings are as much as these recorded values. Therefore, we can broadly estimate the wood cuttings as 48 million tons per year. Since, according to our own observations, 300 kg of biomass (leaves and branches) is obtained as residue per m^3 (0.7 tons) of wood, 20 million tons of biomass is produced corresponding to the wood cuttings per year. Thus, it is estimated that, totally 68 million tons of biomass is produced in forestry per year.

Although these values are rough estimations, they show that the biomass production in Turkey is much below the expected yield (Table 2.2.3).

TABLE 2.2.3. Theoretical and Estimated Actual Biomass Production Per Year in Turkey (million tons).

Production	Agriculture	Grasslands	Forestry	Total
Theoretical	180	174	188	542
Present Est.	34	16	68	118

2.2.2. Reasons of Low Biomass Production

Although the area of Turkey is very large, the ratio of the problematic soils to the total area is also high. The classification of the problems of the soils is such that 1.7 % of the soils is barren, 3.1 % is wet, 31.5 % is stony, 63.2 % is exposed to water erosion and 0.5 % is exposed to wind erosion [11]. There are broad variety of reasons for the low production of biomass and the soil problems existing in Turkey. These are discussed separately for agricultural areas, grasslands and forests:

Forestry: Trees in forests are burned and cut without control. The villagers try to create agricultural fields by destroying forests. Usually the surface slopes of these areas are high and because of that the soil is exposed to erosion and the biomass yield decreases rapidly resulting finally in bare rocks. Hence, the lands, which are supposed to be forest, are not forests anymore. Therefore, the biomass yield from the forest area is much lower than the theoretical value. If these areas were properly managed, their biomass production would have been close to the theoretical value.

Grasslands: The primary problem of the grasslands in Turkey is overgrazing. This is again a matter of improper management. Since the grasslands are overgrazed, the vegetation becomes poor and hence the biomass yield decreases.

Fields are obtained by ploughing the natural vegetation of grasslands, which are not suitable for agriculture. There begins again erosion resulting in bare soil. These type of lands cannot be used neither as fields nor as grasslands.

Irrigation and fertilization are the two important factors that increase the yield of dry matter per unit area. If these two necessities are provided on the grasslands wherever possible, the yield may increase by 2-3 times [9].

Agriculture: Since irrigation systems are not well developed in Turkey, most of the farmers apply summer fallow method on their fields wherever annual precipitation is not sufficient. Therefore, the product is obtained once in two years. If the fields are irrigated the yield may increase to once or twice in a year depending on the soil and climatic conditions.

Middle and south-east Anatolia include the highest portion of agricultural areas in Turkey. Distribution of temperature and solar radiation through out the year is very suitable for agriculture in these regions. On the other hand, the rainfall from May to September, which is the period of fast plant growing, is close to zero, and the temperature is high, 20 to 30°C. Therefore water is the most limiting factor for crop production. If modern agricultural techniques, irrigation and fertilizing, are used, the yield may increase up to 3-5 times in these regions.

Discussions above show that, Turkey is below its capacity in biomass production. Production can be increased by applying modern agricultural techniques. Even if there could be over production (more than the national demand), with well planned export policies, Turkey could always find market for agricultural products in neighboring countries as well as in the world market. Also, overproduction in agriculture will bring new possibilities or necessities for the agricultural industry like canning, cotton string, textile etc.

As conclusion, the biomass yield of Turkey can be increased by;

* putting strong measures for illegal cuttings and cultivating of forests and grasslands,

* providing conditions for modern agriculture and

* educating the farmers.

By increasing biomass yield:

* Erosion of the soils will stop.

* There will be more biomass resources for energy, food and fiber industry.

* This will support the national economy by providing more resources and industrial activities.

2.2.3 Efficiency of Biomass Utilization

The majority of the people in Turkey is highly dependent on animal husbandry and agriculture. So, a substantial amount of animal wastes and agricultural crop residues are produced each year. These wastes and residues are unfortunately not used efficiently. Some crop residues are burned on the field. Animal wastes can be of vital importance for soil, but most of them wastes are utilized as fuel by direct combustion in Turkey [12]. Food industry wastes, which cannot be burned, because of their high water content, but rich in nutrients, are not reused at all. Since transportation and storage is difficult for wet wastes, they are left or discarded where they are produced.

Forestry and other industrial wastes are burned or left on the production sites.

In both cases of burning and discarding, the result is environmental pollution so that biomass which is not used (waste biomass) is an environmental burden. Therefore attempts to find new processes for utilization of wastes will not only provide a gain of economic value but also a decrease of pollution.

Depending on the chemical composition, waste biomass can be utilized as energy source, animal feed or fertilizer. If the kind of biomass is of high protein content, the highest economical value could be obtained by using it as feed (instead of burning or using as fertilizer). The objective of this study is therefore to explore alternatives and new methods of using waste biomass in the most efficient way depening on the kind.

2.3. Sources of Waste Biomass and Estimation of Their Amount in Turkey

Sources of the waste biomass may be classified as in the scheme shown in Figure 2.3.1. The amount of the wastes belonging to the items in this classification were calculated by using the data of production (Table 2.3.1) and information about the waste to product ratios obtained from literature or by consulting the producers directly. Although the figures here are rough estimations, the values will give for the first time an idea about the magnitude of the wastes. In estimating the amount of waste biomass, we took in to account only those, which are produced in abundant amounts. Details of calculations are given in the same order as the classification done in Figure 2.3.1. The results of the calculations and informations are summarized in Table 2.3.2. The wastes that are used as wet feed or burned for heating were also included in the table, due to the fact that there may be more efficient alternative ways to use them.

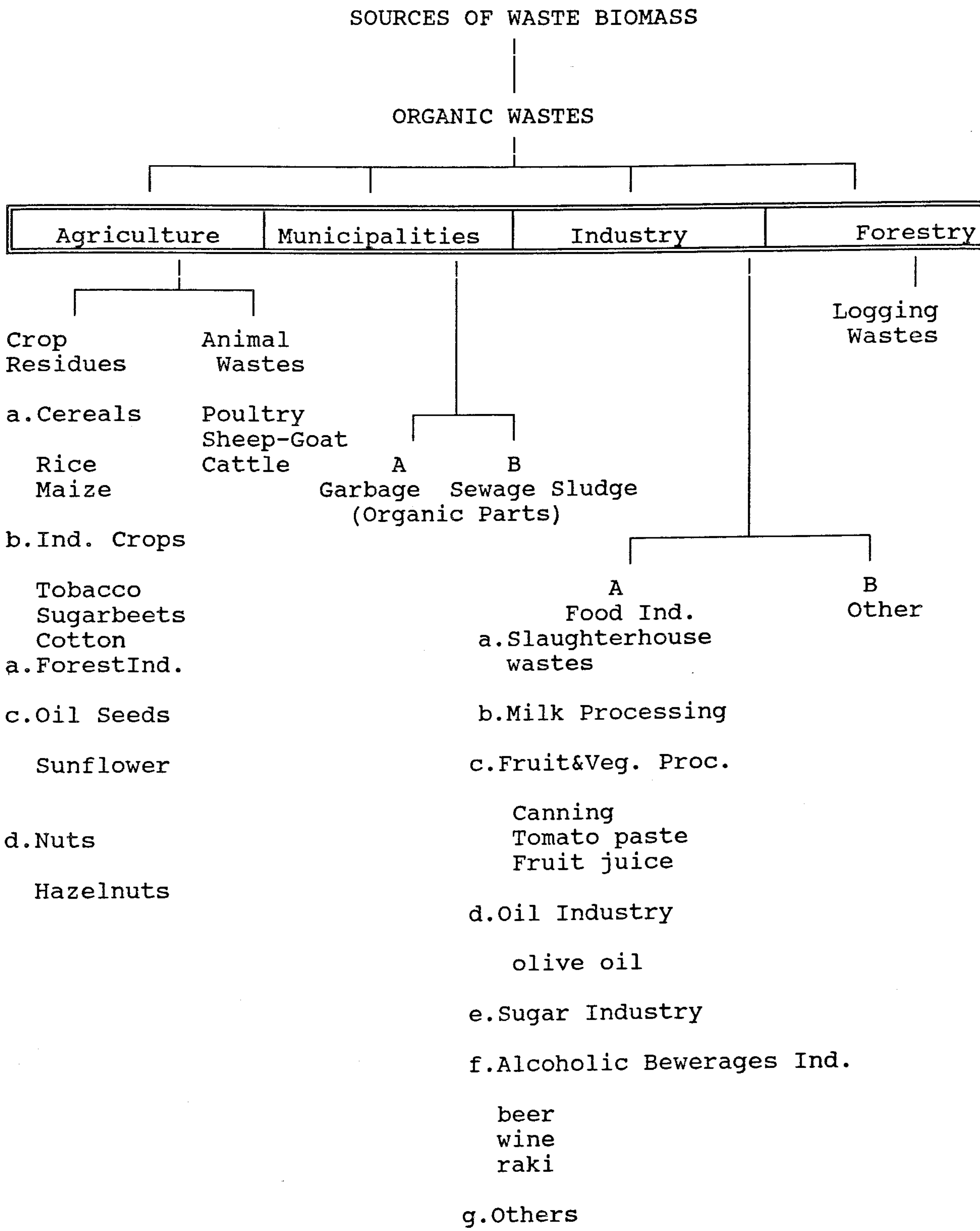


FIGURE 2.3.1. Classification of waste biomass and examples from where waste biomass is obtained in significant amounts.

TABLE 2.3.1. The Production in Agriculture, Industry and Forestry as Important Sources of Waste Biomass in Turkey.

SOURCE OF WASTE	PRODUCTION (tons/year)
AGRICULTURE	
A. Crop	
a. Cereals	
Rice	198 000 [8]
Maize	2 000 000 [8]
b. Industrial Crops	
Tobacco	269 888 [8]
Sugarbeets	10 928 903 [8]
Cotton	617 000 [8]
c. Oil Seeds	
Sunflower	1 250 000 [8]
d. Nuts	
Hazelnuts	550 000 [8]
B. Animals (number/year)	
Poultry	67 179 000 [8]
Sheep-Goat	55 589 000 [8]
Cattle	12 602 000 [8]
INDUSTRY	
A. Food Industry	
a. Slaughterhouses	
number of animals slaughtered	15 385 060 [8]
b. Milk Processing	
Cheese production	145 000 [10]
c. Fruit&Veg. Processing	
Cannery	64 500 [10]
Fruit Juice	52 500 [10]

continued from Table 2.3.1

Tomato Paste	200 000	[10]
d.Oil Industry		
Olive oil	190 000	[10]
Pressed olives	610 000	[8]
e.Sugar Industry		
Sugar	1 650 000	[10]
f.Alcoholic Bewerages Inustry (million liters/year)		
Beer	250	[10]
Wine	44	[10]
Raki	55	[10]
OTHER INDUSTRIES		
Industrial wood processing (m^3/year)	9 449	[10]

TABLE 2.3.2. The Amount of Waste Biomass, their Kinds and Uses Depending on the Sources.

SOURCE OF WASTE	AMOUNT OF WASTE (dry tons/year)	KIND	USES
I. AGRICULTURE			
A. Crop Residues			
a. Cereals			
Rice	75 000	stalks	burned on the field
Maize	690 000	stover	burned for heating
b. Industrial Crops			
Tobacco	44 000	stalks	burned on the field
Sugarbeets	956 000	leaves etc.	used as feed or left on the field
Cotton	1 500 000	stalks	burned for heating
c. Oil Seeds			
Sunflower	3 750 000	stalk & head	burned for heating
d. Nuts			
Hazelnuts	69 000	hulls	used for bedding livestock or as fertilizer
B. Animals			
Poultry	610 000	manure	discarded
Sheep-Goat	14 600 000	manure	} 10% fertilizer, 30% left on grassland, 60% burned
Cattle	31 400 000	manure	
II. MUNICIPAL WASTES			
Garbage	2 200 000	food wastes	discarded
Sewage Sludge	1 500 000	organic part	discarded
III. INDUSTRY			
A. Food Industry			
a. Slaughterhouses	340 000	blood meat bone	partly rendered usually discarded

continued from Table 2.3.2

b.Milk Processing			
Cheese production	76 000	cheese whey	discarded
c.Fruit&Veg. Processing			
Cannery	2 300	pea hulls	used as wet feed
Fruit Juice	1 100	peel,rag,seed	used as wet feed or discarded
Tomato Paste	4 500	skin,pulp,seed	sold as wet feed
d.Oil Industry			
Olive oil Pressed olives	100 000	whey black water	discarded
	56 100	pressed cake	used as fuel
e.Sugar Industry			
Sugar Factories	375 000	solid slurry	discarded
	1 300 000	bagasse	sold as wet feed
f.Alcoholic Bewerages Industry			
Beer	13 000	bagasse	sold as wet feed
Wine	500	bagasse	sold as wet feed
Raki	33 000	grape peelings aniseeds	discarded
III.2 OTHER INDUSTRIES			
Industrial wood processing	649 000	wood pieces	sold or burned
IV. FOREST WASTES			
Logging Wastes	1 417 000	branches&leaves	left on the forest field

2.3.1. Agricultural Wastes

A. Crop Wastes

a. Cereals

Rice: For small grains the straw yield change from 1.5 to 2.25 (av. 1.88) times the grain yields in weight [13]. Since the production of rice is 198 000 tons per year [8] and 20 % of the stalks is dry, the production of dry matter of the wastes are about 75 000 tons/year. Since these cellulose rich wastes are not valuable as animal feed, they are burned on the field.

Maize: Typical mature maize is 50 to 65 percent (58 %) stover and 42 % grain [13]. Since the production of corn is 2 000 000 tons/year [8] and 25 % of the stover is dry matter, the wastes are 690 000 tons dry matter/year.

b. Industrial Crops

Tobacco: 65 % of production is tobacco stalks. Since these wastes have no nutritional value, they must be destroyed [14]. The dry matter of the stalks is 25 %. Therefore, 269 888 tons of tobacco per year [8] gives 44 000 tons dry waste/year.

Sugar beets: The wastes of sugar beet (leaves) left on the field are 30-40 % of production [15]. With 25 % dry matter, 10 928 903 tons/year [8] production yields about 956 000 tons dry matter of waste/year.

Cotton: Stalks of the cotton plant removed after harvesting constitute 3 times of the cotton fiber [16]. The stalks are usually burned for heating. With the production of 617 000 tons/year [8] cotton fiber, the stalks (80 % dry matter) amount to approximately 1 500 000 dry tons/year.

c. Oil Seeds

Sunflower: The head of the matured sunflower contains about 50 % of the dry matter of the whole plant. Nearly one half of the weight of dried head is seed. About 35-50 % of the seed consists of hull [13]. So, 75 % of total plant is stalk and head (without seeds) and 25 % is seeds. Then stalk and head yields 3 times the sunflower seed yield in weight. Therefore, production of 1 250 000 tons/year [8] sunflower seeds give

3 750 000 tons dry wastes/year. Since the stalks are rich in cellulose, they are burned for heating.

d. Nuts

Hazelnut: According to the information given by Dr. Ahmet Bilgen, director of Giresun Research Institute of Nuts, 50 % of yield is green hulls and 25 % of hulls is dry matter. Therefore the yearly production of hazelnut, 550 000 tons [8], yields about 69 000 tons dry waste per year. These wastes are generally used as litter material or rarely as fertilizer.

B. Animal Wastes

Turkey is rich in animal husbandry with the population of 67 179 000 poultry animals, 55 589 000 sheep and goats, and 12 602 000 cattle [8]. The amount of manure from these animals can be calculated by using the information given in Table 2.3.3. The dry manure from poultry was calculated as 610 000 tons per year. Since the ammonia content of this manure is very high, the farmers don't want to use it as fertilizer. Most of the poultry producers look for places to dump their wastes. The amount of dry manure from sheep, goat and cattle is 46 000 000 tons/year of which 10 % is used as fertilizer, 30 % is left on grasslands and 60 % is burned for heating or cooking [17].

TABLE 2.3.3. Average Weight and Amount of Wet Manure per Animal [18].

	Av.Weight kg/animal	Wet Manure g/kg/day	Wet Manure kg/animal/day	Moisture[19] %
Poultry	2	62	0.124	75-80
Dairy Cattle	450	84	38	
			}34	85
Beef Cattle	450	66	29.7	
Sheep	50	72	3.6	80

2.3.2. Municipal Wastes

A. Garbage

There are no systematic records of the amount of household solid wastes in Turkey. Therefore the average values given for Istanbul, [20,21], were used to estimate the total amount of organic solid wastes in Turkey as approximately 500 g/person. Since the dry matter of food is around 20 %, with the population of sixty millions, produce 2 200 000 tons of dry food wastes are produced per year.

B. Sewage Sludge

The organic matter in domestic waste-water can be divided into three main classes: proteins, carbohydrates, and fats. The proteins, which comprise 40-50 % of the organic matter, are complexes of amino acids and constitute the major source of bacterial nutrients. Approximate quantity and organic matter content of solids in fresh sewage sludge range within the range 81.5-100 g/head/day (dry basis) and 60-85 %, respectively [22]. Therefore, the amount of dry organic matter in sewage sludge is calculated to be approximately 1 500 000 tons/year. In Turkey, this significant amount of organic matter is unfortunately discarded directly to municipal sewerage systems or to the sea.

2.3.3. Industrial Wastes

A. Food Industry

a. Slaughterhouse Wastes

The main wastes of slaughterhouses originate from killing, hide removal or dehairing, paunch handling, rendering, trimming, processing and clean-up operations. The wastes contain blood, grease, inorganic and organic solids, and salts and chemicals added during processing operations [19].

The information given by Mr. Adil Öncü, the general director of MARET, is as follows: Beef cattle wastes constitute bones (7 % of live weight), meat (5 % of live weight), and blood (4 % of live weight). On the other hand the processing of sheep and goats produces no waste bones but only meat (5 % of live weight) and blood (4 % of live weight). Dry matter content of these wastes are 12, 30, and 50 % for blood, meat and bone, respectively. Depending on this information, we calculated the amount of wastes from the slaughterhouses by using the total number of animals slaughtered/year [8]. The amount of wastes from slaughtering of sheep, goats and beef cattle added up 310 800 tons dry matter per year.

According to the personal communications with KÖYTÜR, which is the biggest poultry producer company in Turkey, the following information is obtained: At poultry processing plants, wastes originate from killing, scalding, defeathering, evisceration, washing, chilling, and clean-up operations. In the processing of broilers, about 75.4 % of the original weight of the bird represents the finished product. The remaining 24.6 % includes feathers, intestines, feet, head, and blood which require liquid and solid disposal at the processing plant. The waste of greatest pollutional significance is the blood from the slaughtering operation. About 2.36 % of the body weight of chicken is drainable. Since the poultry meat production is 300 000 tons per year [10], the amount of dry matter of blood was calculated as 1 127 tons/year and that of the feathers, intestines, feet and head, with 30 % dry matter, as 26 737 tons per year.

The drainable blood has a pollutional load of about 156 000 mg BOD/liter and 218 300 mg COD/liter [19]. Therefore, all wastes from slaughterhouses must be sent to rendering plants after which a valuable animal feed is obtained. As a matter of fact only a few of meat producers have rendering plants and only some of them are running their rendering plants. Since they don't get profit out of drying meat and bone, and they have deficit when drying blood, they prefer sending these wastes wherever possible. Hence, due to lack of governmental control, hundreds of tons of valuable organic matter are polluting the environment instead of providing an increase in amount of national resources as animal feed.

b. Milk Processing Wastes

The most important waste from milk processing plants is cheese whey during production of cheese. 5-10 kg (av. 7.5) of fluid whey is obtained per kg of cheese produced. Since the dry matter of whey is 7 % [19], having 145 000 tons of cheese produced per year [10], the amount of waste adds up 76 000 tons per year. Since the dry matter content of this waste is high, the processes of producing protein out of it is expensive. Therefore the producers are generally sending this waste to sewage system.

c. Fruit & Vegetable Processing

Cannery: The only vegetable that yields significant amount of waste during canning process, is pea plant. Pea cans constitute 32.5 % of total amount of cannery products in Turkey, and 45 % of the pea plant, processed for canning, is hull [23]. Since 800-110 kg pea is used for 1 ton pea can production [23], and the total cannery production in Turkey is 64 500 tons/year [10], the amount of hulls removed are calculated to be approximately 9000 tons/year. These hulls are used as wet feed. Being 25 % dry, these wastes are about 2 300 dry tons/year.

Fruit Juice: The kind of fruits that yield significant amounts of waste after extraction of juice or making other products from the fruits, are those belonging to citrus family. The waste material which contains peel, rag, and seeds, is rich in carbohydrate, poor in proteins, and accounts for about 46-60 % of the weight of processed fruits [24]. Since the average yearly citrus juice production in Turkey is 4000 tons/year [25], the waste of this production can be calculated as 4 500 tons/year of which the dry matter constitutes 1 100 tons/year. These wastes are used as wet feed or discarded.

Tomato Paste: During processing, 7-18 % of the tomato is discarded as waste. The dry matter of this waste is 15 % [23] and since the yearly production of tomato paste is 200 000 tons, the amount of this waste as dry matter was calculated as 4 500 tons/year. Since 21 % of dry matter is protein, it is a valuable animal feed. Therefore the farmers buy these wastes from the factories and use it as wet feed.

d. Oil Industry

During the extraction of oil from olive fruits, appreciable quantities of residue and liquid waste are produced. The solid waste is composed of fragments of skin, pulp, and stone, and up to 40 kg of solid waste (press cake) may be obtained from 100 kg of olives. It contains 3.5-12 % olive oil and 20-30 % water. However, its composition depends on the variety of olive and processing methods. Press cake is rarely used as animal feed and mostly used as fuel in Turkey. Recently, furfural production from this material has been started [26].

During extraction, the pressed olives are washed with hot water and as a result, 1.5 kg liquid waste, black water, which has 10-12 % dry matter and, 0.28 % nitrogen, is obtained per kg of olive pressed [27, 28]. This liquid waste is generally discarded but recently some of the olive oil producing companies are investigating the ways to use this material as fertilizer or in biogas production.

Since the amount of olives for pressing is 610 000 tons/year [10], the press cake amounts approximately to 56 100 dry tons/year after its oil is extracted out. The black water amounts to 915 000 tons/year in which the dry matter is approximately 100 000 tons/year.

e. Sugar Industry

According to the information given by Müjgan Ertürk, director of the technology department of Turkish Sugar Industry; the total amount of solid slurry discarded from the treatment plants of all sugar processing factories is 936 750 m^3/year and 40 % of this slurry is dry matter. So total amount of dry wastes is calculated as 375 000 tons/year. Although this material can be used as fertilizer after drying, mostly it is discarded.

Succorose content is 17.5% of the dry matter of the sugar beet [15]. Total amount of sugar beets as dry matter (25%) is about 2 700 000 tons and 956 000 tons of this is left on the field. Since 17.5% of the rest is succorose, the bagasse from the sugar factories amounts to 1 300 000 tons per year. This material is sold to be used as wet feed.

f. Alcoholic Bewerages Industry

The following information is obtained through the communications with the general directors of the beer, wine, and factories of TEKEL:

During production of one liter of beer 0.2 kg waste (20-25 % dry) is obtained. This material, called as bagasse, is sold as wet feed. Almost 4-5 % of wine production is waste

(20-25 % dry matter) that is named as yeast sediment. Most of the wine factories discard their wastes to the sewage system instead of drying and reusing as animal feed. Since contamination of this material by mold is easy, this application pollutes the environment seriously. During production of 1 tons of raki, 10 m^3 of liquid waste (5.5 % dry), 180 kg of solid waste (25 % dry), peelings and seeds of grapes, and 25 kg of anise seeds (25 % dry) are obtained. All of the solid wastes are dumped to the municipal waste lands and the liquid wastes are discharged to sea or wherever possible.

Since the yearly production of beer, wine, and raki are 250, 44, and 55 million liters, respectively, the amount of wastes on dry basis are calculated approximately as 13 000 tons/year, 500 tons/year, and 33 000 tons/year in the same order.

B. Other Industries

Although most of the industrial wood processing wastes are sold to be reused, 0.37 m^3 of waste, which is not reused but only burned, is obtained per m^3 of timber processed (information given by Mustafa Öz, the vise director of the Institution of Forestry Products Industry). As the production of timber for processing is 5 010 000 m^3 per year [10], the wastes, with 50 % dry matter, are calculated to be 649 000 dry tons/year. One m^3 of wood material is taken as 0.7 tons in this calculation.

2.3.4. Forest Wastes

Logging wastes are those wood wastes effected by timber harvesting operations. 300 kg residue is obtained per 1 m^3 timber after removing the useful parts. The rest are branches and leaves, which are not used even by villagers, left on the forest field. Since the total timber production is 9 449 000 m^3 per year [10], the wastes add up 1 417 000 dry tons/year.

III. ALTERNATIVE WAYS OF UTILIZING WASTE BIOMASS

3.1. Classification of the Waste Biomass

In order to decide on the ways of utilizing waste biomass, like feed, energy or fertilizer production, it would be helpful to divide the wastes into two groups as, nitrogen rich and cellulose rich wastes. Nitrogen rich wastes are potential as feed or fertilizer sources, whereas, cellulose rich wastes should be undoubtedly considered as energy sources.

Crop residues are usually cellulose rich wastes and nonintensively produced on different regions in Turkey. Because of the high collection costs associated with these wastes, the high price payed to the nitrogen fertilizers, and the loss of organic material from soil, there is considerable question about the practicality and wisdom of collecting and using these materials for energy production [29].

In case of animal wastes, the portion left on the grasslands are 30 % and it is very difficult to collect them. 60 % of these wastes are readily collected, dried, and used as fuel for heating. Although nitrogen rich, they are not suitable as feed. They should be used in anaerobic digestion, to produce energy and fertilizer.

The task of disposing organic municipal wastes is a serious problem in expanding cities due to high transportation costs to dumping sites outside the city. There are two disadvantages here; a waste of raw material as well as environmental pollution. Recycling and reuse are the principles which can solve both of the problems. These food wastes are nitrogen rich and can be used principally as feed. The only problem for a safe feed production, which will enter the human food chain, is the necessity of separate collection at homes.

Significant amounts of solids in sewage can be obtained principally from treatment plants as sludge. It can be used for methane and fertilizer production.

The solid wastes, produced by different industrial activities, are not collected by the municipality. Usually these wastes are stored in the factory premises, recycled either directly within the firm or sold [20]. Since these wastes are produced in a concentrated form, on a regional basis they represent significant source of animal feed (wastes of food industry), or energy (wastes of forestry and forest industry).

3.2. Energy from Biomass

3.2.1. Introduction

Conversion processes to produce useful energy forms from biomass may be direct combustion, thermo chemical gasification and liquefaction, fermentation and biogasification (anaerobic digestion). Amongst these processes, anaerobic digestion is an effective process for the conversion of a broad variety of biomass to methane to substitute natural gas and medium calorific value gasses. The effluent from this process is in form suitable for reaplication to the land as fertilizer.

For efficient use of bioenergy sources, it is essential to take account of their energy potential. Biogas yields of some biomass samples are given in Table 3.2.1.

It can be concluded from the data in Table 3.2.1 that, in average, 4 kg of dry biomass is equivalent to 1 m^3 methane. Since energy value of 1 m^3 methane is approximately equal to 1 kg of petroleum [30], it is now possible to estimate the energy potential of all biomass sources in terms of TOE (tons oil equivalent). The estimated bioenergy values of some waste biomass in Turkey, which are suitable for energy production rather than feed production, are listed in Table 3.2.2.

TABLE 3.2.1. Biogas yields of some organic materials [30].

Organic Material	Biogas Yield (m^3/ton dry matter)	Methane Content (%)
Livestock Manure:		
Cattle dung	270	
Pig dung	560	50-60
Horse dung	250	
Plant waste:		
Fresh weeds	630	70
Wheat straw	430	60
Green leaves	250	60
Rice husks	620	70
Sewage waste	640	50
Liquid waste from wine or spirit making factories	300-600	60

TABLE 3.2.2. Estimated bioenergy potential of waste biomass.

BIOMASS SOURCE	AMOUNT dry tons/year	ENERGY VALUE TOE/year
AGRICULTURAL WASTES		
* Crop residues from rice, maize, tobacco sugarbeets, cotton, and, sunflower	7 000 000	1 750 000
* Animal Wastes 60 % of total	28 000 000	7 000 000
INDUSTRIAL WASTES		
Wood processing	649 000	162 000
FOREST WASTES		
Logging	1 417 000	354 000
	TOTAL	9 266 000

Importing 44 % of total energy production (Table 3.2.3), Turkey should seek for alternative energies urgently. Although energy from waste biomass could contribute 18 % of total energy consumption in Turkey, this energy can not be considered as totally available since the wastes are produced not centralized and collection also requires energy and other costs (capital, labor, etc.)

TABLE 3.2.3. Energy situation in Turkey (TOE/year)*.

TOTAL PRODUCTION	29 000 000
TOTAL CONSUMPTION	52 000 000
TOTAL IMPORT	23 000 000

*6th Five Year Development Plan, DPT: 2174, 1990-1994.

3.2.2. Energy Farms

The location of Turkey is suitable for plantation of biomass. If we can grow energy plants yielding 2 % of solar energy (5.8 kg dry mass/m^2 year), it may be feasible to establish an energy farm with digesters in the middle of the plantation area. To compensate the 23 000 000 TOE energy import, the calculations only for the energy balance of such a farm where biogas is produced are given below:

The amount of biomass : $23x10^6x4 = 92x10^6$ dry tons/year
Total plantation area: $92x10^6/5.8x10^6 = 15\ 900\ km^2$
This area is equivalent to a circle with a radius of 70 km.
A 10 tons truck
carries 55 550 MJ biomass
spends 40 liter diesel/100 km
1 liter diesel = 37.6 MJ
If the truck travels 140 km, it will spend 3.8 % of the energy that will be gained from the biomass it carries.

Regarding to Table 2.2.1, the area of this energy farm is only 2 % of total land area, 5.7 % of agricultural areas and 7.3 % of grasslands of Turkey. Since the longest distance from center to biomass source is 70 km and the truck spends only 3.8 % of the energy potential it carries, it may be a promising farm for energy. The benefits of such a farm are very important; environmental benefit, energy contribution, diversification of agriculture, contribution to industrial and socio-economic activities. In these calculations, the establishment, plantation and labor costs are not included, but the above benefits should attract interest to consider such farms.

Forests and agricultural areas cover almost half of Turkey. Many different kinds of biomass, named as weeds, grow on the rest of the lands. In some regions these weeds grow so intense that they may be considered as promising sources for energy. Amongst these, we observed two of them, elder and thistle, grow widely in many regions. Elder grows naturally in some areas that they give 5 kg dry matter per m^2 (especially in Marmara region). Thistle may be important as well since it grows especially in middle Anatolia in arid lands. As far as the increasing interest of the world to energy crops and the availability of suitable land in Turkey are concerned, making research on increasing the yield of these two species at optimum conditions should be taken into consideration.

3.3. Feed from Biomass

3.3.1. Introduction

In some cases the food value may compete the energy value of biomass. So some forage biomass and food processing wastes, having high protein content, must be taken into account as sources of animal food. Some of these sources, like wastes of tomato paste factories, wine, beer and sugar factories etc., are currently used as animal feed. However most of the factories, especially slaughter houses, discharge their wastes rather than utilize. Since they have high moisture content they are spoiled easily. On the other hand, if these wastes are dried, there will be environmental and economical benefits. Therefore, research has to be done on drying these wastes by cheap and efficient methods.

3.3.2. Potential of Different Kinds of Waste Biomass for Feed Production

Wastes of sugar beets (956 000 tons/year), food wastes from municipalities (2 200 000 tons/year), and all of the wastes from food industry (2 301 500 tons/year) are potential sources of feed (Table 2.3.2). Although most of them are used as wet feed, the others, especially food wastes from municipalities are not used at all.

Up to a quarter of the biomass transported to domestic areas for human consumption is discarded as food wastes; peelings, left-overs, spoiled food etc. Mixed with other wastes (glass, plastics, metal), the food wastes represent an appreciable portion of domestic refuse. Once refuse is mixed, recycling and reuse is not economically feasible, so landfilling is the common way of disposal. There are two disadvantages here; a waste of valuable biomass containing proteins, carbohydrates, fats etc. and pollution of the environment. Therefore new possibilities are discussed all over the world for separate collection and processing of refuse.

For hundreds of years, the primary strategy for disposing of solid wastes has been to dump it on land. Due to rapid urbanization, the existing dumping sites are increasingly encircled by settlements and housing estates. They are subjected to growing opposition from the public due to reduction of property values, smell and sight of garbage and physical harm from landfill gasses, microorganisms and toxins. Many of the recently selected sites in larger cities are located at distances 20 to 40 km from the central collection areas. This results in high transfer and transportation costs as well as in additional investments in the infrastructure of roads [31].

Material recovery and recycling from the inorganic part of municipal solid wastes is widely practised easily in many countries. However there are still some problems in recycling the organic part. The possibilities to recycle organic wastes which contribute a high portion of municipal solid wastes are:

composting, incineration and biogas recovery. Compost from a refuse is not a good fertilizer because; any nitrogen it contains is released slowly into the soil and as composting reduces the volume of refuse, any heavy metals in it become more concentrated [32]. A different way of recycling refuse is to consider it as a source of energy through incineration or anaerobic digestion. Incineration reduces the volume of rubbish but it is expensive and pollutes the environment with toxic gasses and great amount of ash. This requires further treatment systems such as gas scrubbers etc. which bring additional cost. Biogas recovery is a slow process and yet is not a solution [33].

It is convenient to use the food wastes of humans as food for animals. This is practiced in many countries in piggeries [31]. A drawback here is the limited time before spoilage, which therefore requires an adequate organization of transportation from the sources to the farms. Also, its direct use as feed in farms with animals other than pigs may not be safe (and therefore economical) due to daily variations in food value and bacteriological conditions. Drying and the use of human food wastes as ingredients in animal feed could be a solution to this problem. Following points should be considered at this stage: - The food wastes should be collected separately from the rest of the garbage. The food wastes, unlike most other biomass, are readily attacked by bacteria. Therefore, sufficient sterilization should be achieved while processing these wastes. - Although properly sterilized during processing, they might still contain toxins due to previous bacterial activity. Therefore, to obtain a good quality product, daily collection and transport (e.g. overnight) has to be organized. - To stop recontamination during storage, the moisture content of the product should be below the safe storage value of 10 % (wet basis).

Drying, on the other hand, is an energy intensive process. The economical feasibility as well as the ecological benefits of drying wastes by burning fuels is questionable. An economical solution at least for countries with abundant solar insolation would be the use of solar energy for drying.

IV. SOLAR DRYING OF WASTE BIOMASS

4.1. Introduction

Diverse agricultural products such as fruits, vegetables and grains are dried in many countries using solar energy in its simplest form. Basically the products are spread on the ground or on platforms and are dried by sun in a natural manner. However this process presents several technical problems. In order to avoid these problems, artificial drying has been preferred in many developed countries since the beginning of this last century.

Most of the artificial solar drying studies are made by using either of the two basic types of dryers: solar dryers-direct and solar dryers-mixed mode. In direct solar dryers, the material is placed in an enclosure with a transparent cover. Heat is generated by absorption of solar radiation on the material itself as well as on the internal surfaces of the drying chamber. In mixed mode solar dryers, the combined action of the solar radiation incident directly on the material to be dried and air, preheated in a solar air heater, furnishes the heat required to complete the drying [34].

Solar drying research and application have been done generally on drying of agricultural products like grains, fruits, vegetables, wood etc. [35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45]. It has been observed experimentally that the products dried in the solar dryers are of much superior quality and can be preserved for longer duration as compared to open sun drying. It is, therefore concluded that the solar dryers can be used successfully for drying a variety of agricultural products, especially fruits and vegetables, to prevent spoilage and retain nutritional value of the material.

However there is no study on solar drying of food wastes (especially waste of human meal) that necessiates sterilization as well. As far as the meal is concerned, one may think about solar cookers. Solar cooker designs have been developed and field tested for many years [46, 47, 48]. The solar box-cookers are simple glass-topped boxes. The glass transmits visible light, but is opaque to re-radiated infrared wavelengths: the ovens are miniature greenhouses. The pots containing the food rest directly on a conducting metal floor plate (both painted black) so the oven does not need to be constantly moved to face the sun. The ovens can reach temperatures of 150°C in less than an hour, and can exceed 170°C. The lid is covered in aluminium and doubles as an extra solar collecting panel. The ovens have been used to boil, bake, simmer, braize and statue foods, and to pasteurize naturally contaminated water; in moderate to strong sunlight a full meal can be cooked in 2-4 hours.

Basing on this background about solar dryers and cookers, different types of solar dryers were developed to dry food wastes. Also the phenomenon of natural sun drying of freshly collected and unspoiled leftovers from Bogazici university restaurant were inspected in the present study.

4.2 Open Air-Drying and Forced-Air Drying Experiments

In order to understand the drying behavior of the food wastes in open air, natural sun drying was performed. Restaurant leftovers were collected and checked visually for the presence of foreign materials. Materials like cigarette butts or broken glass fragments had to be removed. The wastes were filtered through a fine meshed sieve for 20 min to remove excess water and ground using an ordinary meat grinding machine. They were then placed on a metal tray (0.5mx1m) at a depth of 4 cm and exposed to sun in open air. After determining the moisture content (wet basis: mass of water per unit weight of wet material) at the begining of the experiment, the tray was reweighed every day. In the initial phase of drying (2-3 days) the rate was almost constant as the surface of the material was saturated with water. Here mixing had no effect on the drying rate. As the material shrunk in the later stages, a hard impermeable skin formed on the surface. This resulted in a decrease in the drying rate. In this period, mixing had an increasing effect on the drying rate.

The disadvantages, here, were the typical food smell at the begining of the experiment, and the smell of fermentation in the later stages. Since the smell attracted birds, cats, and flies, the food had to be protected by covering it with a fine meshed net. As Table 4.1 shows, three days were necessary to reach the safe storage moisture contentof 10 % in August, in Istanbul. The material showed an unacceptable concentration of mold at the end ($1.5x10^6$/g).

TABLE 4.1. Daily Average and Maximum Temperatures, Solar Energy, Humidity, and Moisture Contents During Open Air Drying of Food Wastes.

Date in 1991	Drying time (day)	Daily Av. Temp. (°C)	Max. Temp. (°C)	Daily Av.Sol En. (MJ/m^2d)	Daily Av. Humid. (%)	Total Amount of waste (kg)	Moist. Conent (%)	Amou. of water (kg)
25.7	0	22.4	28	17.3	82	10.0	78	7.8
26.7	1	23.1	28	18.5	64	7.0	69	4.8
27.7	2	24.3	27	17.2	79	4.2	48	2.0
28.7	3	24.8	27	15.1	78	2.5	10	0.3
29.7	4	24.5	28	17.1	92	2.3	4	0.1

Drying by forced air convection was tested in two ways: (a) the wastes were placed in a barrel with a perforated base and open top. Solar heated air at 40°C was blown from the bottom through the wastes. Since the wastes formed a paste, air passed through only a few channels that formed in the material. Thus the air-material contact area was very small. (b) Heated air was blown parallel over the wastes, which had been placed on a tray. In both methods of forced air convection, drying was slow and not uniform. Therefore unacceptable mold growth was again observed during drying.

The above experiments showed that the restaurant food wastes require a special method of solar drying in order to prevent bacterial spoilage during drying. For this purpose, we designed and constructed new low-cost drying units that we call "solar boiler-dryer", working at temperatures above 100°C.

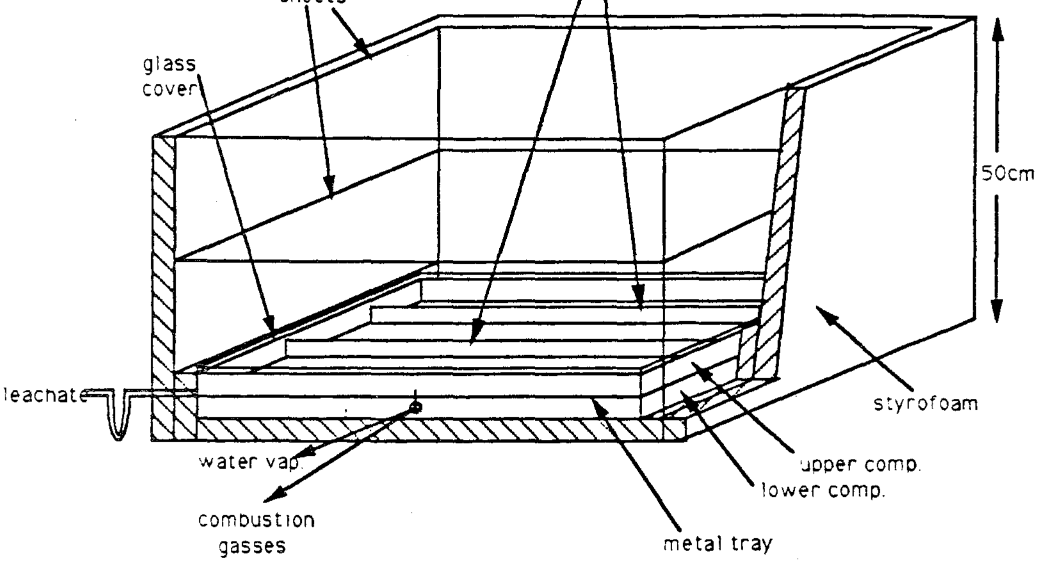
4.3. Design and Construction of the Solar Boiler-Dryer Units

Solar Boiler Dryer Unit-1

As seen in Figure 4.1, the solar boiler-dryer system has a metal tray (0.5mx1mx0.04m) that is insulated at the bottom and sides by glass-wool and styrofoam. A glass cover, one which reduces heat losses due to radiation, is placed over the tray, which is sealed with rubber to ensure it is airtight. An additional cover with two transparent polypropylene sheets, sides made of styrofoam, is placed over the tray to decrease heat losses by convection. The solar radiation falling on the top surface of the dryer passes through the two polypropylene sheets and the glass cover, and reaches the material to be dried. The inside walls of the styrofoam cover are painted black. The food wastes are placed on the tray. Perforated baffles, placed in the tray, prevent sliding down of material when the tray is tilted. Alongside the first baffle at the front of the tray, the leachate drains out of the dryer from the side through a U-shaped pipe (in order to prevent air exchange). Droplets of partially condensed vapor on the glass surface roll down to a drainage channel just before the first baffle and leave the system through a hole in the middle (Fig 4.1).

The metal tray has an additional compartment at the bottom. A supplementary gas heating system, connected to this lower compartment, can be used during cloudy intervals. The combustion chamber of this system is simply an insulated metal pipe of 10 cm diameter and 50 cm length. The gas burns in the center of this pipe. The combustion gasses flow through the lower compartment of the metal tray and leave the system by an opening at the front. There is a hole at the bottom of the drainage channel connecting the upper and lower compartments.

General view



Side view

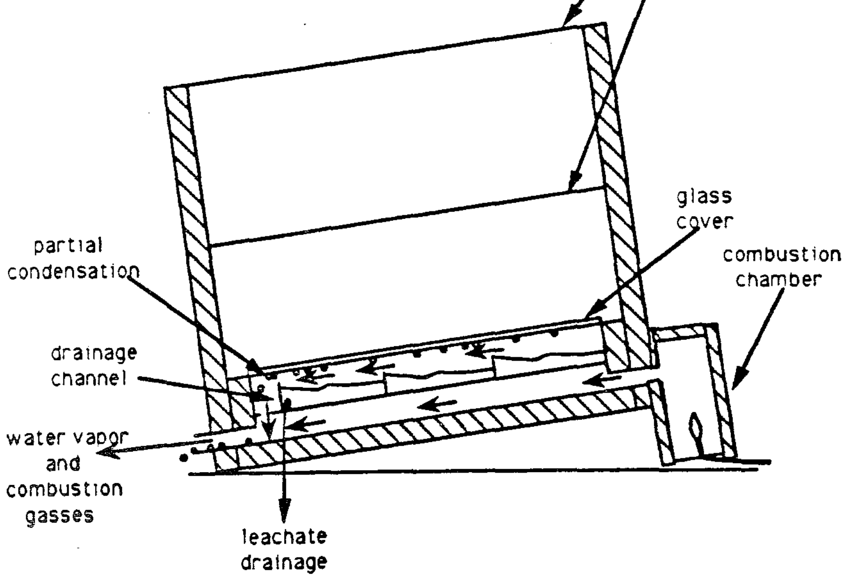


FIGURE 4.1. Solar boiler-dryer unit-1.

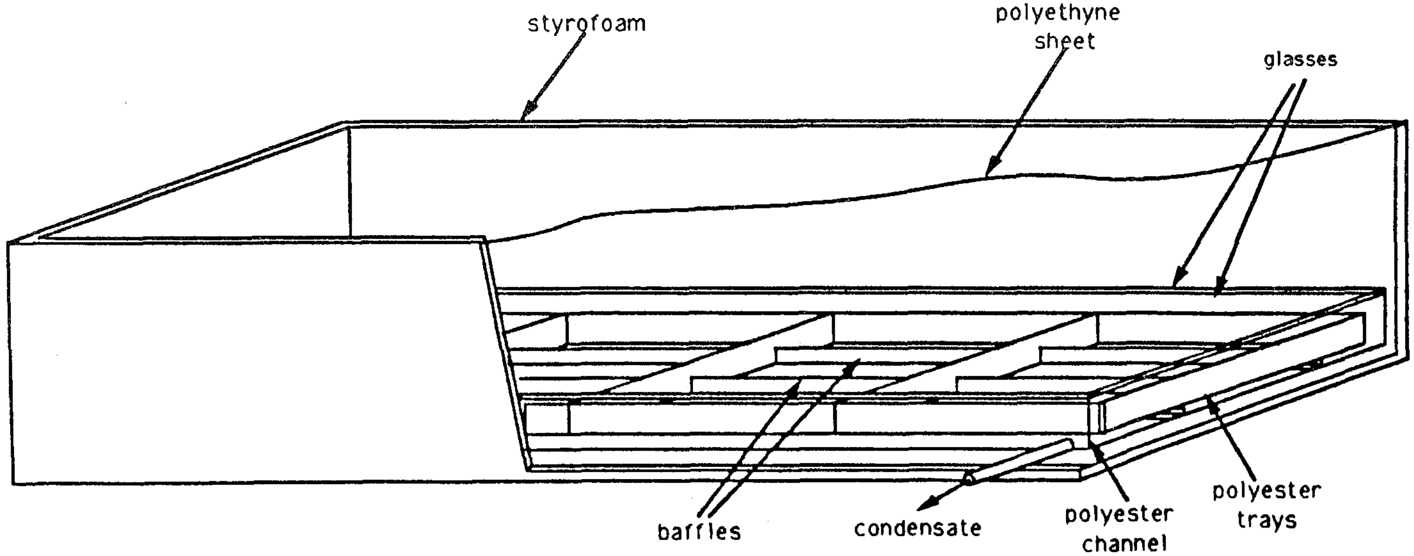


FIGURE 4.2. Solar boiler-dryer unit-2.

The vapor and condensed water from the upper compartment, as well as the combustion gasses, leave the system through the same opening at the front (Fig. 4.1). The combustion chamber is disconnected from the system on days of full sunshine.

The whole system is built on a frame that can be adjusted for azimuth and tilt angles, so that solar radiation is always normal to the collector surface.

Preliminary experiments were made by using the unit described in Figure 4.1 and with the data obtained, thermal analysis of this unit was carried out. Basing on the results of the thermal analysis, it was decided to construct another unit, working with the same principle but having some differences to be more practical.

Solar Boiler Dryer Unit-2

As seen in Figure 4.2, the solar boiler-dryer unit-2 is a black rectangular polyester channel (4mx0.9mx0.2m) that is insulated at the bottom and the sides by glass wool and styrofoam. Two layered glass covers were placed over the channel and sealed with silicon air tight. Another transparent polypropylene cover with styrofoam sides is placed on top of the system to reduce heat losses by convection. The drained and ground food wastes were spread on four black polyester trays (1mx0.85mx0.1m) with wheels at the bottom. The baffles in the trays prevent the sliding down of the material when the system is tilted. The solar radiation falling on the top surface of the apparatus passes through the polypropylene sheet and the glass covers, and reaches the material to be dried. Water vapor condenses partially on the glass surface and droplets roll down to the front side of the channel and leave the system through a hole at one corner. The whole system was built on a frame, as shown in Figure 4.3, so that it could be adjusted to the position of the sun to have solar radiation to be normal to the surface.

FIGURE 4.3. General view of the solar boiler-dryer unit-2.

4.4. Results and Discussion

4.4.1. Experiments on Solar Boiler-Dryer Unit-1

The drained and ground food wastes were spread on the metal tray and thermocouples were placed at selected points in the system. After placing the glass over the tray, the system was closed by the styrofoam cover. The tray was adjusted hourly, according to the position of the sun. The experiments started at approximately 9 A.M. and ended at 5 P.M. Temperatures at different points were measured and recorded every 30 min. The experiments described below were done on full sunshine so that supplementary gas heating was not necessary.

As the temperature reached 70°C, the homogenous material released an oily fluid (leachate) for about two hours; this was drained out. After 105 °C, the temperature of the food stopped rising and the water was removed by boiling. There was also partial condensation on the glass surface. Droplets of condensed water rolled down the glass to the drainage channel without dropping back onto the food wastes. Temperature data, obtained during solar heating, were plotted against time for three different amounts of waste (Fig. 4.4). It was found that one hour of heating was necessary for 1250 g of waste to reach 100°C. The amounts of leachate and the water removed by condensation and vaporization are given for two different experiments in Table 4.2. In principle, the amount placed into the boiler determines the moisture content at the end of the day. When the latter reached a value of 10- 15%, the temperature started rising again, and a black, burned material was obtained. Therefore, we decided to stop drying at a specific moisture content and to continue drying on the next day in open air (second phase). By following this method, drying and sufficient sterilization could be

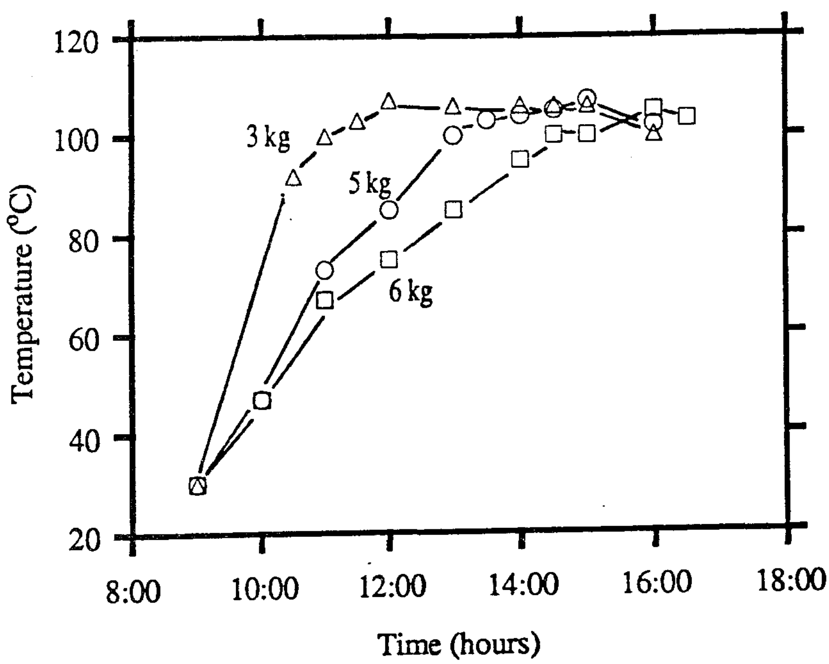


FIGURE 4.4. Variation of temperature with time for different amounts of food wastes placed on the tray at an average solar insolation of 17.5 MJ/m^2 per day.

TABLE 4.2. Total Amount of Leachate and Average Water Removal Rate by Vaporization.

Amount of waste in dryer (kg)	Time to reach 100°C (h)	Total leachate (ml)	Vapor production rate (g/h)	Condensation rate on glass (g/h)	Efficiency at* 100°C
6.0	5.5	550 (9%)	417	156	0.85
5.0	4	350 (7%)	378	196	0.85

*By a solar energy input of 840 W/m^2, the thoretical evaporation is 1.3 kg/h per m^2. The enrgy efficiency for vaporization is the ratio of the observed evaporation (vaporization + condensation) and the thoretical evaporation.

achieved without overheating. The initial quantity of material was chosen so that at the end of the first day the moisture content would reach approximately 20%. After five to seven hours of drying in open air on the second day, a light brown colored product of a quality adequate for animal feed, with minute amounts of mold, was obtained. When the second phase had to be extended for one more day (due to higher initial moisture content), the product obtained showed again high contamination by mold.

4.4.2. Thermal Analysis of Solar Boiler-Dryer Unit-1

A steady state energy balance around the solar boiler-dryer can be written as follows:

$$q_{sol.} = q_{refl.} + q_{vap.} + q_{conv.} + q_{rad.} \quad (4.1)$$

where;

$q_{sol.}$: solar energy input

$q_{refl.}$: heat losses due to reflection

$q_{vap.}$: heat used for vaporisation

$q_{conv.}$: heat losses due to reflection

$q_{rad.}$: heat losses due to radiation

The measured temperatures of different regions for a typical case are shown in Figure 4.5. No temperature profile was observed within each compartment. The given temperatures of polypropylene sheets are the arithmetic averages of the measured temperatures from both sides.

Heat losses due to reflection can be calculated as:

$$q_{refl.} = \tau\alpha IA \qquad (4.2)$$

where, τ is transmissivity, α is absorptivity for solar radiation, I is total solar radiation incident upon the top surface, and A is the area of the top surface. The term $\tau\alpha$ was calculated as 0.13 utilizing the Stokes' equations (see Appendix A) derived for the reflectance of multiple transparent layers [49].

The quantity of heat used for the vaporization is:

$$q_{vap.} = m\lambda \qquad (4.3)$$

where, m is the rate of vaporization and λ is the heat of vaporization of water at 100°C.

The convective heat losses can be expressed variously as:

$$q_{conv.} = q_1 = q_2 = h\Delta T = h_1\Delta T_1 = h2\Delta T_2 \qquad (4.4)$$

The convective heat transfer coefficient h is related with the dimentionless group, Nusselt number (Nu), such as:

$$Nu = hL/k \qquad (4.5)$$

in which, L is the thickness and k is the thermal conductivity of air.

A review of correlations quantifying convective heat transfer has been carried out by Buchberg et al. [50] and O'Toole and Silveston [51] (see Appendix B). The Rayleigh number was calculated utilizing the data given in Figure 4.5. Since the value of Ra_t was about 10^7, eqn (B.6) was used for the calculation of convective heat transfer coefficient.

Heat losses due to radiation were calculated from eqn (4.1) by difference:

$$q_{rad.} = q_{sol.} - q_{refl.} - q_{vap.} - q_{conv.} \qquad (4.6)$$

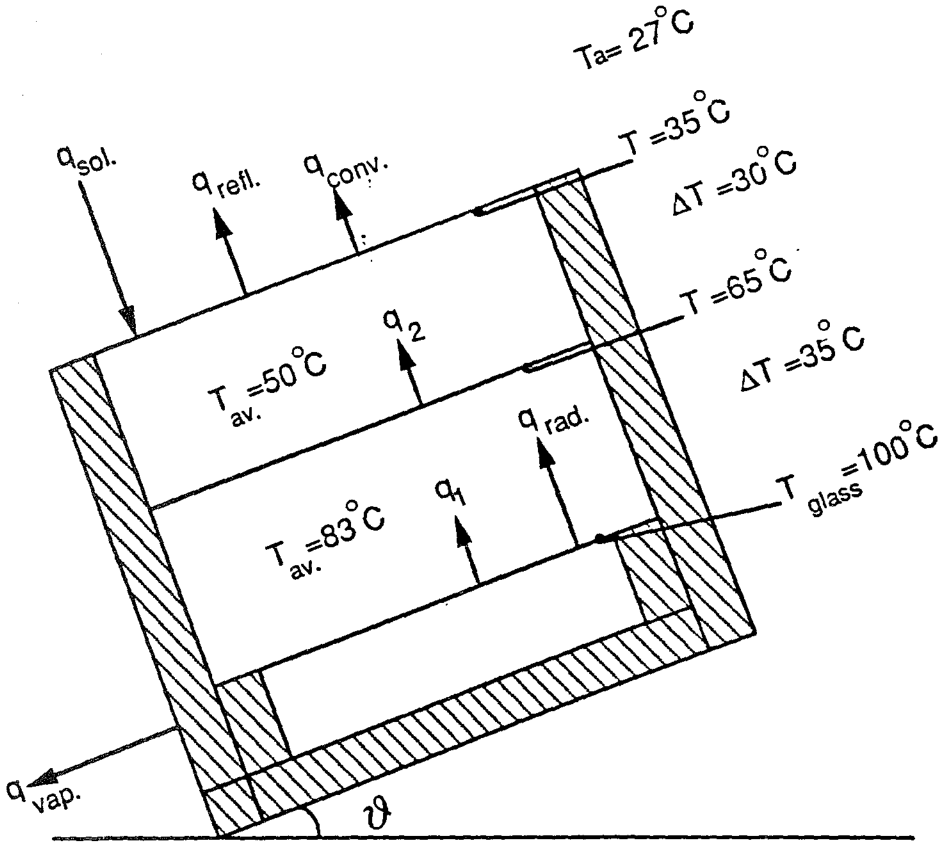


FIGURE 4.5. Energy balance around solar boiler-dryer unit-1.

The steady state efficiency of the dryer, after reaching 105°C, can be calculated from the ratio of observed evaporation. This was calculated as 0.85 in two experiments (Table 4.2). Since 29.4% of the vapor produced was condensed on the glass surface, 60% of solar radiation left the system as latent heat of the vapor. The calculation based on the steady state energy balance, eqn (4.1), showed that heat losses due to reflection, convection, and radiation were 13%, 7%, and 20% of total solar radiation, respectively.

4.4.3. Experiments on Solar Boiler-Dryer Unit-2

As it is obvious from Table 4.2 that the leachate discarded is 7-9 % of the total amount of the material to be dried. This may be a considerable amount in industral scale. On the other hand, if this leachate is kept in the system to be vaporized, only the heating period before boiling may increase with the same percent per unit area. Therefore the second unit was designed so as to vaporize the leachate within the unit. Thermal analysis of the first unit showed that convective heat loss is the least important parameter (7%) within the total energy balance. For this reason only one propylene sheet was put on the styrofoam cover (Fig. 4.2).

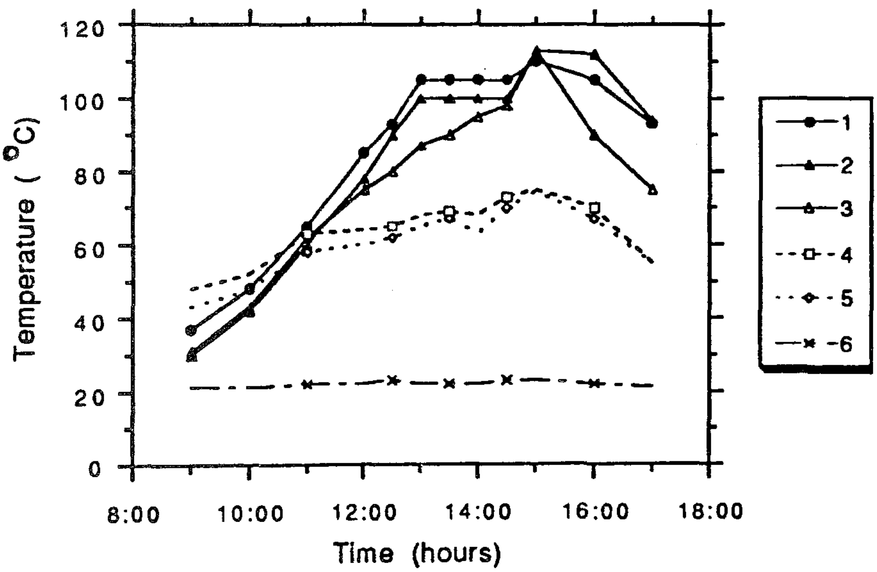


FIGURE 4.6. Variation of temperature with time at selected points of the solar boiler-dryer unit-2 (1.Temp. of waste, 2.Air temp., 3.Lower glass temp., 4.Upper glass temp., 5.Temp. between glass and polyethyl. sheet, 6.Ambient temp.).

The same procedure was followed for the experiments by the second unit in placing the food wastes on the trays. The amont placed into the boiler was 9.4 kg/m^2. The system was adjusted according to the position of the sun and the temperatures were recorded hourly. Figure 4.6 shows the time dependence of temperature (measured by thermocouples) at selected points in the system. It came out that 1 hour of heating was necessary for 2 kg of waste to reach 100°C. Although we didn't take out the leachate, the amount of material to be heated up to 100°C is more than that of observed in the previous unit. This increase may be due to two layered glasses that decrease back radiation. After 100°C, the temperature of the wastes stopped rising and the water was removed by boiling. 70 % of water content of the material was removed at the end of the first day. By drying in open air on the second day, again a light brown colored product of good quality was obtained (Fig. 4.7).

FIGURE 4.7. Examples of the foodwastes dried in the solar boiler dryer system.

The second unit is especially used for the production of dried food wastes so as to get enough material for breeding experiments. The dried food wastes of the university restaurant for five successive days were mixed and suitability of this material, as animal feed, was tested in the experiments of which details are given in Chapter V.

V. EFFECTS OF REPLACING SOYBEAN MEAL BY SOLAR DRIED FOOD WASTES IN BROILER DIETS ON THE PERFORMANCE

5.1. Introduction

According to FAO reports [52], the annual rate of increase in population of the world is 1.8 % per year. The rapid growth of population increases the demand for protein rich foods. Since the requirement of protein per capita per day is 60-70 g, there is no deficiency of protein in the world (Table 5.1). However, 50 % of total protein must be met by animal protein. Although the total amount of protein per capita per day in Turkey is over the average of world, the animal protein is less than required. Therefore, the yield of animal production must be increased by decreasing the unit cost. Since the poultry meat is the richest source of protein per unit of energy [53], attempts of discovering new feed ingredients are wellcome to lower the cost of poultry production, to serve local demand and to decrease the dependency on foreign markets.

TABLE 5.1. Food Supply-Protein Per Capita Per Day (g) for 1987-1989.[52]

Region	Total	Vegetable	Animal
World	70.4	45.7	24.7
USA	109.6	36.4	73.2
Europe	102.0	42.4	73.2
Turkey	84.8	66.8	18.0
Africa	58.3	45.8	12.5

In Turkey, researches are being conducted to investigate the possibilities of using new, uncommon or irregular feed ingredients depending on the local conditions. The alternative feed ingredients may be all kinds of organic wastes such as by products of meat packing, poultry, distillers, cotton, fermentation and dairy processings, rendering and food industries. Ozen and Erener [54] investigated the possibility of utilizing hazelnut kernel oil meal (HKOM) in layer diets as a replacement for soybean oil meal (SBM). They concluded that replacement of over 40 or 60 % of the SBM is not recommended.

Karapinar and Okuyan [24] studied on the utilization of citrus waste for microbial production. Biomass containing about 31.9 % protein was obtained with a medium of pH of 5.0 in 4 days incubation. Waste products of olive oil extraction were used to produce bioprotein [26]. The protein content of the product was about 19-24 %.

As mentioned in the previous chapters, human food wastes from households, e.g., peelings, leftovers, etc. have been hitherto an unexploited source of biomass produced approximately 50 to 100 g dry weight per capita per day. Considering urban municipal landfills, this unused biomass constitutes also environmental pollution. Recycling and reuse of municipal waste as compost fertilizer has been one elective solution to reduce this environmental burden. Food wastes consist of 16 to 20 % protein and 10 to 15 % fat by dry weight (Table 5.2). Therefore this biomass could be a useful feed supplement and, hence is too valuable for bacteriological mineralization to compost fertilizer.

The dried food wastes, of which the processing details are described in Chapter IV, were investigated to be used as animal feed ingredient. This chapter presents information on the effect of replacement of soybean meal (SBM) in broiler diets by solar-dried food waste meal (SDFWM) on broiler performance.

5.2. Materials and Methods

The experimental diets were formulated according to the standards given by National Research Council [55]. The diet formulation varied over the successive 2 weekly experimental periods as shown in Table 5.3. Diet 1 was the control diet, and Diets 2, 3, and 4 consisted of replacement by 20, 40, and 60% protein from SBM with that of SDFWM, respectively.

The diets for each period were made isonitrogenous, i.e., 23, 20, and 18% crude protein in 1st (1-3 wk), 2nd (3-5 wk), and 3rd (5-7 wk) periods, respectively, and calculated to be isocaloric at 3,200 kcal ME/kg per diet. The composition of SDFWM used is presented in Table 5.2 and that of the experimental diets and their calculated nutrient contents for each period are reported in Table 5.3.

The experiments were conducted in a four-tier individual cage system, each cage measuring 40 x 36 x 28 cm. Twenty female 1-wk-old broiler chicks of the Ross strain at approximately equal weights (135 to 145 grams) were used in the experiments carried over for 6 successive weeks. The birds were randomly alloted to a total of 20 cages with 5 replications for each treatment in a completely randomized design. Temperature was maintained at 32°C for the 1st wk and then gradually reduced to 20°C. They were illuminated and ventilated naturally through the windows of the building. Feed and water were consumed _ad libitum_. Live weight and feed consumption were recorded weekly. At the end of the experiment, the 7 wk old birds were slaughtered and eviscerated.

The performance of the chicks in terms of average final live weight, final live weight gain, feed consumption, feed conversion ratio (grams of feed per gram of weight gain), carcass yield (carcass weight per live weight), abdominal fat ratio (grams of fat per gram of carcass weight) and edible visceral ratio (grams of viscera per gram of carcass weight) are shown in Table 5.4.

TABLE 5.2. Composition of Solar Dried Restaurant Wastes[1]

Variable	Ratio (%)
Crude protein[2]	21.4
Crude fiber[2]	6.5
Ether extract[2]	13.8
Ash[2]	5.5
Calcium[2]	.62
Phosphorus[2]	.26
Lysine[3]	1.84
Methionine[3]	.38
Sodium[2]	1.03
ME[4], kcal/kg	2,953

[1]University restaurant leftovers were dried daily over a period of 4 weeks and mixed.

[2]Methods of analyses are described in Official Methods of Analysis (1990).

[3]Amino acids were analyzed in the laboratories of the Scientific and Technical Research Council of Turkey (TÜBİTAK), İstanbul.

[4]Metabolic energy = 37.1(%protein) + 82.1(%ether extract) + 39.9(%starch) + 31.1(%sugar)

5.3. Results and Discussion

According to the analysis of variance, the differences among treatment means were tested by F values. Tables C.1 to C.7 in appendix C, present the details of the analysis of variance of each performance. The effect of % SDFWM on the performances was evaluated by linear regression analysis and the relations were tested by t values. Least significant differences (LSD) at .05 level between the diets for each performance were also calculated [56, 57]. The average values of each performance, the results of the analysis of variance (F values), linear regression analysis (t values), and LSD values are listed in Table 5.4.

As F values showed, all the criteria evaluated, except the feed conversion ratio, did not differ significantly (P > .05) among the four dietary groups. In case of feed conversion ratio, Diet 4 differed highly significantly (P < .01) as compared with Diets 1, 2, and 3.

Although there were a general decrease from Diet 1 to 4

TABLE 5.3. Composition of Experimental Diets for Periods

gredients	Periods	Diets			
		1	2	3	4
		(%)			
ound corn	1	59.15	47.58	41.15	40.00
	2	63.12	56.29	50.19	44.75
	3	66.96	62.78	58.33	54.15
ybean meal	1,2,3	22.57	18.12	13.56	9.03
sh meal	1	10.00	10.00	10.00	10.00
	2	7.00	7.00	7.00	7.00
	3	3.72	3.72	3.72	3.72
ed waste meal	1,2,3	-	9.01	18.19	27.29
nflower meal	1	2.93	7.83	9.64	8.69
	2	.48	2.35	4.00	5.35
	3	-	-	-	-
flower oil	1	4.00	5.41	5.53	4.29
	2	4.45	4.70	4.64	4.26
	3	3.99	3.88	3.82	3.36
alcium phosphate	1	.86	1.70	1.58	.35
	2	1.87	2.18	2.07	1.97
	3	2.24	2.14	2.03	2.10
amin premix[1]	1,2,3	.25	.25	.25	.25
t	1	.14	-	-	-
	2	.16	-	-	-
	3	.17	-	-	-
ineral S[2]	1,2,3	.1	.1	.1	.1
culated composition					
de protein	1	23	23	23	23
	2	20	20	20	20
	3	18	18	18	18
er extracts	1	8.04	10.45	11.55	11.25
	2	8.19	9.39	10.31	10.90
	3	7.57	8.36	9.21	9.65
de fiber	1	3.15	4.06	4.56	4.69
	2	2.77	3.27	3.75	4.19
	3	2.73	2.97	3.20	3.44
cium	1	.90	1.18	1.20	.93
	2	.98	1.10	1.13	1.15
	3	.87	.89	.92	.80
ilable phosphorus	1	.70	.70	.70	.67
	2	.62	.70	.70	.67
	3	.60	.60	.60	.55
ne	1	1.31	1.38	1.43	1.47
	2	1.13	1.18	1.23	1.28
	3	.95	1.01	1.06	.95

ntinued from Table 5.3.

	1	.50	.50	.50	.50
hionine	2	.38	.39	.40	.42
	3	.31	.32	.34	.28
	1	.15	.19	.28	.38
lium	2	.15	.22	.30	.35
	3	.15	.19	.27	.35

[1]Vitamin premix provided the following per kilogram of diet: vitamin A, 10,000 cholecalciferol, 1,500 IU; vitamin E, 20 mg; vitamin K_3, 3mg; vitamin B_1, 2 mg; amin B_2, 6 mg; vitamin B_6, 4 mg; vitamin B_{12}, .015 mg; niacin, 25 mg; biotin, .05 Ca-d-pantothenate, 8 mg; folic acid, .6 mg; choline chloride, 300 mg.

[2]Trace mineral premix provided the following per kilogram of diet: Mn, 80 mg; Fe, mg; Zn, 60 mg; Cu, 5 mg; Co, .4 mg; I, 2 mg; Se, .15 mg.

BLE 5.4. Effect of Increasing SDFWM Levels on the Performance of Broiler Chicks and the Results of Variance Analysis, Linear Regression Analysis and Least Significant Difference Calculations for Comparison.

	Diets (% SDFWM)						
formance	1 (0)	2 (20)	3 (40)	4 (60)	F	t	$LSD_{.05}$
al live weight, g	2,209	2,166	2,122	2,030	1.08^{ns}	1.88^{ns}	227
al live wt. gain, g	2,069	2,028	1,983	1,891	1.13^{ns}	1.89^{ns}	222
d consump., g	4,590	4,571	4,565	4,786	$.72^{ns}$	1.12^{ns}	390
d conv. ratio, g/g	2.22^{a}	2.25^{a}	2.30^{a}	2.53^{b}	8.27^{**}	4.26^{**}	.15
cass yield (%)	73.5	71.8	71.3	71.0	1.80^{ns}	2.24^{*}	2.37
ominal fat (%)	3.13	3.17	3.24	3.38	$.04^{ns}$	$.37^{ns}$	1.73
ble viscera (%)	5.31	5.76	5.93	5.60	$.33^{ns}$	$.33^{ns}$	1.20

[a,b]The difference between the values indicated with different letters is nificant

[ns]non significant

[*]significant at .05 level

[**]significant at .01 level

in terms of final live weight and final live weight gain, this was found to be no significant according to the linear regression anlysis. On the other hand, the reduction of the performances among the diets from 1 to 4 were highly significant in terms of feed conversion ratio and only significant in carcass yield. As a matter of fact, LSD values also indicated that there were significant reductions at Diet 4 with respect to the others in case of feed conversion ratio and carcass yield.

If amino acid concentrations (lysine and methionine) of SDFWM (Table 5.2) are compared with those of experimental diets (Table 5.3), it can be seen that there are no great differences among them. However due to heta process applied to the SDFWM during drying might lower the bioavailibilty of the amino acids. On the other hand, crude fiber and sodium contents of the diets 1 to 4 increase gradually. These facts may be the reasons for the reduced performance of the birds fed Diet 4. Therefore, as a conclusion, up to 40% of the protein contributed by SBM can be replaced by SDFWM (i.e., 18.2% SDFWM in the diet) without any significant effect on the economically important criteria of live weight, carcass weight and feed conversion of broiler chickens.

VI. CONCLUSIONS

The comparison of the expected biomass capacity and the estimated actual biomass production in Turkey, showed that the latter is much below the expected yield. Whether the production is increased or not, the utilization of biomass is not efficient at all. A substantial amount of agricultural, forestry, domestic and industrial organic wastes are produced each year. The investigations on exploring methods of efficient utilization of different kinds of waste biomass showed that the most economical way is to use the relatively high nutritional wastes as feed.

Solar drying could be an economical way to process food wastes for the production of animal feed in the future. The major difficulty here is how to obtain a product of adequate quality for animal consumption from the wastes. Bacteriological spoilage during the period of drying as well as the amount of toxins, due to bacterial activity prior to collection, should be considered. The results show that the product is bacteriologically inadequate if restaurant leftovers are dried from the beginning in open air. Only drying at high temperatures can produce bacteriologically safe products. The absence of any poisonous material in the wastes should also be ensured at the outset of collection. A homogenous composition can be obtained by mixing products from different places. The low cost solar boiler-dryer allows the wastes to be dried and sterilized simultaneously.

To obtain a safe product, management problems associated with collection and transportation must also be solved. Control feeding experiments with the product, before marketing, is necessary.

APPENDIX A

Stokes' Equations

The total reflectivity ρ and transmissivity τ of a layer of transparent material are:

$$\rho = r\{1+[t^2(1-r)^2/1-r^2t^2]\} \quad (A.1)$$

$$\tau = t[(1-r)^2/1-r^2t^2] \quad (A.2)$$

where

r: the perpendicular($\perp$) or parallel(//) components of reflectence

t: transmittance

For normal incidence the two components of reflectance are equal:

$$r_{\perp} = r_{//}=r=(n-1)^2/(n+2)^2 \quad (A.3)$$

where

n: the index of reflection ratio for the transparent material

Transmittance can be calculated from the relation:

$$t = e^{-\beta L} \quad (A.4)$$

where

β: monochromatic extinction coefficient of the transparent material

L: thickness of the transparent material

The total absorptance (α) is simply unity decreased by ($\rho+\tau$), or

$$\alpha = 1-\rho-\tau \quad (A.5)$$

Stokes' also derived expressions for reflection and transmission of multiple layers of transparent media using the results for one layer:

$$\rho_j = \rho_1+(\rho_{j-1}\tau^2)/(1-\rho_1\rho_{j-1}) \quad (A.6)$$

$$\tau_j = (\tau_1\tau_{j-1})/(1-\rho_1\rho_{j-1}) \quad (A.7)$$

$$\alpha_j = 1-\rho_j-\tau_j \quad (A.8)$$

APPENDIX B

Calculation of Heat Transfer Coefficient

Buchberg, Catton and Edwards [50] recommended the use of the following correlations for calculating Nu for flat plate solar collectors:

1. Three region correlation [50]:

$$N_u = 1+1.446(1-1708/Ra_t);\ 1708<Ra_t<5900 \quad (B.1)$$

$$N_u = 0.229(Ra_t)^{0.252};\ 5900<Ra_t<9.23x10^4 \quad (B.2)$$

$$N_u = 0.157(Ra_t)^{0.305};\ 9.23x10^4<Ra_t<10^6 \quad (B.3)$$

2. O'Toole and Silveston's correlation:

$$N_u = 0.00238(Ra_t)^{0.316};\ 1700<Ra_t<3500 \quad (B.4)$$

$$N_u = 0.299(Ra_t)^{0.252};\ 3500<Ra_t<10^5 \quad (B.5)$$

$$N_u = 0.104(Ra_t)^{0.305}(Pr)^{0.084};\ 10^5<Ra_t<10^9 \quad (B.6)$$

where Rayleigh number generalized for tilted layers is:

$$Ra_t = (\Delta T g \beta L^3 \rho^2/\mu^2) Pr$$

and Prandtl number is:

$$Pr = Cp\mu/k$$

being

ΔT: temperature differences between top-most cover and absorber plate

g : acceleration due to gravity

β : tilt angle

L : gap spacing between top-mostcover and absorber plate

ρ : density

μ : dynamic viscosity

c_p : specific heat

k : thermal conductivity

APPENDIX C

Tables for the Analysis of Variance

TABLE C.1. Analysis of Variance for Final Live Weights (*)

Source of variation	Degrees of(**) freedom	Sum of squares	Mean square	F
General	17	0.424		
Between diets	3	0.080	0.027	1.08^{ns}
Error	14	0.344	0.025	

(*) Coefficient of variation= 7.4%

(**) Two of the birds were excluded since one of them was male and the others leg was injured.

TABLE C.2. Analysis of Variance for Live Weight Gains in Six Weeks(*)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	0.420		
Between diets	3	0.080	0.027	1.13^{ns}
Error	14	0.340	0.024	

(*) Coefficient of variation= 7.8%

TABLE C.3. Analysis of Variance for Feed Consumpsions in Six Weeks (*)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	1.190		
Between diets	3	0.160	0.053	0.72^{ns}
Error	14	1.030	0.074	

(*) Coefficient of variation= 5.9%

TABLE C.4. Analysis of Variance for Feed Conversion Ratios(*)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	0.431		
Between diets	3	0.273	0.091	8.27^{**}
Error	14	0.158	0.011	

(*) Coefficient of variation= 4.5%

TABLE C.5. Analysis of Variance for Carcass Yields (*)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	0.424		
Between diets	3	0.080	0.027	1.08^{ns}
Error	14	0.344	0.025	

(*) Coefficient of variation= 2.3%

TABLE C.6. Analysis of Variance for the Ratio of Abdominal Fat to Carcass Weight (*)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	20.58		
Between diets	3	0.18	0.06	0.04^{ns}
Error	14	20.40	1.465	

(*) Coefficient of variation= 37%

TABLE C.7. Analysis of Variance for the Ratio of Edible Viscera to Carcass Weight.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
General	17	1.464		
Between diets	3	0.70	0.23	0.33^{ns}
Error	14	9.76	0.70	

(*) Coefficient of variation= 14.8%

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