A STUDY OF CATTLE-DUNG GAS AS A HOUSEHOLD FUEL

By

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I. INTRODUCTION.

Ever since man learnt to appreciate cooked foods, fuel came to occupy an important place in his home. Today he uses fuel not only for cooking purposes but also for lighting and heating.

There are many varieties of household fuels in use all over the world. Among these, soft coke, kerosene, charcoal, firewood, cattle-dung-cake and gas are the important fuels used in India, as reported by National Council of Applied Economic Research (1959)[1]. Some of these, such as wood and cattle-dung should not be used as fuels because of their economic value for other purposes. For instance, nearly forty million tons of wood are burnt as fuel in India every year, causing a heavy depletion of forest reserves, which are essential to check floods and soil erosion (Raghavan, 1958)[2]. Likewise, as stated by Lokanathan (National Council of Applied Economic Research, 1959)[1], in rural areas, about 300 million tons of wet cattle-dung, which is a very valuable manure, is burnt annually for cooking purposes. If this amount is used as manure, it can help to produce about nine million tons of grains annually.

The chief reason for using firewood and cattle-dung as fuels is the non-availability of satisfactory substitutes. Hence arises the need to find inexpensive and satisfactory fuels to replace the use of the invaluable cattle-dung and firewood for cooking purposes.

A few attempts have been made in the recent years to find satisfactory substitute fuels for firewood and cattle-dung specially for the rural areas. Special efforts are being taken in the Community Development Blocks to save cattle-dung for manurial use through introduction of cattle-dung gas plant. The cattle-dung gas plant designed by the Indian Agricultural Research Institute is one such effort in that direction. The principles involved in the numerous cattle-dung gas plants which are popularised in the rural area is that cattle-dung and other organic wastes are fermented to give off gaseous hydrocarbons which are drawn off as fuel, leaving a nitrogenous residue with enhanced manurial value. It was envisaged that construction of such gas plants and use of cattle-dung gas would help to solve the problem of fuel, deforestation and loss of cattle-dung manure simultaneously, according to Tamhane and Ghosh (1961)[3].

However many people do not know the existence of this gas plant and its economic advantages due to lack of publicity and information. Moreover while many claims are being made regarding the workability and advantages of the cattle-dung gas plants, no data are available to indicate their values for the homemaker. Therefore the need for a comparative study of the savings that could accrue from the use of cattle-dung gas plant for popularising these plants is very great.

This investigation has been undertaken to throw light upon the suitability of the cattle-dung gas as a household fuel for cooking purposes in relation to the expenditure of time, money and energy.

This study was designed to compare cattle-dung gas with firewood by cooking standardised meals with reference to time taken, fuel consumption and cost, palatability of the foods, attention needed, cleanliness and convenience.

It is hoped that the findings of this study will enhance the use of the dung gas plants and save the precious manure for food production.

II. REVIEW OF LITERATURE.

Sanderson (1956)[4] states that the ultimate source of all forms of energy available to man is the sun. Heat is a form of energy and it can be quantitatively measured. Solar energy is essential for plant life. The plant tissues become foodstuffs to animals. Plants and animal excreta are used as fuel. Rowland (1955)[5] points out that the materials such as wood, oil or coal formed from ancient plant and animal life have combustible components which burn in oxygen or in air, giving rise to fire.

Factors Determining the Value of a Fuel.

Avery (1955)[6] defines, "Fuel is a material which when burned furnishes heat energy at a reasonable cost". Different fuels catch fire at different temperatures. Rowland (1955)[5] defines 'Ignition Point' as the temperature at which a substance catches fire. The lower the ignition point of a fuel, the easier it is to start a fire with it.

According to Partington (1957)[7], the value of a fuel depends primarily upon its heat-producing capacity per unit mass or calorific value, which is expressed as the number of British Thermal Units of heat evolved by the complete combustion of one pound of that fuel. A British Thermal Unit (B.T.U) of heat is defined as "the amount of heat taken in when one pound of water is heated through 1°F", and is equal to 250 calories. The

"Bomb Calorimeter" is the apparatus used in the laboratory for determining the calorific value of fuels. The value obtained by using "Bomb Calorimeter" is the gross value and hence is higher than the net calorific value obtained under common household conditions. This is due to incomplete combustion and loss of heat through radiation under ordinary conditions.

All fuels contain the combustible elements, such as carbon and hydrogen, along with the non-combustible materials, such as mineral salts, nitrogen, carbon-dioxide and moisture (Avery 1955)[6]. The calorific value of a fuel is reduced when the proportion of non-combustible materials is increased. Krishna and Ramaswamy (1932)[8] state that moisture in a fuel reduces its heat-producing power, not only by reducing the proportion of combustible materials, but also by absorbing part of the heat produced for its vapourisation.

Weaver and Foster (1954)[9] state that the liquid fuel when converted into a vapour of finely divided state burns more effectively, because the fuel effect in solid or liquid fuels is produced only if the substances are first changed into vapour by heat or give off gas by chemical action. According to Hamlett (1953)[10], the cost of the fuel is an important factor, and the cost depends upon the kind, economy of production, availability and transportation. She further adds that fuels differ in the ease of handling, maintenance of cleanliness of the work area where they are used, labour involved in removing the residues left after burning, and conveniences of storing. Krishna and Ramaswamy (1932)[8] state that the selection of fuel does not depend upon its heat value alone, but also upon other factors such as freedom from smoke, ease and completeness of combustion, rapidity of burning and sparking.

Classification of Fuels.

Fuels fall under three main categories, namely, (i) solid fuels; (ii) liquid fuels, and (iii) gaseous fuels. Of these, some are naturally occuring fuels and some are manufactured.

(i) Solid Fuels. Solid fuels are used in their solid state, for example, wood, soft coke, peat, lignite, charcoal and coke. These may be natural fuels like wood and coal or manufactured fuels like coke and charcoal.

(a) Wood. Wood is an antique fuel. Krishna and Ramaswamy (1932)[8] state that wood is composed principally of cellulose and ligno-cellulose, also of gums, resins, oils, inorganic matter and moisture, the proportions of which depend on the kind of wood, the season in which it is cut and the extent to which it has been allowed to dry. Heart wood (otherwise called duramen, the hard central region of the secondary xylem) as a rule has a higher heat value than sapwood (called as alburnum, the soft peripheral region); for the heart wood has greater concentrations of organic substances such as tannins colouring matter, salts of inorganic acids, which may occur as infilterations in cell walls or as deposits within the cell itself. The heat value of such wood is considerably enhanced by these deposits (Krishna and Ramaswamy 1932)[8].

According to Krishna and Ramaswamy (1932)[8], the ash content or mineral salts of wood is found to differ with trees of the same species cut from different localities, depending on the soil and climatic conditions. The ash content in wood usually varies from one per cent to four per cent, but in certain woods, as in the heart wood of Anogeissus latifolia (Vella Nagam), it is as high as eleven per cent.

Ritter and Fletcher quoted by Krishna and Ramaswamy (1932)[8], give the chemical percentage composition of wood when completely freed from water as carbon 50, hydrogen 6, oxygen 42.75 and ash 1.25. After determining the calorific values of hundred and fifty species of Indian woods on zero moisture and ash-free basis, Krishna and Ramaswamy (1932)[8] state that the average heat value of Indian wood is 5016 calories per pound and for conifers the value is slightly higher, being about 5120 calories per pound. The calorific values of some common varieties of Indian wood are given in the Appendix I.

(b) Coal and Coal Related Fuels. Coal is defined in Encyclopaedia Britannica[11] as the stratified mineral formed by the action of decay, heat and pressure upon accumulation of vegetables and woody or cellulose matter laid down for ages. When plant tissue is changed into coal it loses its water, carbon monoxide and methane contents.

The coal related fuels are peat, lignite, bituminous coal and anthracite. Weaver and Foster (1954)[9] remark that plant and animal matter decayed and matted together form peat which can be dried and used as fuel. Layers of peat covered by soil and rocks lose water and gases and change in its chemical nature due to the pressure of the material on top, giving rise to lignite or brown coal. Increased pressure gradually changes the lignite to soft coal or bituminous coal. Hard coal or anthracite representing the latest stages in coal formation is produced under special conditions of high pressure. According to Partington (1957)[7], bituminous coal burns with a bright smoky flame. Anthracite has a high ignition point and burns with a brilliant lustre, gives very little smoke. Coke is also a variety of amorphous carbon derived from coal.

(c) Charcoal. Obtained when wood is destructively distilled or by incomplete burning of wood. It is black and burns readily, leaving little ash and emitting no smoke, as pointed out by Partington (1957)[7].

(d) Other Solid Fuels. Saw dust, leaves, twigs, waste paper, cow-dung-cakes, husk, coconut shells and other organic wastes are also used as fuels.

(ii) Liquid Fuels. Partington (1957)[7] states that liquid fuels are obtained from vegetable oil, animal oil or petroleum. Weaver and Foster (1954)[9] remark that petroleum is a natural mixture of hydrocarbons and obtained from the earth and from petroleum may be obtained many useful fuels, such as, gasoline, kerosene, fuel oil and paraffin by fractional distillation, which is the process of separating a liquid according to range of boiling points. Gasoline is used as motor fuel. According to Encyclopedia Britannica[11], liquid fuels weigh less and occupy less space than equivalent amount of solid fuels. Also they produce high heat in less furnace space, burn instantly and cleanly and require little ash removal and relatively little attention.

(iii) Gaseous Fuels. Gas is composed of molecules continuously in motion. They have a tendency to diffuse, which is the fundamental essential for gas flow. The specific gravity of all the fuel gases is less than air except liquified petroleum gases, which are one and a half to two times as heavy as air (Weaver and Foster, 1954)[9].

Gaseous fuels can be grouped under three main types, such as natural gas, coal tar derivatives and chemical derivations.

(a) Coal Gas. This is obtained as a by-product of destructive distillation of coal, which is a process of heating in the absence of air, as stated by Hansrath (1951)[12].

Weaver and Foster (1954)[9] remark that coal gas consists chiefly of hydrogen and methane with some carbon monoxide and nitrogen. Hanerath (1951)[12] points out that coal gas is very poisonous due to its carbon monoxide content and also it tarnishes silverware.

(b) Producer Gas. Producer gas is got by burning coal with limited oxygen to form carbon monoxide, says Hanerath (1951)[12]. According to Weaver and Foster (1954)[9], producer gas contains nitrogen, carbon monoxide and hydrogen. It is very poisonous and is used as industrial fuel, or to heat coke ovens or to run gas engines.

(c) Natural Gas. Consists chiefly of methane occuring naturally and it is pumped out directly to the household and it is an efficient and clean fuel according to Hanerath (1951)[12]. It is available in countries like United States and is non-occurrant in India.

(d) Water Gas. According to Hanerath (1951)[12], water gas is produced by passing steam over white hot coal or coke and it consists of hydrogen and carbon monoxide. ($H_2O + C \rightarrow CO + H_2$). Water gas has so little odour, that leaks in gas connection in a home would not be detected easily and accidents may occur. So coal gas or natural gas is mixed with water gas to give a detectable odour.

(e) Acetylene (C_2H_2) is produced by chemical action of water on calcium carbide as stated by Partington(1957)[7].

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$

Acetylene is used in the process of cutting and welding metals because of its capacity to give intense heat (Hanerath, 1951)[12].

(f) Liquified Petroleum Gases. These are made from liquified products consisting of propane (C_3H_8) and butane (C_4H_{10}). A comparative study of gas ranges using propane gas with electric range conducted by United States Department of Agriculture (1955)[13] revealed that more heat energy is utilised by gas range using propane than electric range.

(g) Cattle-Dung Gas. This organic fuel gas is of recent discovery. Gotaas (1956)[14] remarks that it is a product of putrefactive breakdown of organic materials such as cattle-dung and other wastes through the action of anaerobic organisms, which break down the organic components. It is further stated by Gotaas (1956)[14] that the anaerobic organisms use nitrogen, phosphorus and other nutrients present in the organic wastes, to develop their cell protoplasm, but reduces the organic nitrogen compounds to ammonia and organic acids and the unutilised carbon combined with hydrogen is liberated in the form of methane (CH_4) gas, which is combustible.

Other Sources of Heat.

Heat may also be produced by other forms of energy. Fuels are not the only sources of energy for cooking purposes. Electricity, microwaves, infra red waves and solar energy also produce heat which may be utilised for cooking purposes. Atomic energy is also utilised to produce heat. But it is not used in any household at present.

(a) Electricity. When a current of electricity passes through a conductor, heat is produced. The heat produced is proportional to the resistance offered to the passage of the current through the conductor. The heat thus produced is transmitted by conduction to the media to be heated through appropriate devices such as toaster, boiling plate, coffee oven percolators. The absence of smoke, smell or ash are advantages of electric devices along with the possibility of readjustment and regulation (Haslett,1953)[10].

(b) Infra Red Waves. Waves from about 0.03 to 0.00008 centimeters and are known as infra red or heat waves (Avery 1955)[6]. Tubular infra red quartz lamps as a source of infra red radiation was introduced recently and in order to do cooking, these lamps had to be placed in appropriate equipments as shown by Beveridge et al (1956)[15].

Beveridge et al (1956)[15] found that meat broiling was more rapid with the infra red quartz lamp unit than with the commonly used electric unit and there was neither advantage nor disadvantage for the lamp unit as to the quality of foods cooked.

Microwaves are electronic waves which are five inches in length, about 1/700th the length of radio waves and electronic wave is not heat but it is energy as Fenton (1957)[16] points out. She further remarks that electronic ovens are devices in which a magnetron tube or generator is used as the means of changing electronic waves into microwaves. In her experiments, time spent on cooking in electronic ovens was found to be from half to one tenth of that required by the 'conventional method' and as much as or more nutrients like ascorbic acid, thiamine, riboflavin, niacin and amino acids are retained.

(c) Solar Energy. The radiant energy from the sun is solar energy. Telkes (1958)[17] points out that in order to utilise solar energy, it should be concentrated through devices known as solar ovens, by using reflectors or mirrors, such as "spherical parabolic reflectors", "cylindrical parabolic reflectors" and plane mirrors. On clear days, solar ovens with five to seven square feet of solar energy concentrating area, can supply about 750 to 1000 B.T.U heat per hour and this heat is sufficient to heat five to seven pounds of water to boiling point in one hour. The size and shape of cooking utensils and their capacities for absorption of solar heat are additional determining factors for the amount that can be cooked. Practically all types of foods can be prepared with the use of solar ovens as shown by Telkes (1958)[17]. She found that vegetables cooked with minimum quantity of water in the solar ovens were excellent in taste, texture and colour; baked foods like bread, rolls and cakes had good texture; roasts had highly pleasing flavour and tenderness. Telkes (1958)[17] also found that the cooking time varied with the intensity of solar radiation; on clear days, the cooking time was approximately the same as with the usual gas or electric range and on hazy or partly cloudy days, the cooking time was longer.

Pattern of Use of Fuel in India.

Very valuable data regarding fuels have been collected through a study conducted by the National Council of Applied Economic Research (1959)[1]. Through surveys conducted by random sampling methods with a household as the sampling unit, the comparative study of the pattern of consumption of fuels in Delhi, Calcutta and Bombay cities showed the following facts:-

The percentages of families which use cattle-dung cakes as fuel are found to be as one in Bombay, 27 in Delhi and 28 in Calcutta.

From the data collected from the cities of Delhi, Calcutta and Bombay, it is found that there is a high positive correlation between the income of a household and its total energy consumption. However a point of interest is that the number of members were also high in these households.

Per capita expenditure per month on fuels for cooking works out to Rs.2/46 in Bombay city; Re.1/52 in Calcutta city and Re.1/70 in Delhi city.

In households in the areas going under the name of cities or towns in India, firewood is the major source of fuel for cooking and kerosene for lighting. Use of firewood and charcoal for cooking purposes is decreasing as the urbanisation of the area increases, giving place to more efficient and costly fuels such as kerosene and gas. In the coal-bearing areas of North and East India, soft coke and in the Western areas, charcoal is the major item of fuel for cooking. In Bombay, kerosene and gas are gaining importance as cooking fuels. In general, the rural domestic fuel consists of firewood and dung-cake for cooking purposes and kerosene for lighting purposes. The amount of cattle-dung used seemed to be higher where it is available as home-production or free of cost.

Consequences of burning firewood is viewed with great concern by National Council of Economic Research (1959)[1]. The firewood supplied from the forest area would meet only one sixth of the total requirements and the rest is to come from non-forest areas. This high rate of cutting from non-forest areas is injurious to the maintenance of a healthy normal natural cycle.

Consequences of burning cattle-dung for fuel is detrimental to our economy. According to 1956 census, as given in India (1960)[18], the livestock, excluding poultry in India consisted of the following:-

Cattle.	1587	Lakhs.
Buffaloes.	449	"
Sheep.	392	"
Goats.	554	"
Horses and ponies.	15	"
Others (Donkeys, pigs, camels, mules, etc.).	68	"
Total...	3065	Lakhs.

Subbiah (1960)[19] divides the cattle into three main categories on the basis of their utility. They are - 'draught type' providing motive power; 'milk type' giving milk and 'beef type' providing meat.

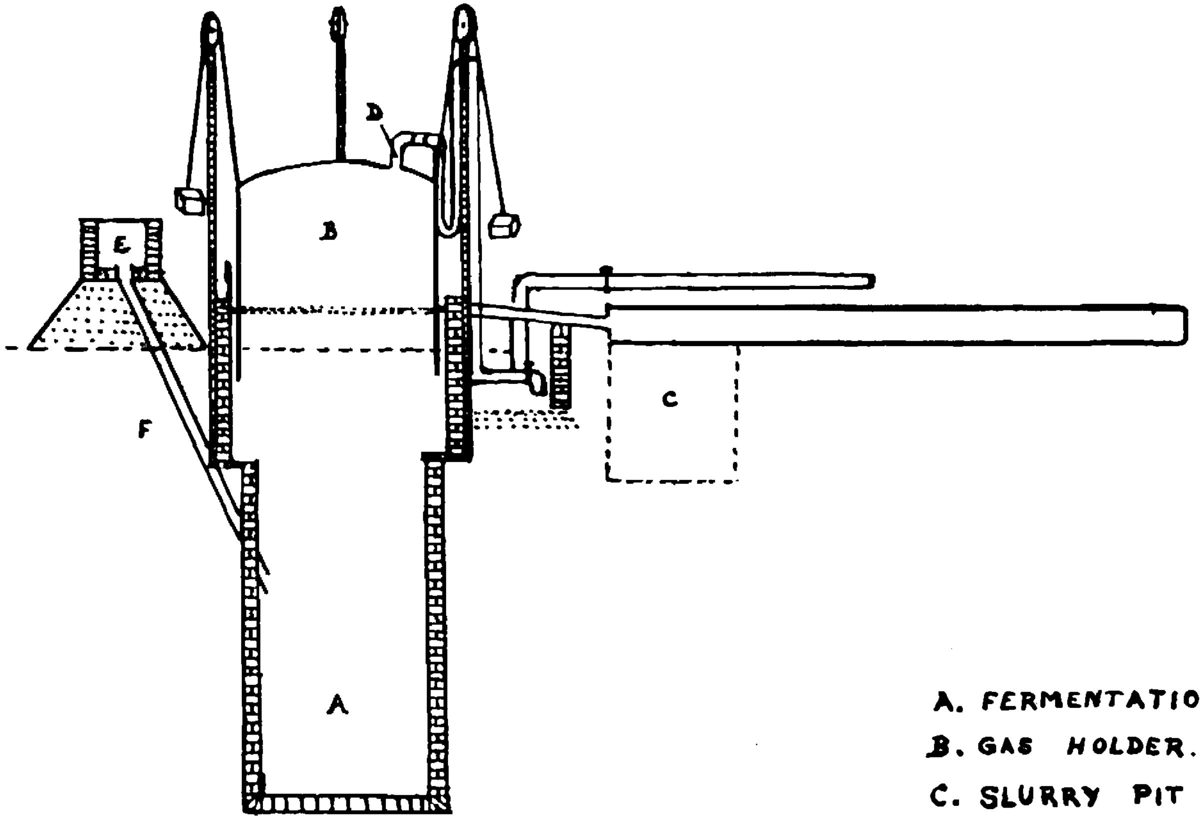
Rattan Singh (1961)[20] claims that 'Gobar' (as cow-dung is called in Hindi, meaning the best thing produced by the cattle) is the main product, while milk and draught power are only the by-products of the cattle. The proper and legitimate use of cattle-dung is as manure. However dung is usually put into various other uses such as fuels and for cleaning floors. National Council of Applied Economic Research (1959)[1] estimates that in rural homes, about 300 million tons of wet dung is dried into cakes and burnt every year. It is also estimated that 300 million tons of dung will give nine hundred thousand tons of nitrogen and four hundred and fifty thousand tons of phosphorus pentoxide which are equivalent to 450,000 tons of ammonium sulphate and 2.25 million tons of phosphate fertilisers. Assuming an average of extra yield of ten pounds of grains per pound of nitrogen, nine hundred thousand tons of nitrogen will give nine million tons of grains annually, apart from other benefits such as general improvement of the soil structure resulting in higher fertility all round.

The problem of rural domestic fuel supplies should be tackled and resolved at local level because in the rural areas the fuel economy is not influenced by price, while in the urban areas, the fuel economy is almost wholly monetized and the price remains the only economic factor to be considered. Therefore the Council of Applied Economic Research (1959)[1] recommends the cattle-dung gas plant as one of the solutions.

Cattle-Dung Gas Plants.

Cattle-dung gas plants, as illustrated in Figure 1, on page 18, designed by the Agricultural Research Institute, consists of a well (A), which serves as the fermentation tank. The tank is covered with a metal drum (B), which acts as the gas holder. An inlet tube connects the fermentation tank with the cattle-dung mixing tank. An outlet connects it to the slurry pit (C). A gas outlet tube (D) is led out from the drum.

Daily fresh dung is diluted in the mixing tank with



A. FERMENTATION TANK.
B. GAS HOLDER.
C. SLURRY PIT
D. GAS OUTLET TUBE
E. COW DUNG MIXING TANK.
F. INLET TUBE

FIGURE 1

CATTLE DUNG GAS PLANT (I.A.R.I.) MODEL.

water and introduced into the fermentation tank, where the fermentation takes place. The gas formed is accumulated in the gas holder forced into the outlet pipe by the pressure of the drum. It is taken to the kitchen through pipes. The digested material called slurry overflows from the top of the well and collects in slurry pit. (Tamhane and Ghosh, 1961)[8].

Ramdas (1962)[21] states that the design of cattle-dung gas plant has been modified and 'two-staged digesters' are installed. He points out, the cattle-dung gas plants with two-staged digesters are advantageous because it reduces short-circuiting which is not always easy to prevent and gas collection is simple and removal of supernatent water is easy.

Joppich (1957)[22] gives details of three types of cattle-dung gas plants used in Germany. They are 'Schmidt Eggergluss' type; 'Weber' type and 'Kronseder' type.

'Schmidt Eggergluss' type is shown in Figure 2, on page 20. This gas plant is suitable for farms of 570 to 1300 acres. Cow-dung, urine and chopped straw are mixed with thin digested slurry in a small mixing tank and transformed into a pulp, fit for pumping. The pulpy fluid is brought into a fermentation tank protected from air (oxygen) and light and methane fermentation takes place. The temperature is maintained between 77°F and 88°F by blowing steam in. In order to eliminate the straw layer on the surface of the liquid, thin slurry is taken from

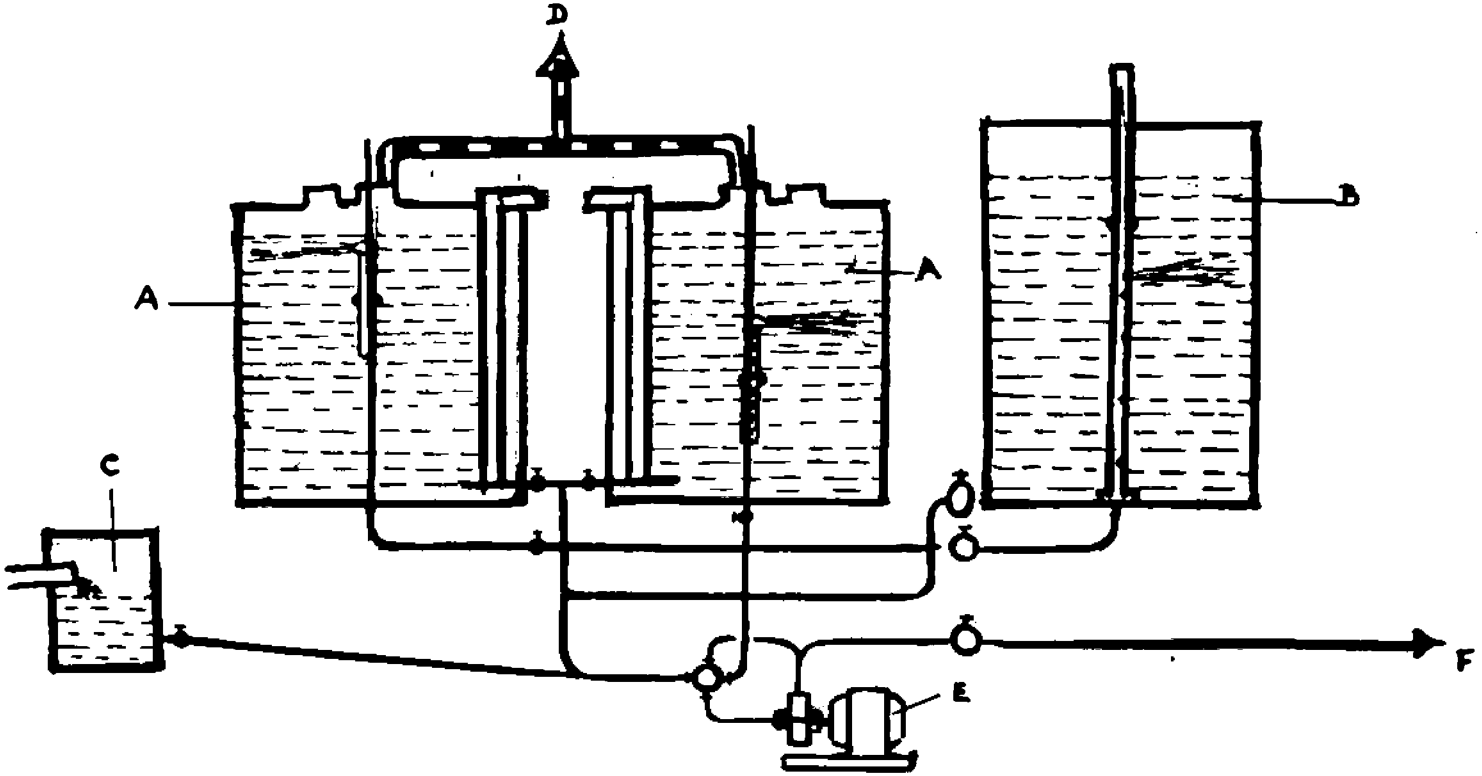


FIGURE 2

THE SCHMIDT-EGGERSGLUSS TYPE OF CATTLE DUNG
GAS PLANT.

A. FERMENTATION TANKS
B. STORAGE TANK FOR DIGESTED SLURRY
C. MIXING TANK
D. PIPE LEADING TO THE GAS STORAGE TANK.
E CENTRAL PUMP.

the bottom of the tank by the central pump and forced as a strong flush into the straw layer. With the help of a small electric motor, the flush is turned round and moved upward and downward by a telescope-like tube. Working of the flush twice a day for about 10 to 15 minutes is sufficient to destroy the straw layer. The gas produced in the tank is stored in a separate gas tank and the slurry is stored in a special tank for manurial purposes. Fresh material is added daily and the slurry is removed once in two or three weeks.

The 'Weber' type, illustrated in Figure 3, on page 22, consists of two fermentation tanks, one tank for the storage of digested slurry and one for gas. The fresh material is filled into the small mixing tank inside the cowshed. Simultaneously, a thin slurry flows from the bottom of the fermentation tank placed at a higher level, into the mixing tank. This flush enters the mixing tank, causing a circular movement. By this and with the sucking effect of the conical outlet at the bottom, the fresh material is mixed into a pulp fit for pumping. Other organic wastes are added into a second mixing tank outside the cow-shed. The pulp enters the central pump and is forced into the fermentation tank. Four conical wooden beams are fixed in the tank, which by moving up and down while filling or removing of digested material prevent obstruction of gas rising by the straw layer. When the straw layer becomes thick,

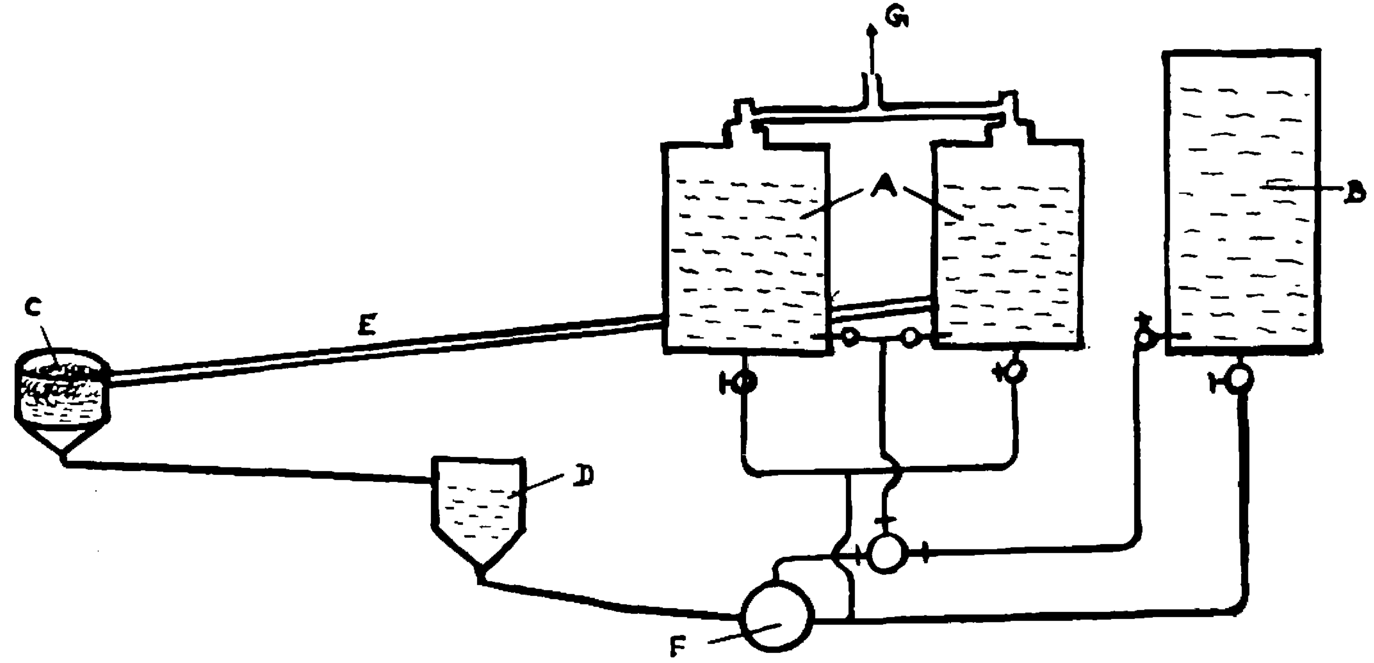


FIGURE 5.

WEBER TYPE COW DUNG PLANT

A. FERMENTATION TANKS
B. STORAGE TANK FOR DIGESTED SLURRY
C. MIXING TANK INSIDE THE COWSHED.
D. MIXING TANK II
E. THIN SLURRY
F. CENTRAL PUMP
G. PIPE LEADING TO THE GAS STORAGE TANK

it is removed and the liquid is taken to the fields.

'Kronseder' type of gas plant is suitable for providing gas for cooking purposes in small farms. As shown in Figure 4 on page 24, a tub split in the longitudinal axis floats in a cesspool. The liquid ferments inside the tub. The gas produced is collected in the tub from where it is taken to the kitchen through a rubber tube and the slurry is removed by removing the tub.

Factors Influencing the Production of Cattle-Dung Gas.

Acharya (1957)[23] carried out experiments to examine some of the factors which influence the production of this combustible gas and manure during anaerobic digestion of bullock dung and other organic materials. He found that a period of four weeks for digestion at 30°C is necessary for obtaining the potential gas per pound of dry matter in the added dung, and about 1.5 c.f.t of gas per pound of fresh bullock dung is produced. The gas contains 55 to 60 per cent of methane. Dilution of bullock dung with water in ratio of 1:1 or 1:1½ was found to increase the rate of gas production. The proportion between the quantities of old slurry present in the fermentation tank and fresh dung added daily was found to be an important factor in controlling the rapidity of decomposition and gas production. A proportion of four to one between the quantities of old slurry and fresh dung was found to be satisfactory. But the rapidity was found to increase with increasing proportions of inoculum of fresh dung added.

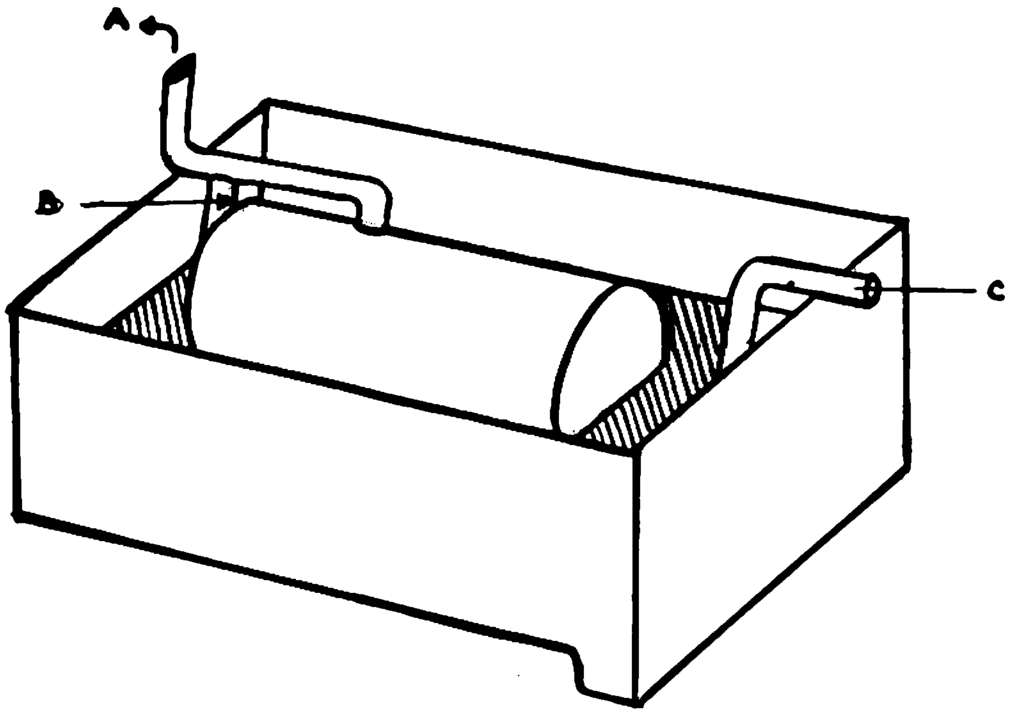


FIGURE 4

KRONSEDER TYPE OF CATTLE DUNG GAS PLANT

A GAS TO THE RANGE
B OUTLET FOR CONDENSED WATER
C. PUMP FOR TAKING OUT DIGESTED SLURRY.

The production of gas was at its best when the fermentation chambers were fifty to sixty times the volume of the daily addition of bullock dung. Addition of nutrients, for rapid anaerobic digestion, like nitrogen, phosphoric acid, did not enhance or increase the gas production due to the sufficiency of nutrients already present in the bullock dung used. The organic materials containing balanced quantities of hemi-celluloses, celluloses, groundnut shell and sugarcane baggasse yielded on anaerobic digestion, considerable quantities of combustible gas possessing a high calorific value rich in methane. Materials rich in easily fermentable carbohydrates such as jaggery, molasses, potato, maize grain, gave a gas of low calorific value and rich in hydrogen. The thermal value of the abovementioned biological fuel gas was about 550 B.T.U. The gas production was affected by the development of acidity. As Gotaas (1956)[14] points out, the desirable pH for gas production ranges between 6.8 and 7.5, the optimum being above seven.

Advantages of Cattle-Dung Gas Plant.

The manure can be fermented in a smaller space without production of any obnoxious gases that are found in the ordinary practices of fermenting dung in heaps and also the time taken to complete the manure-making varies from three to five months in the common methods, such as composting, while in the gas plant, it takes only about seven to ten days, remarks Acharya (1957)[23].

Joppich (1957)[22] states that the superiority of dung gas plant-digested manure in quality has been proved through the fact that farms have reported increase in the yields by eight to ten per cent after applying the digested slurry to potato, beets, grains, and other crops and about ten per cent to thirty per cent after applying to grass land.

The digested manure is absolutely odourless as there is no further decomposition to take place on the digested manure coming out. Gotaas (1956)[14] claims that ideal sanitation is ensured by the use of cattle-dung gas plants because the manure does not contain pathogenic organisms and is not conducive to fly-breeding. Self-sufficiency and simplicity of design, freedom from gas hazards are other advantages of cattle-dung gas plants, as stated by Majumdar (1961)[24]. Majumdar (1961)[24] suggests to set up gas plants, one for each village all over the country, and foresees large benefits by such a step through saving of other fuels and manure.

Uses of Cattle-Dung Gas.

The gas given out by the plant can be put into various uses such as for heating rooms, heating water and as a fuel for purposes of cooking in the households, running stationary motors, for driving chaff-cutters, flour grinders, working of refrigerators, driving tractors, for production of electricity, as claimed by Joppich (1957)[22]. Harkirat Singh (1958)[25] points out that cattle-dung gas can be utilised as fuel for cooking, for lighting, for room heating, heating appliances, for ironing clothes, for churning milk and working fans.

Studies Made on Fuels in Relation to Cost, Cooking Time and Convenience.

Chetty (1958)[26] experimented on wood, charcoal, kerosene and electricity, with a view to study the relative fuel consumption, cost and cooking time. Her findings showed that wood was not a first class fuel, as it was difficult to maintain a constant temperature with it; especially it was disadvantageous for deep fat frying where a constant temperature of the frying medium was required. Longer time for ignition, frequent blowing, a greater emission of smoke and soiling of the cooking utensils due to soot deposition, were some of the practical problems with regard to firewood. Charcoal was found to be a better fuel than wood for it did not give rise to smoke, nor did it blacken the cooking utensils. However, hands were soiled while transferring the charcoal to the 'sigri' or stove. Charcoal was comparatively easier to light and gave steady, direct flame. Cooking was slow, hence cooking time was increased. Charcoal pieces had to be stirred once in a while because of the ashes. The ash formed on combustion, covered the remaining charcoal, thus restricting complete combustion. In order to revive the fire, the charcoal had to be stirred. While doing so, the temperature of the product cooked was considerably lowered and it took some time before the original temperature was reached. Kerosene was found to be the most economical fuel with regard to the amount of fuel consumed, time taken and cost. It was easy to light, gave steady and intense heat. Electricity was found to give steady heat, but the time taken for cooking was relatively higher than that with the other fuels, because the coils through which electricity passed took a long time to get heated and transmit the heat to the cooking utensil. The quantity of electricity used was in direct proportion to the time taken for cooking. Cooking was accomplished with ease and efficiency. There were no problems such as smoke, odour and soiling of utensils. However, the initial cost of installation and the running cost were high.

Lalitha (1961)[27], through a pilot study of four household fuels, namely, firewood, charcoal, kerosene and electricity, with reference to cooking time, consumption, cost and convenience, found that time taken to cook rice and beans was longest when charcoal was used and firewood came next. Kerosene took less time and electricity took the least time. The order was reversed in the case of cost involved. Electricity and kerosene were found to demand less attention than firewood and charcoal when used as fuels. More labour was put in to clean the utensils used over firewood than over other fuels because of the soot. Fuels were found to have no effect on the palatability of foods cooked.

In the above mentioned studies, comparison of various fuels was done by cooking standardised meals under identical conditions.

III. EXPERIMENTAL PROCEDURE.

The experiments in this study were based on cooking standardised meals for a day for a reference family, using two different fuels, namely, firewood and cattle-dung gas simultaneously, all other conditions being identical.

The observations made for assessing the relative merits and disadvantages of selected fuels were:

i) Time taken to cook the meals,

ii) Special attention required to regulate the fire,

iii) Time taken for washing and rinsing the utensils after cooking,

iv) Quantity of fuel used,

and v) Palatability of the foods cooked.

The experiments involved:

(a) Selection of:

i) Fuels,

ii) Equipment,

iii) Foods,

and iv) Cleaning materials.

(b) Standardisation of the procedures:

i) Lighting and maintaining the fire in gas burner and 'chula',

ii) Cooking,

iii) Cleaning the utensils,

iv) Measurement of fuels,

and v) Judging the palatability of the cooked foods.

(c) Observation and recording of results:

Selection of Fuels, Equipment, Foods and Cleaning Materials.

(i) Fuels. As for the cattle-dung gas, the source selected was the cow-dung gas plant erected in a friend's house, as per the given description on page 17.

To ensure a steady supply of gas at uniform pressure, daily two buckets of cattle-dung, diluted with two buckets of water, were added to the feeding tank of the gas plant. The dung was collected from the same three animals - one buffalo, one cow and one calf - to maintain uniformity of quality of dung daily.

Commonly available firewood in Coimbatore, being tamarind wood, was selected. Two hundred and forty pounds of firewood, sold as pieces of about three feet length and one pound weight, were purchased in one lot to last for the entire period of the experiment. The pieces were split longitudinally to ensure uniform thickness without altering the length of three feet, dried in the sun for two days and stored in a room.

(ii) Equipment. The equipment used in the study consisted of, gas burner, 'chula', utensils and measuring devices.

Gas Burner. An iron burner as shown in Figure 5 on page 31, was used with cattle-dung gas. It consisted of a hollow ring with orifices for the passage of gas, four

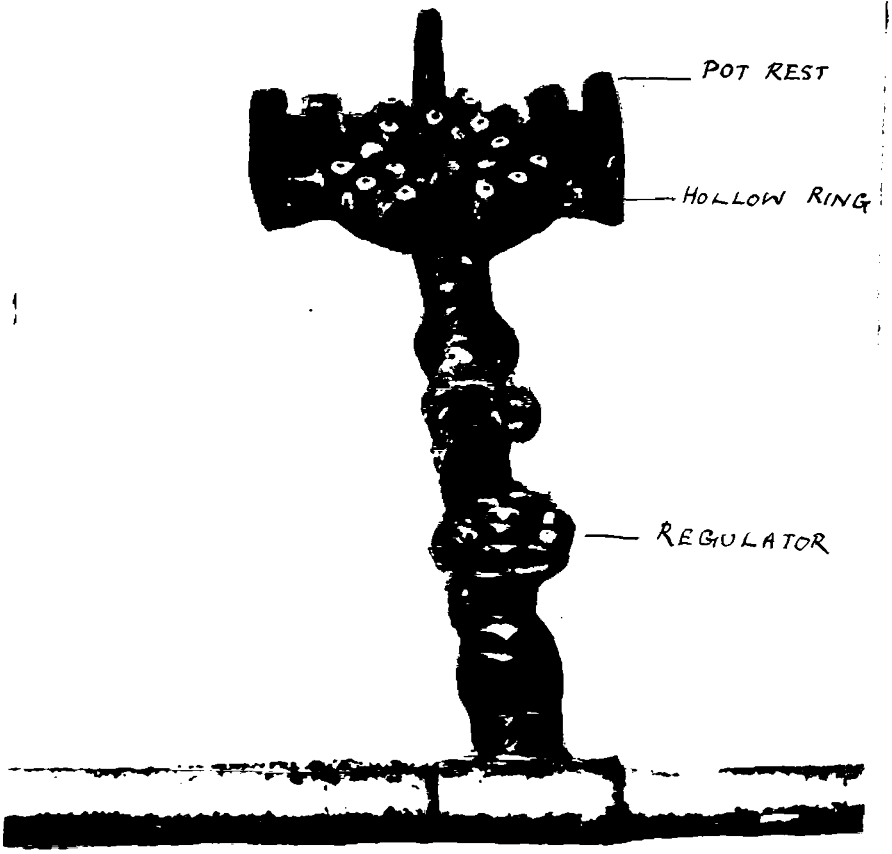


FIGURE 5
GAS BURNER

projections to serve as rests for the utensils and allow space for the flames to heat them, a lead pipe to connect with the gas line and a circular regulator for the gas supply.

'Chula'. A baked pottery 'chula' with a single pot seat as shown in Figure 6, on page 33, was purchased at the local market. The diameter of the pot seat of this 'chula' was identical with that of the gas burner selected, so that, the area of exposure of the bottom of the utensil to the flames was identical in both cases. As pointed out by Monroe and Smith (1934)[28], the area of contact with the heating surface is one of the determining factors in utilisation of heat.

Utensils. For cooking, two identical sets of utensils, each set consisting of, as shown in Figure 7, on page 34, a cast iron 'vanali' (A) for preparation of 'uppuma' and 'idli', a brass 'dekshi' (B) with aluminium lid for boiling milk, egg and cabbage, a brass pot (C) with lid, to cook rice and a brass pot (D) with lid, to cook 'sambar' were selected. The capacities of these utensils were adequate to cook the calculated quantities of the food preparations. The 'vanali' was selected to serve a double purpose, to be used as a steamer for preparing 'idlis' by fitting an aluminium 'idli' plate (E) and a special dome-shaped lid (F). Additional details of the utensils chosen are given in Appendix II. They were identical in shape and volume and the materials of which

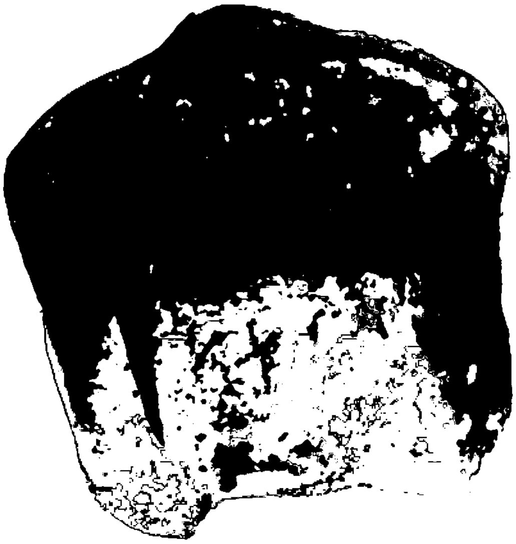


FIGURE 6
'CHULA'

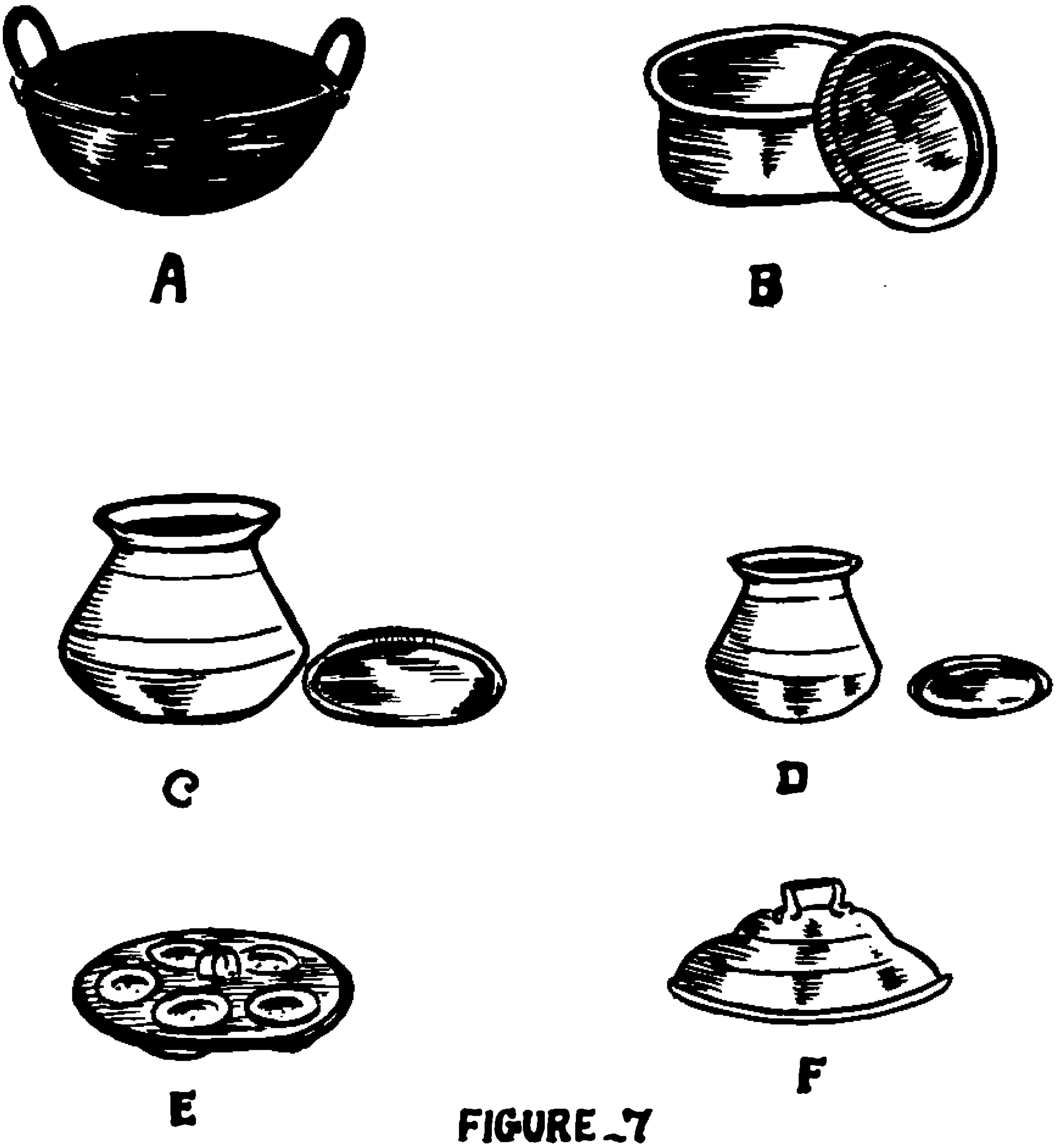


FIGURE-7

ONE SET OF UTENSILS USED FOR COOKING

they were made.

Plain white porcelain quarter plates and cups, stainless steel spoons and glass tumblers were selected for serving the foods prepared to the panel of judges.

Measuring Devices. Measuring devices were needed for weighing the foods and firewood, measuring volumes of liquids and for recording time.

Solid Foods: For weighing the foodstuffs, 500 grams capacity dietetics scale was selected. For condiments, standard measuring spoons were used.

Liquids: A set of standard measuring cups graduated in ounces were selected to measure milk and water. A 50 c.c. measuring cylinder was used for measuring kerosine, used for starting the fire.

Firewood: A vegetable vendor's balance with two pans and a set of weights of pounds and ounces was used to weigh firewood and remnant pieces of charcoal.

Time: A time-piece was selected for recording the timings involved in all the activities of this study. A stop-clock was used to record in seconds the scrubbing times noted.

(iii) Foods. Meals to be cooked were selected on the basis of a day's nutritional requirements of a reference family consisting of one adult male and two adult females as doing moderate work. The nutritional requirements of this family, as recommended by Aykroyd et al (1962)[29] and the foods are given in Tables I and II.

TABLE I.

DAILY REQUIREMENTS FOR A FAMILY OF THREE ADULT MEMBERS; ONE MALE DOING MODERATE WORK AND TWO FEMALES DOING MODERATE WORK.

Nutrients.	Man.	Woman I.	Woman II.	Total.
Calories.	3000	2100	2100	7200
Protein in g.	82	67	67	216
Vitamin A in I.U.	4000	4000	4000	12000
Vitamin C in mg.	50	50	50	150
Calcium in g.	0.8	0.8	0.8	2.4

Using the requirements mentioned in Table I, the foodstuffs which would supply these needs were chosen. The cost of the foodstuffs was calculated on the basis of prices in Coimbatore retail market in October 1961. Quantities of provisions which would be needed for the whole experiment were calculated on the basis of foods chosen. The daily requirement of foodstuffs for the reference family and the cost are given in Table II.

TABLE II.

QUANTITY AND COST OF THE FOODSTUFFS CHOSEN FOR THE DAILY MEAL.

Sr. No.	Foodstuffs used.	Quantity in Ozs.	Cost. (nP)
1.	Rice flour (parboiled).	8	25
2.	Black gram dhal flour.	2	6
3.	Coconut.	3	6
4.	Milk.	36	72
5.	Eggs.	9	60
6.	Red gram dhal.	3½	13
7.	Potatoes.	8	18
8.	Tamarind.	1	6
9.	Cabbage.	10	16
10.	Rice.	16	30
11.	Wheat ravai.	13	31
12.	Cucumber.	6	12
13.	Plantain.	9	9
14.	Gingelly oil.	½	3
		Total cost.	Rs. 3/07
Cost per head per day.			Rs. 1/02

Using the foodstuffs mentioned in Table II, the day's menu was drawn, as shown in Table III.

TABLE III.

MENU FOR A DAY FOR THE REFERENCE FAMILY.

Breakfast.	Lunch.	Dinner.
'Idli'.	Rice.	Wheat 'uppuma'.
Coconut chutney.	Carrot, Cucumber salad.	Plantain fruit.
Egg.	Cabbage 'porial'.	Milk.
Milk.	Potato 'sambar'.	
	Butter milk.	

From the menu given in Table III, preparations which required cooking, namely, milk, 'idli', eggs, 'sambar', cabbage 'porial', rice, 'uppuma' were selected for the cooking experiment in this study, excluding chutney, salad, buttermilk and plantain fruit.

In order to calculate the amount required for standardisation and experimentation recipes for 'idli' given by Desikachar (1959)[30] and for 'sambar' and 'uppuma' by Sarojini (1958)[31] were selected. The investigator developed the other recipes for rice and cabbage 'porial'. Recipes are given in Appendix III to VI. Calculated quantities of dry provisions were purchased in one lot in order to keep the quality of foodstuffs purchased to be kept constant throughout the experiment. They were cleaned and stored in tin containers with close-fitting lids and labelled.

Potatoes, eggs, green chillies, cabbage and milk were bought daily.

iv **Cleaning Materials.** Tamarind pulp, sifted ash and 'vim' were selected for cleaning brass, iron and aluminium utensils respectively. A duster and a bundle of coconut fibre was selected for wiping and scrubbing purposes.

Standardisation of Procedure.

The procedures for the activities of the experiment were first standardised as described.

(i) **Lighting and Maintaining the Fire.** Different methods were followed for each fuel.

The Gas Burner. Each time the burner was lighted, gas regulator was turned on to allow the fullest supply of gas and the burner lighted with a match stick. Immediately the utensil concerned was placed on it.

It was found necessary to effect three levels of heat while using the gas burner, namely high, medium and low, depending on the method of cooking employed. This was achieved by turning the gas regulator fully three-fourths or half a rotation.

The 'Chula'. Through preliminary experimentation, three pieces of firewood with two crossed at the bottom and one on top with two ounces of chips of firewood spread over them, were found to be satisfactory to start and maintain a steady flame. Ten cubic centimetres of kerosene was used as the ignition fuel for lighting the fire. One minute after lighting the fire with a match stick, the utensil was kept on the 'chula'.

In order to maintain a steady flame, whenever the 'chula' was congested with smoke, blowing off the smoke with a blow pipe was resorted to. Poking the firewood and changing the position of the firewood pieces also were done to facilitate burning. When the burning of the firewood pieces was nearing completion, new pieces were placed. It was also noted in the preliminary experiments that after about three hours of steady burning, much ash and charcoal got collected inside the 'chula', obstructing circulation of air. Therefore they were raked out, every three hours period of cooking. All these steps were carefully recorded for assessing the labour involved.

(iii) Cooking. The recipes for various items of menu and the cooking sequence were standardised.

'Idli'. Cooking procedures for 'idli' was slightly modified from the conventional method in order to facilitate standardisation, simplify steps in cooking, minimise expenditure of time and attention needed while cooking.

It was considered desirable to have dry parboiled rice ground into coarse flour and black gram dhal into fine flour and stored for the entire period of experiment in order to minimise variables. In preliminary experiments after trying proportions of rice flour to black gram dhal flour as 2:1, 3:1 and 4:1, proportion of rice flour and black gram dhal flour of 4:1 was satisfactory and therefore, adopted to prepare batter for 'idli'. The recipe for 'idli' was standardised as shown in Appendix III. Batter was prepared for ten 'idlis' each time as the 'idli plate' had depressions to make five 'idlis' at a time. Steaming was carried out in following manner: The 'vanali' for steaming 'idli' with four cups of water was placed on the fire to boil. As water was being boiled, a clean white cloth was moistened with water and spread over the 'idli plate' covering the depression into each of which one-third cup of batter was poured. When the water in the 'vanali' started boiling, the 'idli plate' with the batter was placed in the 'vanali' in which the level of boiling water was well below the level of 'idli plates' and was closed tight with the dome-shaped lid. The batter was thus steamed and the doneness was taken as completed when the mixture does not adhere to the blade of knife inserted in the centre. Time taken to steam 'idlis' over the burner was about ten minutes while those over the 'chula' was about twelve minutes for optimum doneness. Therefore these times were allowed for all subsequent 'idlis'.

<u>'Uppuma'.</u> This was cooked by the commonly used method. Recipe standardised for 'uppuma' is given in the Appendix IV.

<u>Egg.</u> The utensil for boiling egg was kept on the

fire with two and a half cups of water. Four eggs were put into the boiling water and cooked for three minutes to get soft-boiled eggs.

Milk. Four and a half cups of milk were taken in the utensil and placed on the fire and brought to boil. When the milk boiled and foamed up to the brim of the utensil, it was removed from the fire.

Rice. The method adopted for cooking rice involved using just adequate quantity of water as described by Pearson *et al* (1948)[32]. The quantities of rice and water standardised were 495 g. of rice and 7½ cups of water. The water was boiled and washed, cleaned and drained rice was added. The preliminary experiments showed that about 40 minutes were optimum time to cook rice to the desired doneness.

Cabbage 'Porial'. The 'conservative method' of cooking vegetables, as elaborated by Holt (1958)[33] which involves cooking of vegetables in a little water in a tightly closed utensil for about ten to fifteen minutes was adapted for preparing cabbage 'porial'. For each set of experiments, a big cabbage purchased was cut into two equal halves, longitudinally, for use with the cattle-dung gas and firewood. After discarding outer damaged leaves, cabbage was chopped into uniform pieces (½" x 2"). The cut pieces were mixed thoroughly, and the standardised quantity taken for preparation as per recipe given in Appendix V. Through the preliminary experiments it was observed that about seven minutes were required in the gas burner and about twelve minutes in the case of 'chula' for cooking cabbage for obtaining identical preparation.

'Sambar'. The recipe for 'sambar' powder was standardised as shown in Appendix VI and prepared in one lot and stored in a dry container to last through the experiment and the 'sambar' prepared as shown in Appendix VI. In the preliminary experiments it was shown that the total time taken for preparation of sambar was approximately 55 to 65 minutes for gas burner and 'chula' respectively.

Sequence of Cooking. The cooking of the two meals, one using cattle-dung gas as fuel and the other using firewood as fuel were planned to be carried on simultaneously, so that the atmospheric conditions of humidity, room temperature, pressure and air currents would be the same for both.

Following the customary pattern of breakfast, lunch and dinner, and keeping in view the frequency of use of the utensils, the sequence of cooking the different items arrived at was: milk, 'idli', egg, 'sambar', cabbage 'porial', rice and 'uppuma'. The cooking was started at 11.30 a.m. over the 'chula' and at 12.20 p.m. over the gas burner daily so that the completion of cooking the meals in both cases coincided at about 4 p.m. This timing was decided upon to suit the convenience of the panel of judges.

Throughout the cooking experiment, each set of utensils were rotated evenly in their use over the gas burner and the 'chula', in order to equalise any difference that may be latent in the utensils.

Recording of Attention Needed. During this experiment the following activities were done:-

i) Stirring of the food so that they are not boiled over or charred at the bottom. The number of times the preparations were stirred in both cases was standardised.

ii) Blowing in case of the 'chula'.

iii) Flame control which meant adjusting the regulator in case of gas burner and adjusting the firewood through poking, raking in the case of 'chula'.

iv) Adjustments of the lids.

All these activities were noted and recorded.

iii Cleaning of Utensils. The procedure for washing utensils, amounts of cleaning agents used were standardised as follows: The four utensils, lids and the 'idli plate' used over cattle-dung gas were collected near the sink. The utensils were soaked after which the food particles which were loosened in the utensil were removed with the aid of the coconut fibre. The outer side of brass utensils were smeared with tamarind pulp moistened with water, followed by scrubbing with moistened coconut fibre, dipped in ash, first inside and then the outside of the utensil. The scrubbing was continued till the surface was shiny and then was rinsed in water. As for 'vanali', the same procedure was used except that the application of tamarind pulp was omitted. The procedure was even more simple for the aluminium lids and 'idli plate'. No preliminary wiping of food particles was involved. They were scrubbed with 'vim' and rinsed in water.

Procedure to wash utensils used over firewood were the same as in the case of cattle-dung gas except that of an additional wiping off of the thick deposit of soot found on the outside and bottom of the utensils. Hence the utensils taken near the sink were first wiped with a dry duster for one minute to remove the soot deposit to an extent possible before soaking. Also scrubbing the utensils with moistened ash and coconut fibre, on the outside, the gradual removal of the black soot could be seen through the black streaks it formed mixed with ash. The scrubbing was continued till the streaks stopped appearing. The utensils were then rinsed with water. Consequently the quantities of cleaning agents used were different. Through a preliminary experiment, the amounts of cleaning agents to be used were standardised in both series of experiments as given in the Table IV.

TABLE IV.

CLEANING AGENTS USED FOR WASHING THE UTENSILS, LIDS AND 'IDLI PLATE'.

Utensils.	Cleaning agents.	Quantity used for: Cattle-dung gas.	Quantity used for: Firewood.
Aluminium plates and lids.	'Vim'.	1 table spoon.	1-1/3 table spoon.
Brass utensils.	Tamarind.	½ Oz.	½ Oz.
Brass utensil and 'vanali'.	Wood-ash.	3 table spoons.	8 table spoons.

Thus it may be seen from the Table IV, the quantity of cleaning materials were less for utensils used over cattle-dung gas than that of firewood.

Time taken for the various activities in washing the utensils were standardised through preliminary experiments as given in the Table V.

TABLE V

TIME TAKEN FOR VARIOUS ACTIVITIES IN WASHING THE UTENSILS, LIDS AND 'IDLI PLATE'.

Type of utensil.	Activity.	Time taken in Minutes. In the case of utensils used over:	
		Cattle-dung gas.	Firewood.
Brass utensils and 'vanali'.	Wiping off the soot.	Nil.	1
-do-	Soaking in water.	15	15
Brass utensils.	Application of tamarind pulp.	2	2
Brass utensils and 'vanali'.	Scrubbing with ash.	Variable.	Variable.
-do-	Rinsing in water.	2	2
Aluminium lids, 'idli plates'.	Scrubbing with 'vim'.	Variable.	Variable.
-do-	Rinsing in water.	½	½

As can be seen from the Table V the only variable was the time taken for scrubbing, as all other activities were standardised.

Throughout the experiment, care was taken to wash with the same speed, effort, force and type of movements to the extent possible.

Measurement of Fuel.

Cattle-Dung Gas. The rate of flow of gas was measured by simple displacement method. A gas jar completely filled with water and covered with a ground glass cover was inverted over a beehive-shelf placed in a trough of water and the cover was carefully removed under the water. The burner was detached and gas was led to the shelf by means of a rubber tube. Gas was collected for a known period of time in the jar by displacement of water. After turning off the gas, the levels of water inside the jar and outside were equalised in order to equalise the pressure of the gas collected to atmospheric pressure and the volume of the water collected was measured by pouring it in a measuring cylinder. This was repeated twice and the average rate of flow of gas per second was found out. The atmospheric pressure and room temperature were noted. By applying the gas equation, $PV = RT$, where P, V and T stand for pressure, volume and temperature measured in absolute scale of the gas collected and R is a constant, the volume of gas per second at N.T.P was calculated. By appropriate manipulation of the regulator, the rate of flow of gas under high, medium and low flames were obtained. This was repeated on two days and average was taken. The readings are given in Table VI.

TABLE VI.

RATE OF FLOW OF CATTLE-DUNG GAS.

Replicates.	Volume of gas per second at N.T.P. High flame level.	Medium flame level.	Low flame level.
1	131 c.c	101 c.c	83 c.c
2	178 c.c	129 c.c	81 c.c
Average.	180 c.c	115 c.c	82 c.c

By knowing the rate of flow of gas per second under high, medium and low flame and time taken for cooking under high, medium and low flames, the total volume of gas consumed during the entire period of cooking was calculated.

Firewood. Before starting the experiment, six pieces of firewood to be used for cooking were weighed with a vendor's balance. At the end of the experiment, the remnant stumps of unburnt firewood were withdrawn, the burning end extinguished and pieces of charcoal were dislodged by tapping into a tin container. The remnant firewood pieces were weighed. The difference between the original and final weight of firewood was taken as the weight of firewood used. The live coal pieces were collected from the inside of the 'chula' by means of tongs, leaving the ash, and put in the tin container and covered loosely to put out the fire. When cooled, this was weighed. As charcoal has also fuel value and could be further used as household fuel, the firewood equivalent of charcoal residue was estimated, using the 'conversion table' given in the report of National Council of Applied Economic Research (1959)[1], wherein the energy equivalent of firewood and charcoal residue for a maund is shown as 165:126.

Judging the Palatability of the Cooked Foods.

Preparations, namely rice, cabbage 'porial' and 'sambar' were chosen to be presented to the tasting panel for appraisal for comparison of the effects of cooking with the two different fuels on a cereal, pulse and vegetable. A 'check type' of score card was used on a three-point scale for each preparation in relation to the colour, doneness, taste and smell of the foods cooked, using the two fuels. A sample of the score card is given in the Appendix VII.

Four judges who had previous experience with use of score cards, from a homogenous group of members with the same type of education, training and of the same age group (between 22-28) were selected to constitute the tasting panel.

One tablespoon of rice taken from the middle of the cooked portion, about half a tablespoon of cabbage 'porial' were served on a porcelain plate and two tablespoons of 'sambar' and two pieces of potato into a cup marked I. The other seriesof sample foods cooked over the other fuel was served in dishes marked II. The next day the order was reversed so as not to give any clue to

IV. RESULTS AND DISCUSSIONS

The data obtained in the experiments conducted as described in the previous chapter, were studied in relation to the three aspects of home management, namely, time, energy and money and with regard to acceptability of foods cooked and general cleanliness, convenience, care and maintenance during handling of the fuels. Application of the findings in the home was considered.

i) Time Management.

a) Cooking Time.

The time taken for cooking the items constituting the three meals, namely, rice, milk, eggs, 'sambar', 'idli', 'uppuma' and cabbage 'porial', using firewood and cattle-dung gas as fuels respectively, is given in the Table VII below.

TABLE VII.

TOTAL TIME TAKEN FOR COOKING THE THREE MEALS, USING FIREWOOD AND CATTLE-DUNG GAS AS FUELS.

Replicates.	Time taken in minutes.		Average saving of time in Min. (B - A)	Percentage of time saved. $\frac{B-A}{B}\times100$
	Cattle-dung gas. (A)	Firewood. (B)		
1	182	253		
2	172	253		
3.	181	243		
4	181	248		
Average.	179	249.2	70	28%

As can be seen from the Table VII, the time taken to cook the meal, using cattle-dung gas as fuel was 70 minutes less than the time taken to cook the same meal, using firewood as fuel. This difference was found to be significant beyond one per cent level when statistical analysis through analysis of variance and 't' test were done, as shown in Appendix VIII.

Table VIII shows the average time taken to cook the various items at stages: 1 seasoning, 2 boiling of water and 3 completion of cooking.

TABLE VIII.

AVERAGE TIME TAKEN FOR COOKING THE VARIOUS ITEMS OF THE THREE MEALS USING FIREWOOD AND CATTLE-DUNG GAS AS FUELS.

Utensils used.	Items.	Fuel.	Stages of cooking			Total time.
			Stage 1.	Stage 2.	Stage 3.	
Iron 'vanali'.	'Idli'.	1) Cattle-dung gas.	-	6.50	22.0	28.50
		2) Firewood.	-	18.25	26.0	44.25
Brass 'dekshi'.	Eggs.	1) Cattle-dung gas.	-	4.50	3.0	7.50
		2) Firewood.	-	6.75	3.0	9.75
Brass pot.	'Sambar'	1) Cattle-dung gas.	1.25	5.50	45.0	51.75
		2) Firewood.	2.25	10.25	50.0	62.50
Brass 'dekshi'.	Cabbage 'porial'	1) Cattle-dung gas.	1.75	1.25	11.0	14.00
		2) Firewood.	1.75	2.00	12.0	15.75
Brass pot.	Rice.	1) Cattle-dung gas.	-	10.50	38.0	48.50
		2) Firewood.	-	21.75	45.0	66.75
'Vanali'.	'Uppuma'	1) Cattle-dung gas.	2.75	8.00	11.0	21.75
		2) Firewood.	2.75	22.75	16.0	41.50

From Table VIII, the time taken to cook the various items of meals individually may be noted. In the case of milk, for boiling four and a half cups of milk, the average time taken with firewood was 10.75 minutes and with cattle-dung gas, 8.5 minutes.

The average time taken to boil four eggs was 9.75 minutes, using firewood as fuel and 7.5 minutes, using cattle-dung as fuel; thus 2.25 minutes were saved by the use of cattle-dung gas.

The average time taken to cook 'sambar' was 62.5 minutes, using firewood as fuel and 51.75 minutes, using cattle-dung gas as fuel, thus a saving of 10.75 minites was resulted.

In the case of 'idlis', the average time taken to cook ten 'idlis', using firewood as fuel was 44.25 minutes and 28.5 minutes with cattle-dung gas, thus 16.75 minutes were saved by the use of cattle-dung gas fuel.

In the case of cabbage 'poriyal', the average time taken to cook the cabbage was 15.75 minutes, using firewood and 14 minutes with cattle-dung gas, and thus, on an average, 1.75 minutes were saved.

Time taken to cook rice was, on an average, 66.75 minutes, using firewood as fuel and 48.50 minutes, using cattle-dung gas as fuel. Thus a saving of 18.25 minutes resulted by the use of cattle-dung gas, as compared with the use of firewood.

The time taken to cook 'uppuma', using firewood as fuel, was recorded as 41.50 minutes and time taken over the use of cattle-dung gas was 21.75 minutes. The gas cooking therefore secured a saving of 19.75 minutes as compared to firewood cooking.

The difference in the time taken to cook, using the two fuels, was least in the case of cabbage and highest in 'uppuma', 'idli' and 'rice', which consisted of a large amount of cereal. These differences may be explained by the fact that the total cooking time is analysed by the stages - seasoning, boiling of water, completion of cooking, as shown in the Table VII. The time taken for the stage 2 seems to be the chief factor determining the difference in cooking time, which is influenced directly by the quantity of water used for cooking. The shape of the utensil which decides the surface area exposed for evaporation in the utensil is another factor.

b) <u>Time for Washing Utensils Used for Cooking.</u>

The time taken for scrubbing the utensils while washing them, as per the procedures described on page is shown in Table IX.

TABLE IX.

TIME TAKEN FOR SCRUBBING THE UTENSILS AFTER COOKING.

Replicates.	Time in Minutes. Cattle-dung gas. (A)	 Firewood. (B)	Saving of time. B - A.
1	4.8	14.4	
2	4.1	12.4	
3	4.5	10.2	
4	4.7	10.5	
Average.	4.5	11.9	7.4

On statistical analysis of the data given in Table IX using the 't' test as given in the Appendix IX, the difference in time taken for scrubbing the utensils after cooking, using the two fuels, was fixed to be significant beyond one per cent level.

The utensils used over firewood needed an average time of 11.9 minutes of vigorous scrubbing to remove the soot, while those used over cattle-dung gas needed only 4.5 minutes, on an average, as there was scarcely any soot adhering to them, as illustrated in Figure 8, page 57. The saving of time in the scrubbing of utensils used over gas burner, using cattle-dung gas, was 7.4 minutes, amounting to 63 per cent.

ii) Management of Money.

Consumption of Cattle-Dung Gas.

The gas consumption for the total cooking time in terms of litres calculated on the basis described in

FIGURE 8- A

UTENSILS USED OVER CATTLE-DUNG GAS

FIGURE 8-B

UTENSILS USED OVER FIREWOOD

TABLE XI.

FIREWOOD CONSUMED DURING COOKING THE THREE MEALS.

Replicates.	Amount of firewood used.		Amount of charcoal residue.	Firewood equivalent for charcoal residue.	Amount of firewood used after correction for charcoal residue.	
	Lb.	Oz.	Oz.	Oz.	Lb.	Oz.
1	4	13	4			
2	5	2	10.25			
3	4	9	8			
4	4	7	7			
Average per day.	4	11.75	7.31	5.56	4	6.2
Average per year (365 days).					1595	-

Thus the figures in Table XI shows that 1595 Lbs. (66.5 maunds) of firewood per year were needed for cooking the meals for the reference family.

Daily 10 cc of kerosene were used as ignition fuel. This totalled upto 3.65 litres per year.

The firewood used for the experiment was purchased at the rate of 88nP per maund of 24 pounds. Therefore the cost of firewood consumed amounted to Rs.58/52 per year. The kerosene for ignition purposes was bought at 25nP per bottle, which contained 700 cc of kerosene. Therefore the cost of kerosene used amounted to Re.1/30 per year.

In common practice, twice or thrice a year, the 'chulas' are changed. But the burners are used indefinitely. If two chulas are bought every year, the cost of the chulas is only Re.0/75 per year. There is no cost of maintenance in the case of 'chula', while cattle-dung gas plant needs painting of the metal drum to prevent corrosion with water. Table XII shows the comparative money expenditure involved for both fuels.

TABLE XII

RECURRING EXPENDITURE INVOLVED IN THE USE OF CATTLE-DUNG GAS AND FIREWOOD FUELS.

Items of expenditure.	Expenditure in Rupees.			
	Cattle-dung gas.		Firewood.	
	Rs.	nP.	Rs.	nP.
Cost of 'chula'.	—		0	75
Maintenance charges.	10	00	—	
Cost of the fuel.	—		58	52
Cost of ignition fuel.	—		1	30
Total per year.	10	00	60	57
Saving of cow-dung gas over firewood per year.	—		50	57

From the figures given in Table XII, it is evident that a saving of Rs.50/57 per year is achieved by the use of cattle-dung gas in the place of firewood as a fuel.

Plant and Installation Cost.

The important factor to be taken into account is the cost of installation of the gas plant which would be considered high for any single household equipment, when compared to the cost of the 'chula', which is 57nP. The cost of installation is Rs.400/00, as given by The Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute[34], which comp-

rises of cost of material for the plant	Rs.303/00
Cost of construction mateials.	57/00
Labour charges.	40/00

Through this saving the installation cost of Rs.400/00 can be realised within eight years. If the labour is supplied by the family, the investment could be recovered in seven years.

With respect to the capital outlay for the gas plant, even if the yearly saving by the use of this fuel is used towards paying off the interest at a rate of 4 per cent and part of the capital, the entire sum may be paid in ten years. Thus the cattle-dung gas helps to effect saving in money to the homemaker.

iii) Energy Management.

Differences in the number of special tasks performed during the use of fuel in cooking, such as blowing, flame control and lid adjustment, recorded, are given in Table XIII below.

TABLE XIII.

SPECIAL TASKS PERFORMED DURING COOKING, USING FIREWOOD AND CATTLE-DUNG GAS AS FUELS.

Type of tasks motions.	Number of times performed.									
	Cattle-dung gas.					Firewood.				
	Replication.					Replication.				
	1	2	3	4	Av.	1	2	3	4	Av.
Blowing.	0	0	0	0	0	11	18	11	16	14
Flame control.	12	12	12	12	12	34	29	22	25	27.5
Lid adjustment.	17	23	18	20	19.5	20	19	21	17	19.25
Total.					31.5					50.75

As shown in Table XIII, no blowing was necessary when the gas burner was used. On the contrary, on an average, blowing was done 14 times during the 249 minutes of cooking, using firewood as fuel. When analysis of variance and 't' test were done, as shown in Appendix X, the difference in blowing was found to be significant beyond one per cent level. 'Flame control' was done on an average of 27.5 times in the case of firewood and only 12 times in the case of cattle-dung gas. This difference was also found statistically significant beyond one per cent level when analysis of variance was done and 't' test was applied, as shown in Appendix XI.

The difference between the number of times of lid adjustment in the case of the two fuels was not significant at 5 per cent level as the flame had been kept at an optimum level, to prevent boiling over, when analysis of variance and application of 't' test were done, as given in Appendix XII.

Hence there was saving of tasks by the use of cattle-dung gas as a fuel, thus leading to conservation of energy. The saving on blowing was especially advantageous because blowing was found to be very tedious and fatigue-producing. In addition to energy saved through this saving of tasks, the time saved in scrubbing the utensils reported in page 58 may also be used as another estimate of energy saved. Thus by the use of cattle-dung gas, 63 per cent of energy spent in scrubbing could be saved. Vigorous scrubbing for 11.9 minutes was found by the investigator to be fairly tedious while scrubbing of utensils used over cattle-dung gas for 4.5 minutes was easily accomplished.

iv) Palatability of Foods Cooked.

The average scores obtained for the appearance (colour), doneness, smell, taste of rice, 'sambar' and cabbage 'porial' are given in the Table XIV.

The data shown in Table XIV was analysed statistically as shown in Appendix and the differences between scores for each quality of rice, cabbage 'porial' and 'sambar' cooked over cattle-dung gas burner and 'chula' were found to be not significant even at five per cent level. Therefore it was proved that the foodstuffs cooked using cattle-dung gas were as palatable as when cooked using firewood as fuel.

(iv) General Cleanliness, Convenience, Care and Maintenance.

While cooking was done over firewood, the cooking place was sooty due to the ash escaping out of the 'chula' while blowing. Also while handling the 'chula' and cleaning it, hands were soiled with ash and charcoal. Moreover, during washing the utensils, hands were soiled and needed great care to be cleaned. Utensils used over firewood even after vigorous scrubbing for a long time had traces of soot and lost their original gloss, while the utensils used over cattle-dung gas had retained their shiny appearance.

After three hours of cooking, it was necessary to remove the coal and ashes from the 'chula' to reduce smoking. The chula needed wiping off the soot adhering to it once or twice in a week if not more often.

Soot deposited on the walls of the kitchen near the 'chula'. But the walls area above the gas burner was clean. This implies the kitchen walls need more frequent white-washing or painting if firewood is used as the fuel for cooking, than would require if cattle dung gas is used. Also in the case of firewood there was the need for a large dry place for storage. Wet firewood had to be dried in the sun before use. Procurement of dry firewood is difficult in rainy seasons. The cattle-dung gas was stored in the gas plant itself, always ready to be used. When firewood had to be bought from the market when the previous supply was over and the labour involved in it depended upon the distance between the household and the market. Further big logs had to be cut or split to convenient size. The cattle-dung gas plant needed only a few minutes to dilute the dung and feed the plant. Firewood, if carelessly handled, caused injury to the hand while cattle-dung gas fuel caused no such problem. Constant attention was needed to keep the fire going. The smoke emitted from firewood was irritating to the eyes. The kitchen where firewood used as fuel needed special chimneys and this was not so in the case of the gas fuel. Cattle-dung gas therefore is safer, cleaner and a more convenient fuel than firewood and hence cooking over cattle-dung gas was very satisfactory when compared to firewood.

Application of the Above Findings.

For a Home.

About one-fourth of the homemakers' time spent on cooking could be saved by the use of cattle-dung gas fuel instead of firewood. Cooking may be completed more quickly and the saved time can be used for other activities. This is very advantageous for an inexperienced homemakers and homemakers who have to provide food early to school-going children or career women.

Since larger the amount of foods cooked, greater the saving of time, it is very advantageous to big households, joint families and even for institutions. A great deal of fuel can be saved by using cattle-dung gas for heating water for bathing.

As mentioned earlier, cattle-dung gas can be utilised for working an iron and fan.

The greatest advantage is in the reduction of time spent in washing utensils. Both energy and time is saved by the use of cattle-dung gas as the household fuel, thus simplifying the work.

The use of cattle-dung gas in general helps to raise the standard of living.

For the Nation.

As mentioned earlier in page 1, if the three hundred million tons of cattle-dung gas which at present is used for the fuel purposes could be diverted to manuring, about nine million additional tons of grains could be produced. This would help towards solving the food problem. Majumdar (1961)[27] estimates that this quantity of dung is equivalent to four and a half million tons of Ammonium Sulphate, which would need twelve factories to produce it. Each such factory requires a fixed investment of twenty five crores of Rupees, of which, ten crores is of foreign exchange component. Even though the investment for cattle-dung gas plants needed to utilise the dung would be approximately the same as that of the twelve factories, yet the total foreign requirement of the 120 crores could be saved because the skill and materials available within the country are enough to erect the gas plants. As the raw materials are readily available for the gas plant than for chemical fertilisers and transportation cost would be reduced to the minimum. Because the gas plants would be spread throughout the country, there would be no need for any elaborate machinery for production and distribution of manure. All these factors would bring down the cost of nitrogen fertilisers by thirty per cent, as viewed by Majumdar (1961)[27]. This would be a substantial help to the agriculturist, as according to Majumdar (1961)[27], at present sixty million rural households burn dung as fuel, equivalent to thirty five million tons of coal and if the same amount of dung is fed in the gas plants, gas fuel valued at 210 crores of Rupees could be obtained as a free fuel. Hence, a portion of electricity, kerosene and coal used now for household purposes could be replaced with cattle-dung gas and diverted towards industrial use. Cutting of trees for fuel purposes could also be minimised, as discussed earlier, by the use of cattle-dung gas.

Installation of the cattle-dung gas plants and use of cattle-dung gas would thus lead to better standard of living for individuals and ultimately for the nation.

V SUMMARY AND CONCLUSION.

This study was undertaken to assess the value of cattle-dung gas as a household fuel. Two identical reference meals for a family of three adult members were cooked, one using firewood and the other using cattle-dung gas, as fuels. The time taken to cook each series of the meal, cost involved, special care, acceptability of colour, doneness, smell and taste of foods prepared and general conditions of cleanliness and convenience were studied. Given below are some characteristics of using cattle-dung gas over firewood:-

(a) A saving of 25 per cent of time for cooking three meals for a family of three was noted.

(b) There was a saving of 63 per cent of time taken for scrubbing the utensils while washing them after their use for cooking.

(c) The foods cooked using cattle dung gas were as acceptable as that cooked using firewood as fuel.

(d) Cattle-dung gas was found to be a cleaner fuel than firewood and incurred less fatigue in the subsequent cleaning of utensils used over it.

The high cost of installation may be made good over a period of seven to ten years.

From every managerial aspect, the cattle-dung gas proved to be a superior substitute for firewood.

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APPENDICES

APPENDIX I

CALORIFIC VALUE OF SOME INDIAN WOOD*

	Name of the Species	Tamil Name	Calorific value in B.T.U.	
			Sapwood	Heartwood
1	Acacia arabica, Willd	Velum	8627	3993
2	Leucophloea	Vel-valu	3818	3795
3	Albizzia lebbek, Benth	Vagai	9294	9301
4	Bombax malabaricum, Dc.	Illavam	8794	..
5	Butea frondosa, Roxb	Porasan	8855	..
6	Casuarina equisetifolia, Forst	Chouk	8910	..
7	Nephelium longana, Camb	Paovati	8626	..
8	Pongamia glabravent	Ponga	8710	..
9	Pterocarpus marsupium, Roxb	Vengai	8825	9256
10	Xylia xylocarpa	Irul	8956	9080
11	Zizyphus jujuba, Lam	Yellendai	8782	..

* Krishna and Ramaswamy (1932)[8]

APPENDIX II

DESCRIPTION OF THE UTENSILS USED IN THE COOKING EXPERIMENT.

Utensil		Metal	Volume in cups *	Weight lb. oz
'Vanali'	(i)	Cast iron	16	4.13
'Vanali'	(ii)	Cast iron	15	4. 9½
Dekshi	(i)	Brass tin lined	7	1. 4½
Dekshi	(ii)	Brass tin lined	7	1. 5
Pot large	(i)	Brass tin lined	11 ½	1.14
Pot large	(ii)	Brass tin lined	11½	1.15½
Pot small	(i)	Brass tin lined	7¼	1. 2½
Pot small	(ii)	Brass tin lined	7¼	1. 3½

* One cup is equivalent to eight ounces.

√

APPENDIX III

Preparation : 'IDLI'.

Number of Servings : 3 (10 'Idlies').

1 Steaming Time : 20—30 minutes.

Ingredients	Description	Quantity
Parboiled Rice flour	Coarsely ground	328 grams
Black gram dhal flour	Finely ground	57 grams
Salt	-	10 grams
Water	-	2½ cups.

Method :-

1) Soak rice flour in water.
2) After six hours add black gram dhal flour and mix well, Add salt
3) Allow to ferment for 12 more hours.
4) Steam the batter in 'Idli' plate, adding ¼ cup of batter for each depression.

APPENDIX VIII

ANALYSIS OF VARIANCE FOR THE TOTAL TIME TAKEN FOR COOKING A DAY'S MEALS USING CATTLE-DUNG GAS AND FIREWOOD AS FUELS.

Source of variation	Sum of squares	d. f.*	Mean square
Total	9935	7	
Between sets	9800	1	9800
Within sets	135	6	22.5

$F = 43.6$ $\quad P < .01$

$t = \sqrt{43.6} = 6.6$ $\quad P < .01$

Foot Note:

For 1 and 6 df $\quad F_{.01} = 13.74; \quad F_{.05} = 5.99$

For 6 df $\quad t_{.01} = 3.71; \quad t_{.05} = 2.45$

$P > .05$ means Not significant at 5% level

$P > .01$ " Not significant at 1% level

$P < .05$ " Significant at 5% level

$P < .01$ " Significant at 1% level

$$F = \frac{\text{Between sets variance}}{\text{within sets variance}} = \frac{9800}{22.5}$$

*d.f. means degrees of freedom.

APPENDIX I

ANALYSIS OF VARIANCE FOR BLOWING INVOLVED IN USING CATTLE-DUNG GAS AND FIREWOOD AS FUELS.

Source of variation	Sum of squares	df	Mean square	F	t	Level of significance
Total	430	7				
Between sets	392	1	392	62.2	7.9	$P < .01$
Within sets	38	6	6.3			

APPENDIX XI

ANALYSIS OF VARIANCE FOR FLAME CONTROL INVOLVED IN USING CATTLE-DUNG GAS AND FIREWOOD AS FUELS.

Source of variation	Sum of squares	df	Mean square	F	t	Level of significance
Total	561.5	7				
Between sets	480.5	1	480.5	35.59	6.0	P <.01
Within sets	81	6	13.5			

APPENDIX XII

ANALYSIS OF VARIANCE FOR LID ADJUSTMENT INVOLVED IN USING CATTLE-DUNG GAS AND FIREWOOD AS FUELS.

Source of variation	Sum of squares.	df	Mean square	F	t	Level of Significance
Total	29.775	7				
Between sets	0.125	1	0.125	0.252	0.50	P >.05
Within sets	29.65	6	4.94			

APPENDIX XIII

AVERAGE SCORES OF PALATABILITY OF RICE, 'SAMBAR' AND CABBAGE 'PORIAL'

Preparations	Quality	Cattle-dung gas Replicates.					Fire-wood Replicates.				
		1	2	3	4	Average	1	2	3	4	Average
RICE	Colour	3	3	3	2.75	2.94	3	2.25	3	2.25	2.63
	Doneness	3	3	3	3	3	2.75	3	3	3	2.94
	Taste	3	3	3	3	3	3	2.75	3	3	2.94
	Smell	3	3	2.75	3	2.94	3	2.5	2.5	3	2.75
SAMBAR	Colour	3	3	2.75	3	2.94	2.75	2.75	2.75	3	2.81
	Doneness	3	3	3	3	3	3	3	3	3	3
	Taste	3	3	3	3	3	3	3	3	3	3
	Smell	2.75	3	3	3	2.94	2.5	3	3	3	2.88
CABBAGE 'PORIAL'	Colour	2	2.75	2.5	1.5	2.19	3	1.75	1.75	2	2.13
	Smell	3	3	3	3	3	3	3	3	3	3
	Taste	3	3	3	2.5	2.88	2.5	3	3	3	2.88
	Doneness	3	3	3	3	3	3	3	3	3	3