REPORT OF COMMITTEE 16

AGRICULTURE AND FOOD CHEMISTRY

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16.0 Summary

Background:

World population is growing at 2.1-2.2% per annum. The demand for food and other agricultural products will grow. Agriculture and food play a major role in the economy of Canada. Chemistry and Chemical Engineering are essential to the development of a modern agriculture and food processing and distribution industry.

Conclusions:

1. Agriculture and food research is multidisciplinary in nature and increases in the purely chemical inputs cannot be justified unless there is a corresponding increase in the biological effort.
2. Agricultural research is concentrated in government and university laboratories and is well established. Co-ordination of current effort to achieve national goals is most essential.
3. Food research is in its infancy and deserves more support.
4. The Canadian Food Industry relies, with few exceptions, on research and development done in the U.S.A. The Industrial R&D effort is not expected to increase significantly.

Recommendations:

1. Develop strong central food research laboratories to carry out basic and applied research programmes.
2. Chemical education should include some orientation towards food and agriculture.
3. The complex nature of food and agriculture R&D makes it imperative that increased support be directed towards expansion of existing laboratories. Fragmentation of manpower and funds among small laboratories will not be effective.

16.1 Introduction

The population of the world is now growing at the highest rate in history, between 2.1 and 2.2% per annum. This rate of growth will probably continue or even increase slightly. Eventually, growth rate will decrease but a world population of about 6.5×10^9 humans seems likely by the year 2000. Even at the present population level of 3.4×10^9 humans, under-nutrition (inadequate daily intake of calories, a quantitative deficiency) occurs in numerous localities while malnutrition (lack of food quality, a qualitative deficiency) is common. Hunger is widespread. Because per capita rate of food production in the highly populated, under- and mal-nourished areas is decreasing or at best remaining constant, the demand for food and other agricultural products will continue to grow.

Through multilateral or bilateral plans, developed countries try to help developing countries. It is generally accepted, however, that gifts of food are palliatives at best and, before long, will be totally inadequate. Developed countries now realize that developing countries need technical and scientific help, e.g. educators, economists, market analysts, sociologists, nutritionists, medical doctors, and home economists. Moreover, they recognize their responsibility to supply specialists to these countries. Therefore, when the need for research in a given field or the need for training in a given trade or discipline is considered, world demand as well as Canadian requirements should be taken into account. Agricultural and food scientists are needed in developing countries to help them produce food and preserve it. Moreover, agricultural problems that are all but solved in developed countries still plague farmers in developing countries and solutions unique to these regions must be found. Transplanted knowledge does not always take root.

New land can still be opened up, other land can be returned to production and land currently farmed can be used more effectively. Through the use of fertilizers, the chemical composition of the soil can be controlled; where indicated, irrigation can bring higher yields. Plant and animal breeding can increase yields and nutritive value of the produce markedly.

Food waste is high in all countries but in some developing countries as much as 50% of the food is lost to the needy consumer. The causes of waste are many: inadequate or inappropriate seed (animal as well as plant), faulty nutrition, lack of protection from pathogens during growth and predators after harvest, inadequate or non-existent processing and storage facilities. Truly, agricultural and food science are badly needed and their chemical and chemical engineering components are important factors affecting food supply and the availability of non-food agricultural products. Both agricultural and food science are needed in both developed and developing countries if waste control is to accompany increased food production.

Biological systems are seldom, if ever, simple. Thus, to solve biological problems, a broad spectrum of scientific disciplines is needed: biology, physics, chemistry and mathematics. More specifically, analytical, inorganic, organic and physical chemistry, biochemistry, cytology, genetics, entomology, pathology, physiology, pharmacology, nutrition, toxicology, statistics, agrometeorology, virology, food science and technology, microbiological, food and instrumentation engineering, soil genesis, chemistry and mineralogy and other disciplines are required. Only through a multidisciplinary approach can complex problems be solved in finite time.

The terms of reference of Committee 16 preclude its analysis of other than chemical and chemical engineering R&D. Thus most of the above disciplines will be reported in other surveys. Part of the truly chemical activity, however, will be assigned to other committees of this survey: 01, Analytical Chemistry; 05, Fuels, etc; 17, Biochemistry; 19, Earth Sciences. The Committee does not wish to deny that disciplines practiced by agricultural and food scientists are used in other fields. It wishes, however, to emphasize the fact that research on the chemical reactions in soils is still an intrinsic part of agriculture and studies of how the plant obtains its nutrition from the soil are needed to improve crops qualitatively and quantitatively. Similarly, natural products chemistry is an intrinsic part of food science and must not be divorced from food.

Multidisciplinary research implies cooperation among scientists. Cooperation on an international scale is also needed if the burgeoning world population is to be fed and clothed. Training centres established by multilateral or bilateral arrangements for agricultural and food scientists and technicians are required the world over. The activity of these centres, however, must be focussed sharply on specific problems selected carefully. The objectives of agricultural and food science must go beyond providing calories and protein for people because the food must be aesthetically attractive and tailored to suit local tastes and needs. Food that is not eaten is food wasted. Therefore, extensive market research and consumer acceptance testing must accompany or preceed the scientific activity if it is to be fruitful. Developed countries must be prepared to supply key personnel during the formative years of the educational or industrial programs. The needs of developing countries must therefore be kept in mind when decisions are made as to the required number of researchers in a given discipline or specialization.

16.2 Definition of Fields

a. General

The Committee decided that a definition of agriculture and food must be sufficiently broad that it includes the full spectrum of activities from the seed (plant or animal), through growth, harvesting, processing and storage to the consumption of the product whether edible or non-edible. Traditionally, however, agricultural research has dealt with problems relating to production whereas the use of the harvested material was considered to be the concern of specific industries: wool, linen, leather, glue, gelatin, sugar, starch, brewing, meat packing, fruit and vegetable processing, milling and baking and many others. Thus, agricultural research was concerned with plant and animal genetics, breeding, nutrition, pathology, taxonomy, physiology; soil genesis, fertility, chemistry and physics;

entomology; pest control through chemicals or by biological control; microbiology. As a corollary, food research covered the conversion of raw materials into consumer goods of adequate storage life, nutritive value and aesthetic appeal. Generally, food research involved the packaging, preservation and storage of the product and employed the following disciplines: chemistry, biochemistry, physiology, pharmacology, toxicology, nutrition, microbiology, food technology, food engineering, physics, instrumentation engineering, and chemical engineering.

Plant and animal breeders require services when selecting strains for further crossing or propagation. For example, breeders of oilseed plants will require information on the chemical composition of the storage fat, carbohydrate and protein in the seed as well as nutritional data on these components. They will also need information on its disease resistance and agronomic behaviour. Chemists and food scientists are invited to supply this information but seldom does this support involve research <u>per se</u> beyond the development of new analytical methods.

In contrast to this service work, agricultural chemistry, biochemistry and food science have a direct research input into agriculture. Fundamental research on the structure of lipids, carbohydrates and proteins and the nature of their conjugates; the chemistry and biochemistry of growth-active substances and pesticides; the chemical and biochemical reactions during fertilization, sprouting, lactation, ruminant metabolism, the metabolism of microorganisms;

thermodynamic studies of membranes, and heat transfer during dehydration and freezing; the impact of food processing on nutritive value are examples of research areas free from the connotation of service work yet of prime importance to food and agriculture.

Contemporary food research has feed-back to traditional agriculture as well as input into food processing and storage. It is, therefore, intermediate in the food chain and the food research chain. Moreover, as non-agricultural foods become increasingly important and displace or augment traditional foods, food research will have to focus on new food problems arising from a variety of sources. Food from the sea, from microorganisms and other lower plants, completely synthetic foods as well as foods of agricultural origin will all be considered substrate for food research. The polygamous marriage of food with agriculture, fisheries and biological engineering and the resultant offsprings must soon be legitimatized.

b. Definitions

This new blurring of traditional distinctions between agricultural research and food research increases the difficulty of defining these fields. Nevertheless, the following compromise definitions are submitted:

Agricultural research is concerned with understanding the processes involved in the production and protection of crops and animals and in the soil that supports them and with the application of this knowledge to the solution of specific problems.

Food research is concerned with understanding the physical, chemical and biological nature of foods and the changes that they undergo during processing and storage and with learning how to effect these changes with maximum benefit to the product.

Only the chemical and chemical engineering aspects of these two fields will be described in this report.

c. Canadian characteristics

Canadian agricultural and food R&D has certain characteristics:

i Canada has a long, severe winter, its population centres are well removed from centres of agricultural production, its population is small but its agriculture and food industries must deal with most of the problems encountered in warmer, more populous countries.

ii Many of the leading manufacturers of fertilizers, pesticides and foods are subsidiaries of foreign-owned companies.

iii Agricultural research, with the major exception of wheat and oilseeds, has been predominantly production-oriented.

iv Food research is in its infancy.

v Research effort has been concentrated in government laboratories with university and industrial research a minor component.

16.3 Estimate of Present Level of Research Activity and its Distribution

a. Sources of information

As of March 31, 1968, the Department of Manpower and Immigration has provided no data. The machine-runs from the C.I.C. Questionnaire data are now complete. Information has been obtained from a survey conducted by Professor Douglas Ormrod of the University of British Columbia on behalf of the Department of Industry. The bulk of Dr. Ormrod's findings will be discussed under Section 16.5, however. The 1966 inventory of agricultural research projects prepared for the Canadian Agricultural Services Coordinating Committee provided information as did "Research Index Ontario. 1967" published by the Ontario Economic Council.

b. CASCC Survey information

In the opinion of the Research Branch of the Canada Department of Agriculture, which conducted the survey for CASCC, the 1966 inventory should be considered as a pilot survey. It suffers from the fault that not everyone who was invited to provide data did so and from the fault the decisions to include certain classes of work and to exclude others may not have been exact. Moreover, the coding system under which the R&D work was classified had not been tested thoroughly before its use in the inventory. Nevertheless, the CASCC survey can be considered useful.

The survey covered 2563 projects, the research projects in progress in the establishments of the Federal and Provincial Departments of Agriculture and in the Faculties of Agriculture and of Veterinary Medicine in Canadian universities. Of these projects,

3.5 % are chemical research

2.6 % are food technology or food engineering projects

2.8 % are biochemical research

Thus, 8.9% of the projects fall under the terms of reference of the C.I.C. Survey. The other 91.1% involve biology, agricultural engineering or economics.

The 90 "chemical" projects absorb 56.5 man-years of research effort, the 67 food technology or food engineering projects require 25.8 man-years while the 71 biochemical projects consume 43.8 man-years. Thus, of the 1200 man-years of research reported by the CASCC survey, 4.7% are chemical man-years

2.1% are food technology or food engineering man-years

3.6% are biochemical man-years.

If a man-year of soil, crop or biological research costs $30000 and a man-year of animal research costs $70000, the following cost figures can be calculated:

Soil Research:

Total man-years = 182.4 = $5,472,000

Chemical man-years = 31.5 = $950,000

Chemical man-years as per cent of total man-years - 17.3%.

Chemical research on fertilizers is not revealed explicitly and there is no guide for extracting this information from the general assembly of chemical man-years.

Crop Research:

Total man-years = 505.7 = $15,171,000

Food research man-years = 17.6 = $540,000

Non-food chemical or biochemical man-years* = 3.6 = $108,000

Food man-years as per cent of total man-years = 3.5%

Non-food chemical man-years* as per cent of total

man-years = 0.71%.

* (Estimated as 5% of the "biochemical-physiological"

man-years).

The food research listed under crops is unevenly distributed across Canada: 36% in Ontario; 31% in British Columbia; 13% by the Federal Government; 10% in the Maritime Provinces; 5.6% in Quebec; 2.8% in Manitoba; 1.1% in Alberta and nil in Saskatchewan.

The 17.6 man-years of Crops food research has the following distribution: 31% fruits general; 29% general; 14% other vegetables; 8.5% small fruits; 8.5% potatoes; 6.3% apples; 2.3% tomatoes; 1.1% other tree fruit. These food research man-years were all listed under Horticulture with no activity assigned to Cereals or Field Crops. Presumably, work on wheat flour, dough and baking is not considered food research.

Animal Research:

Total man-years = 222.1 = $15,547,000

Food research man-years = 22.8 = $1,596,000

Non-food chemical or biochemical man-years* = 4.5 = $315,000

Food man-years calculated as per cent of total man-years

= 10.2%

Non-food chemical or biochemical man-years* calculated

as per cent of total man-years = 2.0%

* (Estimated as 10% of the "physiology" man-years)

The food research listed under "Animals" has the following distribution: 34% by the Federal Government; 31% in Alberta; 18% in Ontario; 11% in Quebec; 2.6% in Manitoba; 6.8% in Saskatchewan; 1.3% in British Columbia; nil in the Maritimes.

The "Animals" food research consists of 16.1 man-years on cattle; 1.4 man-years on poultry and, by difference, 5.3 man-years undesignated. Dairy research accounts for 88% of the "cattle" food research while chickens consume 100% of the "poultry" research.

General Biology Research

Total man-years ≐ 166.2 = $4,986,000

Chemical man-years* = 7.8 = $234,000

Chemical man-years* calculated as per cent of total man-years = 4.7%

* (Estimated as 10% of the sum of "Chemical, Physical and Biological Properties" plus "Reactions to Natural or Imposed Chemical Agents").

The magnitude of the assumptions made in extracting a chemical component from General Biology Research precludes estimating its geographical distribution. The Federal Government, however, conducts 68% of the research on "Chemical, Physical and Biological Properties" and 48% of that on "Reactions to Natural or Imposed Chemical Agents". Chemical research on pesticides is likewise hidden in the total.

c. Dominion Bureau of Statistics Data, Catalogue No. 13-527 and 21-201

In contrast to the CASCC Survey, which dealt solely with federal, provincial and university research, the DBS data are derived solely from industry. These data, however, appear to have

They deal with R&D in general and, except for Tables 11 and 12 (1965 data), there is no way in which chemical costs can be identified. Moreover, although "Food and Beverages" have been reported as a unit, non-food agricultural research such as that on pesticides, fertilizers and tobacco cannot be identified. The items "Other Chemical Products" and "Other Manufacturing" contain data on fertilizers, tobacco and, presumably, pesticides but many other products and manufacturing processes are also covered by these headings. Table 11 shows that 15.8% of the food and beverage industry's intra-mural R&D expenditures were for drugs, medicines and industrial chemicals. Table 12 shows that 85.4% of the engineering effort was chemical; 41.7% of the scientific R&D was chemical and 35.4% was agricultural and biochemical.

The position of the Canadian food and beverage industry relative to the other industries in the tables of data was obtained by ranking. The following comments arose from this exercise:

i The Canadian food and beverage industry is the largest in Canada with a sales volume in excess of 6.1 Billion dollars in 1964. It is the largest employer in Canada with 131,000 employees.

ii R&D expenditures in 1965 were 6.15 Million dollars (excluding equipment and buildings). This figure includes R&D expenditures on animal feeds, drugs, and industrial chemicals of 1.6 million dollars. The net expenditure in 1965 on food and beverage R&D was, therefore, 4.53 MM dollars.

iii Total R&D expenditures including capital in 1965 was 7.94 MM dollars for an overall industry ranking of 12 (20 industrial classifications). Translated into other terms the food and beverage industry spent less than ten cents on R&D per 100 dollars of sales.

iv The Canadian food and beverage industry finances its own R&D operations almost exclusively. In 1965, government R&D grants amounted to 300,000 dollars. Extra-mural R&D expenditures were 730,000 dollars. Of this amount 325,000 dollars were spent outside Canada. This figure ~~probably~~ represents an overhead research charge on Canadian subsidiaries of foreign-owned corporations.

v The number of scientists and engineers employed was 231. The supporting staff was 246. Translated into other terms the food and beverage industry employed 3.6 people in R&D per 1,000 employees. The overall industry rank was 14 (20 industrial classifications) on this score.

The R&D expenditure by the Canadian food and beverage industry is pitifully low in relative and absolute terms. Moreover, the situation is not likely to improve because about 75% of the R&D is performed by no more than 20 corporations and these are mainly Canadian subsidiaries of foreign-owned firms. The general trend among large corporations is to consolidate their R&D effort in central laboratories. The Canadian R&D effort should, therefore, shrink rather than expand because Canadian corporations appear to lack either the resources or the foresight to maintain R&D facilities. Improvement in the amount and quality of the Quality Control work is essentially all that can be expected of the Canadian-owned food and beverage industry.

d. Research Index, Ontario 1967

This survey of R&D activity covers projects being carried on within Ontario Government Departments and Agencies and 36 industrial laboratories. Projects are reported by title only and no indication is given of the number of man-years associated with each project. From knowledge of the R&D activity in Ontario food companies, major differences could be detected in the freedom with which the various companies reported; some reported all activity while others hid all their R&D under one vague heading. Of the 36 companies reporting project titles, 4 or 11% were concerned with food and agriculture.

Of the 613 projects reported in the Research Index, 238 or 39% dealt with agriculture. Of these, 45 involved directly food chemistry, food technology or food processing. Thus, 18.9% of the agricultural projects or 7.3% of all the projects involved food. However, many of these projects must be of minor importance because some researchers list as many as 15 projects per man, with 4, 6 or 9 projects per man not uncommon.

Of the 613 projects, 70 dealt with agricultural or food chemistry and thus 11.4% of Ontario's research effort can be considered by the C.I.C. Survey. Of the 90 chemical projects reported in the Research Index, 24 or 26.7% dealt with agriculture or food whereas only 1 of 73 projects in Life Sciences dealt with food.

Division of research effort between provincial government and industry on the basis of number of projects instead of man years is not too rewarding an exercise. Nevertheless, in Ontario in 1967, 13% of the food and agricultural projects were financed by industry and, of these, 14 or 47% were food projects. Of the provincial government-supported agricultural projects, 14.5% were food projects.

e. C.I.C. Survey

The data from the C.I.C. Questionnaires has been compiled into tables which are published as Section 18, C.I.C. Survey of Chemistry R&D in Canada 1966. Intramural research refers to the research activities carried out by employees of the reporting agency or agencies.

i Government Reporting Unit Questionnaires

These questionnaires show that Federal and Provincial governments supply all the funds for intramural research. Over the 5 year period following 1966, Federal funds will form 99.3% of the operating expenses and, except for 1968 where the value is 97.8%, 99.8% of the capital funds (Table 2). The Federal government contributes no money to provincial research nor does any Provincial government help Federal government research (Table 3). According to Table 9, 97.2% of the reported projects are supported by the Federal government.

Table 5 shows the distribution of man-years of Federal and Provincial government research by discipline and university degrees. A break-down of disciplines according to involvement in food and agricultural chemistry was not available.

Of the 560 projects reported in Table 8, the Federal government supports 97.9%. Of these, 100 (17.9%) projects were coded as Agriculture and Food. A further breakdown within Committee 16 interests produced apparent discrepancies:

(a) Only 2 provincial projects are listed, both on fruits and fruit juices. Yet, the "Research Index, Ontario, 1967" lists many Provincial government agriculture and food projects, including wine making which has a nil report in Table 8.

(b) Food and feed additives are said to constitute ~~21.3%~~ 24.9% of Committee 16 projects. It is common knowledge that the only Canadian R&D on food additives is 4 man-years of analytical chemistry which would be coded Committee 01. It is also common knowledge that no additive is used in Canada unless the necessary toxicity, product application and market development studies have been completed in the U.S.A. by the large corporations.

(c) According to Table 8, there is no Canadian government activity in the chemistry of plant growth regulators. From personal knowledge, at least 4 projects are known to have been active in 1966-67.

These discrepancies seriously reduced the impact of the R.U. Questionnaire data. They are possibly due to:

1) the use of three different questionnaires by the Government, university and industrial agencies;

2) differences in interpretation by reporting scientists;

3) inadequacy of the questionnaire for a particular discipline or research area.

When the projects are reported by the CIC Industry Classification (Table 10), no R&D is shown for Tobacco and only 1.3% of the projects bear on Agricultural Chemicals (fertilizers, sprays etc.). The Food and Beverage industries accounted for 25.2% of the projects but ~~the majority~~ a large percentage of these were listed under "other" and further breakdown was unprofitable. On the basis of R&D operating expenses, Agricultural Chemicals received only 0.8% of the total while Foods and Beverages received 17.5%.

Table 11, which shows Reported Expenditures, would contain the same apparent anomalies as Table 8. On a dollar basis, it shows no single unit of Committee 16 accounts for a large portion of the R&D money attributed to Committee 16 (10.9% of the total R&D expenditure).

Table 11A deals with the distribution of R&D operating funds among Basic, Applied and Developmental research. It shows that the R&D coded to Committee 16 consumes 12.4% of the Basic research dollar, 14.8% of the Applied and 3.5% of the Developmental research dollar. Within Committee 16, the distribution is 36.8%, 55.4% and 7.7% respectively. It seems valid to conclude that quite fundamental chemistry is applied to food and agriculture problems.

As shown in Table 16, the Federal and Provincial government activities coded to Committee 16 involved 13.2% of the total manpower of which 99.2% are Federal government employees. They represent 13.1% of the Ph.D.'s, 19.0% of the M.A.'s, 6.8% of the B.A.'s and 14.1% of the technicians. Among themselves, the Ph.D.'s form 28.5% of the total, the M.A.'s, 9.9%, the B.A.'s 7.1% and the technicians 54.5% of the total manpower coded for Committee 16.

ii Company Questionnaires

As of February 3, 1968, few data were available on the food and agriculture industries specifically. A request has been made for a breakdown of the tables to show Committee 16 interests but this apparently could not be granted.

The following general comments can be made at this time. Over the next 5 years, Industry is forecasting a 32% increase in its operating expenses while indicating a 46.5% reduction in its capital expenditure. Overall R&D expenditure is expected to increase 10.9% over the next 5 years (Table 24).

Canadian industry supplies 87.7% of the operations funds, 95.0% of its capital expenditures and 89.6% of its total R&D costs. The Federal Government grants, respectively, 4.9, 2.9 and 4.4% of the costs. From this it would appear that schemes such as IRA, PAIT, IRDIA etc. are not used extensively. (Table 25). In Table 26, R&D expenses are shown on a Committee basis. Committee 16 ranks 8 of 20 in total research expenditure, consuming 9.3% of the total industrial R&D budget. A further breakdown shows that the industries listed under Committee 16 conduct 5.3% of the basic research, 4.1% of the applied research and 6.3% of the developmental research in Canada. The $4.746 million spent by the Committee 16 industries is divided as follows: 9.3% basic research; 34.7% applied research and 56.0% developmental research.

iii. University Questionnaires

Of the funds spent by universities on R&D, $25.741 million, Federal Government departments contribute $0.820 million or

3.2% of the total. This sum would include the grants from the Canada Department of Agriculture and possibly some of the funds granted by the Food Products Branch of the Department of Industry.

When the expenditure of R&D funds by the universities is considered in terms of the C.I.C. Survey Committees (Table 37), Committee 16 is not a leader. Its sub-total, $0.902 million represents merely 3.6% of the total university R&D expenditure; it ranks 9 out of the 20 committees. Its "Operations and Minor Equipment" figure equals 4.2% of the sum of amounts in that category (rank 8/20); its "Major Equipment" figure equals 0.9% of the total (rank 14/20) and its research receives no support in the form of "Major Installations". "Operations and Minor Equipment" funds comprise 96% of its $0.902 million.

In terms of investment of manpower (Table 38), the R&D covered by Committee 16 involves 5.7% of the academic man-years (rank 7/20), 1.1% of the P.D.F. activity (rank 15/20), 3.7% of the Graduate Students time (rank 9/20) and 6.5% of the [illegible] man-years (rank 5/20). Its sub-total of man-years represents 4.3% of the total and ranks 9 out of 20. The 179 man-years assigned to Committee 16 are divided as follows: 33% academic; 2.[illegible] 44% graduate students and 21% to te[illegible]chnicians.

An analysis of how the "Operations and Minor Equipment" funds (Table 39) were distributed according to type of research showed the following information. The R&D covered by Committee [illegible] consumed 4.3% of the total funds and ranked 9 out of 20. The $0.893 million used by the R&D was spent 27.4% on basic research, 55.6% on applied research and 17.0% on developmental work. The respective ranking was: basic, 14/20; applied, 3/20; and developmental, 2/20 and the percent consumption of funds in these categories was 1.4%, 17.3% and 17.0%.

When the character of the R&D was weighted according to academic staff (Table 40), the sub-total for Committee 16 was 5.8% of the total staff, ranking 7 out of 20. The 59 staff members were divided according to type of research into 33.[illegible] basic (rank 14/20); 54.1% applied (rank 2/20) and 12.0% developmental (rank 2/20). Basis research under Committee 16 absorbed 2.3% of the university staff conducting basic research, 21.9% of that doing applied research and 21.6% of those doing developmental work.

When total staff is used to weight the research character (Table 41), the sub-total for Committee 16 ranked 9 out of 20. The sub-total was 4.4% of the total for all committees and was divided into 33.0% basic research (rank 15/20); 54.8% applied research (rank 2/20) and 12.2% developmental research (rank 1[illegible]/20). The staff time devoted to basic research was 1.7% of the total basic research manpower, that given to applied research, 18.0% of that total and the developmental research was 20.3% of the total developmental research manpower.

In contrast to the industrial Canada, the universities forecast increased expenditure in all areas (Table 43). Over the next 5 years, university spending on "Operations and Minor Equipment" will increase 84.3%, on "Major Equipment", 30.5% and on "Major Installations", 91.3%. The overall university expenditure on chemical and chemical engineering R&D will be increased 72.9% over the next 5 years.

University manpower was examined in terms of R&D area and its distribution into academics, post-doctorate fellows, graduate students and technicians. Committee 16, with a total of 117.0 manyears ranked 8/20 and absorbed 4.3% of the total manpower. These 117.0 manyears were divided as follows: 28.8% academic (rank 8/20); 2.8% PDF (rank 16/20); 40.9% graduate students (rank 9/20) and 27.5% technicians (rank 3/20). In terms of the totals for each class of employee, Committee 16 R&D accounted for 6.3% of the academics, 1.1% of the post-doctorate fellows, 3.4% of the graduate students and 6.8% of the technicians.

The Committee would like to make the following comments on the sources of information available to it:

i the CASCC Survey was useful but food and chemistry were not well segregated by the coding.

ii the DBS data were prepared for the use of economists and not for chemists.

iii the CIC Survey data were of uneven value:

(a) the university data were generally useful and revealed Committee 16 information.

(b) the industrial information was of limited value and could not be broken down into Committee 16 data.

(c) the breakdown of government information was excellent but personal knowledge of the situation caused severe doubts to be raised regarding the accuracy of the coding.

16.4 Respondents' views on neglected areas of R&D

Only two unsolicited letters were received by Committee 16; both were written by directors of Canada Department of Agriculture research establishments. One came from Western Canada and bore the following pertinent paragraphs.

"Pesticides play an important role in the Canadian agriculture industry and are widely used for control of insects, diseases and weeds. Safe, economic, and judicial use of these materials can be achieved by proper understanding of the chemistry of these compounds, with particular emphasis on persistence, metabolism, structure-activity correlation, photodegradation, etc. Research in this field is done mainly in the government laboratories and industries by chemists whose academic training and experience was in organic and natural products chemistry. Universities have done very little in teaching pesticide chemistry to their undergraduates and graduates.

"Agriculture still plays a large role in the economic welfare of Canada and it is time that the chemistry departments in the Canadian universities become more interested in agricultural chemistry."

The other letter, from Ottawa, is reproduced <u>in toto</u>.

"I should like to express on my own behalf and on behalf of the members of the staff of this Institute an opinion which is widely held and which I would formally wish to make known to the Science Secretariat.

"The Canadian research effort would be greatly aided and its efficiency greatly increased if a large number of Post-doctorate fellowships were made available to accredited laboratories. In terms of the overall support of research, this is the cheapest way of increasing the professional competence of key areas of research without increasing the size of establishments, it ensures the influx of "fresh blood" at all times and makes our scientists feel less isolated in their own areas of specialization.

"Such fellowships should be paid out of a special fund (quite apart from salary accounts) portions of which should be made available to Directors of establishments for use as they see fit in creating the kind of flexibility in research support which good research requires but which is not now available in a government laboratory.

"I am convinced that such a plan, if it were to be adopted by the Government, would be a substantial stimulus to better research."

The chairman of Committee 16 sent letters to the department heads at universities and institutes of technology at which agricultural or food chemistry or food science is taught. These letters asked specific questions and replies were received to each letter.

To the question, "Should the natural products chemistry of the carbohydrates, lipids, proteins, phenolics, pigments etc. in primary or processed foods be retained in food chemistry or does it belong more properly to organic chemistry", with one exception all replies were strongly in favor of food chemistry being the proper home of such natural products chemistry. Some of the reasons given were:

a. food chemistry is as much an entity as petroleum chemistry.
b. the natural products in food belong to biological chemistry rather than organic chemistry and food science has a biochemical basis.

c. organic chemistry no longer covers carbohydrates, lipids, etc. systematically whereas a good food chemistry course does.

The reply taking exception to this stand pointed out that while these compounds must be treated well in food chemistry courses, there are non-food uses for carbohydrates, etc. and these must be covered in other courses and thus have their places outside the world of food.

All respondents but one felt that the term "agricultural chemistry" had outlived its usefulness because now too many topics were covered by agriculture and special labels were required for the special parts. The exception to this stand was based mainly on the fact that the term "Agricultural Chemistry" is the best description of the efforts of a researcher studying the chemistry of an agricultural problem.

The technologies of food, feed, pesticides and fertilizers all contain non-chemical components. All correspondents, however, felt that the engineering aspects of these technologies were strong enough to warrant their inclusion in the C.I.C. Survey.

Most respondents felt that for the immediate future, industry would not do research and that what professional help it would hire would be at the B.Sc. level for quality control. A broad training in food technology at the university or technology institute level was therefore considered the best background for this work. One respondent warned that the capacity of industry to absorb graduates was sharply limited and that food science and technology educational facilities should not be multiplied endlessly.

Another popular view was that genuine research laboratories require specialists in disciplines other than food technology; physicists, chemists, biochemists, nutritionists. No clear indication was given, however, as to when these specialists should encounter food science training. Most respondents deplored the small number of undergraduate students working toward degrees in food science. The small proportion of Canadians among the food science post-graduate students was also noted.

16.5 The state of food science and agricultural chemistry and chemical engineering education in Canada

a. Universities

The accompanying table lists the Canadian Universities which provide higher education in the specific areas of agriculture and food. The faculties of agriculture are in general production-oriented and organized into individual departments along traditional lines, i.e., animal and crop science, horticulture, plant pathology, etc. In this environment, chemistry is taught and used primarily as a tool towards an understanding of biological phenomena. Only two faculties of agriculture have departments concerned with chemistry, i.e., Saskatchewan with a Department of Chemistry and Chemical Engineering and Macdonald College with a Department of Agricultural Chemistry.

Undergraduate courses in basic chemistry are usually obtained outside the faculty of agriculture. This approach has its merits provided that the importance of chemistry to agricultural education is recognized. It would appear that chemistry and other basic sciences do not receive the emphasis they deserve within faculties of agriculture.

The establishment of separate food science or technology departments in Canadian universities is a recent development. The first department was formed at Laval in 1962. Alberta, Manitoba, and Guelph (1968 or 1969) have followed. The University of British Columbia does not have a separate department but grants a degree in food science within the faculty of Agriculture. Food science or technology education programmes could be of immense benefit to the Canadian food industry. It is the one educational programme that puts the interdisciplinary nature of food science in perspective, i.e., chemistry, microbiology, biochemistry and engineering concepts. Chemistry is important to Food Science and is taught accordingly in the existing Food Science Departments. Development of food science and technology education should be encouraged to meet the need of the Canadian food industry. Education of the Canadian food industry to appreciate its weakness in the area of quality control and developmental and applied research should also be encouraged.

Dr. D.P. Ormrod's study of education in Food Science and Technology sponsored by the Canadian Institute of Food Technology and the Department of Industry indicates that:

(a) Chemistry Departments have little or no interest in food-oriented chemical research or courses.

(b) Most Chemistry Faculty members believe that their graduates do not require food chemistry orientation.

(c) Faculty members had no contact with the food industry and were not aware that fundamental problems exist.

In view of current and future world population pressures and the wide-spread occurrence of hunger in the world to-day, this apparent lack of interest in chemical research or education oriented towards food and agriculture places chemistry departments in an untenable position.

b. Agricultural Schools

The diploma courses given in various agriculture faculties and at the Agricultural and Vocational Schools across Canada serve a useful purpose. They provide education at the post-secondary school level for students interested in agribusiness, farm operation, technician training, food processing, agricultural mechanics, etc. In theory, graduates from these schools release professionals from routine tasks and thus increase the latter's productivity. A recent survey by the Agricultural Institute of Canada Review (Vol. 23, No. 1) indicates that in these schools there is a trend to stress agribusiness and management subjects at the expense of regular academic subjects. The demand for agricultural technicians is strong and post-secondary school education in this area should be expanded.

c. Institutes of Technology

Post-secondary school education at the technician or technologist level is a relatively new development in Canada. Institutes of Technology in British Columbia, Alberta, Quebec, and Ontario have excellent programmes oriented towards the agriculture and food sector.

Ontario has no programme in food technology although this is under consideration by St. Claire College in Windsor. The need for trained technicians within the agriculture and food industries is not peculiar to these industries. It is probably more severe, however, in that the agriculture and food sector consists of many small operations which lack the "on the job" training resources of the chemical industry.

Closer liaison between universities and institutes of technology offering courses in food science and technology might be profitable.

d. High Schools

In the United States, private industry and the Institute of Food Technology are offering high school graduates with good scholastic standing university entrance scholarships to help them proceed toward a degree in food science. These scholarships range in value from $350 to $1000. No equivalent Canadian effort to interest high school students in undergraduate food science education exists.

16.6 The Ability of Industrial, University and Government Laboratories in Canada to Employ Additional Research Funds and Manpower Effectively

a. Non-food Aspects of Agriculture

As indicated earlier, in Section 16.3 (a)i-vii, Committee 16 is confining its attention to fertilizers, pesticides, soils, animal feeds, tobacco, forage crops and grasses and plant growth regulators. A further restriction is that only chemical or chemical engineering R&D is to be considered. Within these limitations, industry, university and government activity changes will be forecast.

Chemical R&D on fertilizers and animal feeds is essentially confined to industry with only analytical studies conducted by university or government laboratories. New methods for converting N, P and K into suitable form will undoubtedly be studied with elementary sulphur also receiving attention. It is doubtful that much of the basic research will be conducted in Canada; the bulk will be done in the central laboratories of the parent companies. Canadian firms will conduct developmental research to test the properties of possible new ingredients. The Canadian fertilizer industry should be able to employ effectively additional manpower and funds approaching a 50% increase over present expenditures.

The converse obtains with pesticides, soils, forage crops and grasses and plant growth regulators in that university and government laboratories conduct the bulk of the chemical R&D in these areas. Undoubtedly, each laboratory engaged in research in these areas could employ additional staff and funds gainfully. The existing research talent is of high calibre and new staff and facilities could be exploited readily. Whether additional staff and funds reach these laboratories depends, therefore, on whether the strategic planning boards responsible for these laboratories decide to allot additional man-power and money to these areas. The requests are defensible.

b. Food Aspects of Agriculture

Unless a large number of the smaller food processing companies pass out of existence, over the next few years, the structure of the industry will continue to be that of a multitude of small plants producing a small (20%) proportion of the processed food with a minority of large plants producing the bulk of the food. At present, many plants do not even practice quality control and, where Q.C. is done, many plants do not employ professional personnel. As a result, most (90%) of the research conducted by the Canadian food industry is concentrated in a few laboratories. Canada Packers Ltd., John Labbatt Limited, Lever Brothers Ltd., Canadian Canners Ltd., Griffith Laboratories, S and L Seasoning are some of the food companies conducting research. Of these, Canada Packers is outstanding.

Many of the large food companies in Canada are subsidiaries of foreign-owned firms. The current trend toward centralization of R&D facilities in one of the laboratories of an international corporation has had the effect of reducing the laboratory work in Canadian food plants to the level of Quality Control. For example, Kraft Foods and Proctor and Gamble invest heavily in Quality Control but can report truthfully that they conduct no research in Canada. Moreover, developmental research by Canadian food companies is often a "one-shot" venture, e.g., "What Canadian flour can be used in a cake mix developed elsewhere?". Once a problem of this type is solved, no further R&D on cake mixes is required.

For the above reasons, the Committee feels that it is unlikely that the Canadian food industry, as presently structured, will be able to employ profitably any marked addition to its scientific staff or research funds. Even if funds for capital expenditures, operational costs and salaries became available, few food companies could take advantage of the situation because the present management of most food companies is not research-oriented. Product improvement or product development R&D would be superficially attractive but it is considered that unless funds to cover marketing costs were also made available, few food companies could afford to use the fruits of their subsidized R&D. Another limiting factor is a marked shortage of food technologists at the bachelor degree level.

All Canadian food science departments are developing, with that at Laval University the most advanced. Most departments employ a 4- or 5-man professional staff which, because of the small number of undergraduate and postgraduate students, has only a moderate teaching load. The staff members are thus free to conduct research themselves and to direct postgraduate students or post-doctorate fellows. Most departments are reasonably well equipped for food science training at the undergraduate level in unit operations. Most of the current post-graduate research, however, appears to be on properties of food or on studies of the reactions that occur in food during processing. Adequate chemical and biochemical equipment appears to be available for this research. However, food engineering - the study of the basics of unit processes - is an almost neglected research area in Canada. This could be due to lack of funds to purchase pilot-plant scale equipment for post-graduate research.

The Committee feels that where physical facilities and university policy permit, most food science departments could employ additional staff members and research funds effectively.

In most provinces, with possibly only Quebec and Ontario as exceptions, the place of food in agriculture has yet to be established. Until that is done, food research will not receive full attention from the strategic planners of research activity. Consequently, in provincial government laboratories, food research tends to be product or crop oriented. As a result, food chemical studies per se are uncommon and food processing R&D is devoted to developing products from specific crops. This orientation seems appropriate and the Committee anticipates no major change in emphasis. Increased activity at the provincial level could be effective but it should be coordinated with food research at provincial, or private, universities in each province. In this way more effective use could be made of the manpower and funds.

University Education in Agriculture and Food Sciences

	Agriculture Faculty	Department of Food Science or Technology	Chemistry or Chemical Engineering Emphasis	Food Technology Emphasis
University of British Columbia	Faculty of Agriculture	No	Chemistry or Chemical Engineering applied to production and processing.	Taught within [illegible] the structure [illegible] offered within [illegible] of Agriculture.
University of Alberta	Faculty of Agriculture	Department of Food Science	Applications to Agriculture and Food. Food Chemistry and Chemical Engineering courses offered.	Food technology considered important.
University of Saskatchewan	Faculty of Agriculture	No	Department of Chemistry and Chemical Engineering exist. Slanted towards food or agriculture applications.	Limited emphasis
University of Manitoba	Faculty of Agriculture and Home Economics	Department of Food Science	Limited emphasis on Chemistry and Chemical Engineering	Limited emphasis
University of Guelph	Ontario Agricultural College	Will be operational by fall 1968	Limited emphasis on Chemistry and Chemical Engineering	Believe it will be strong
Macdonald College	Faculty of Agriculture	Department of Food Science teaches in essence home economics	Department of Agricultural Chemistry teaches application of chemistry to agriculture.	Limited emphasis

Laval University	Faculty of Agriculture	Department of Food Science	Chemistry and Chemical Engineering applications to agriculture and food emphasized	Strong emphasis on food technology
University of Toronto	No	Faculty of Food Science exists but essentially an amalgamation of home economics and food chemistry	Application of chemistry to food	No concerted emphasis
Nova Scotia Agricultural College	Faculty of Agriculture			

c. Non-agricultural food aspects

For this discussion, non-agricultural foods are either foods from genuinely non-agricultural sources such as the sea, the forest or the fermentation vat or else foods of sufficient novelty that although they are prepared from material of agricultural origin, they have not as yet been accepted by agriculturalists. For example, margarine and shortenings are generally accepted as foods of agricultural origin whereas "filled" and synthetic milks are considered non-agricultural.

The Federal Department of Indian Affairs and Northern Development (then Northern Affairs and National Resources), aided by the Food Research Institute, has been concerned with the processing of fish and marine animals and their edible organs into food for both the Indian and Eskimo population and for sale as gourmet items further south. This has involved food technology only and no basic studies. About three years ago, the Fisheries Research Board intensified its development of Canada's inland fishing potential. Its present Winnipeg laboratory works in close cooperation with the University of Manitoba. This work, like that of the Department of Indian Affairs and Northern Development is still in its infancy. It would appear likely that additional effort would be a good investment provided market research indicated good sales potential and experienced food scientists were employed on the projects.

Eleven years ago, the Fisheries Research Board in Halifax developed "fish protein concentrate" and recently has further improved the process which is now the basis of most current competitive processes. A bland, defatted, high protein powder can now be prepared from either scrap fish (defilleted) or whole fish. This R&D has involved chemistry and chemical engineering and is continuing. Until 1967, other countries evinced more interest in the product than did Canada and pilot plants have been built elsewhere to exploit this development which could play an important role in world feeding. Private industry and the Food Research Institute of the Canada Department of Agriculture are studying various aspects of the utilization of fish protein concentrate in foods. More work of this nature, research on the functional properties of proteins, could be done provided experienced food scientists are employed.

The Fisheries Department and the Fisheries Research Board are concerned with preserving the quality of fish from the time it is caught until it is eaten. The use of antibiotics was advocated several years ago but now exposure to gamma radiation appears to be an attractive means of extending shelf-life. The technology of fish handling and the biochemistry of post-mortem changes are receiving considerable attention from these two establishments.

The Food Research Institute also developed a product line of instant potato:protein products of which fish:potato was one of the items, further indicating the need for food research on fish.

Fish meal continues to be a valuable animal feed component. The bulk of the R&D effort to prepare improved fish meals were conducted by the Vancouver Laboratory of the Fisheries Research Board of Canada in what is probably the only government pilot plant in Canada. Utilization of fish meal in feeds is studied in departments of nutrition in faculties of agriculture and by the major feed manufacturing companies. This work can best be described as part of an overall program of investigation to extend the application of linear programming to the preparation of nutritious feeds from the widest possible variety of sources.

"Tall oil" obtained from the effluent from sulphite pulp mills furnishes a variety of products of which fatty acids are of major interest. The technology of preparing feed- or food-grade "tall oil" fatty acids and of forming triglycerides from them through esterification with glycerol has been worked out. Economic considerations govern their use. This R&D has been conducted primarily by private industry, e.g., Canada Packers Limited, Toronto. This synthesis of glyceride oils from tall oil acids is the one Canadian example of the chemical synthesis of food. The application of this type of R&D depends so heavily on economic factors that care must be exercised in advocating further work of this type.

Petroleum can serve in two ways as a source of material for feed or food. The petrochemical industry can produce by chemical synthesis mono- and polyhydric alcohols, fatty acids, amino acids and a great variety of feed and food additives. Paraffinic hydrocarbons can also serve as substrate for certain microorganisms. They serve as energy sources for these microorganisms which have the faculty of converting non-protein nitrogen into protein. Private industry has led in this R&D but very little work of this nature is done in Canada. Because Canadian crude oils contain only a small portion of paraffinic hydrocarbons, a preliminary fractionation, possibly by urea adduct formation, would be required if Canadian crudes were to be used.

Fermentations are also used to preserve food and to add to its aesthetic appeal. However, aside from the preparation of conventional pickles, essentially no R&D of this nature is attempted in Canada.

Algae and other lower plants can be grown in quantity and probably in a high density of algae per litre. Algal protein is of reasonable quality but the accompanying carbohydrate cannot be digested by man. Therefore, algae provide feed or, on extraction of the protein, an amorphous protein concentrate. Essentially no R&D is invested in Canada for food or feed purposes.

The degradation of cellulose to glucose, the conversion of non-protein nitrogen to protein by microorganisms and the growing of algae for food uses are all areas that have received insignificant attention in Canada where biological engineering is in its infancy. The University of Western Ontario, Waterloo University, John Labatt Limited, the Prairie Regional Laboratory and, to a lesser extent, the Division of Biosciences of the National Research Council have conducted biological engineering with agricultural or food overtones. This R&D is very expensive but the capacity for expanded effort exists in Canada.

"Filled" milk (skim milk to which non-dairy fats are added to bring the fat content up to 2% or 3.5% fat) and synthetic milk (milk made from non-milk sugar, fat and protein) are two non-agricultural foods. "Filled" milk and synthetic milk were developed outside Canada and the only Canadian R&D that might need be done is that to determine whether a Canadian ingredient might be substituted for one of the standard ingredients. This R&D would probably be done by industry.

Tissue culture can be used to produce mushrooms and primitive "parts" of carrot, tomato and other vegetables or fruits. These non-agricultural foods are developed by biological processes, however, and chemical R&D plays a very minor role in their production. Moreover, no tissue culture for food purposes is conducted in Canada.

In summary, foods of marine origin are being studied by Federal Government laboratories and also by provincial laboratories in Newfoundland, the Maritime Provinces, Quebec, Manitoba and British Columbia. The fishing industry itself supplies little chemical or chemical engineering R&D. University research is mainly nutritional.

These laboratories are staffed with capable researchers and are adequately equipped. The Committee feels that if additional manpower and funds were made available they would be used capably.

The conversion of petroleum or tall oil fatty acids into food or food additives is to be covered by Committees 04, 05, 06 and 17 and the areas of algal culture, tissue culture and microbial processes belong to Committee 17. Moreover, the chemical component of the R&D in these areas is small. Much of the R&D has already been done and the Canadian contribution is not likely to be more than that required to domesticate an imported technology. Whether Canada should do more than this will be presented in the final section of this Report. The potential to perform the required R&D probably exists at this time.

d. Engineering aspects

No information is available on the extent or adequacy of present engineering R&D in the areas of feeds, fertilizers, pesticides or tobacco. However, the four pilot plants that the Canada Department of Industry is establishing will be available for contract research and these industries will no doubt make use of them as the need arises. Similarly, food processing pilot plant studies, in addition to those mentioned above in (c), could presumably be conducted in these Department of Industry sponsored pilot plants.

Except in industry, pilot plants for food engineering studies do not exist. Except for the fish meal pilot plant in Vancouver, no Federal or Provincial Government laboratory contains a pilot plant. The one university that employs a food engineer has no pilot plant for him and the one university that could be said to have a pilot plant has no engineer. Major food companies have well equipped pilot plants but these are used almost exclusively for product development work. There is a genuine lack of true food engineering research in Canada.

Most of the very large food processing plants in Canada have pilot plants for product development work. Some experimental flour milling is conducted and the Ivey-Palyi association in Toronto has developed an interesting process for milling a high-protein, "aleurone" flour. Also on a small scale is the experimental work of Canadian Freeze-Dried Foods Limited. The major vegetable oil refineries have developed refining, bleaching, deodorizing and hydrogenation techniques but Canada lacks an oilseed crushing pilot plant. As a result, Canadian oilseed crushing techniques are basically untried adaptations of techniques developed in the U.S.A. The mobile food irradiator of the Commercial Products Division of Atomic Energy of Canada Limited is, perhaps, the sole example of a Canadian "first".

The Food Technology Section of the Canada Department of Agriculture Research Station at Summerland, British Columbia has developed excellent rapport with the fruit and vegetable processing industry in the Okanagan Valley. Several laboratory-scale processes have appealed sufficiently to local industry that the industry itself has undertaken the up-scaling of the process. Often the resulting plant is no larger than the pilot plant of a major food processor but, in this way, the transition from laboratory-scale to pilot-plant scale operations is effected.

Because of the cost of pilot plants and their operation, it is difficult to assess how much additional pilot plant scale R&D could be done by Canadian industry with greater assistance. Many of the firms are only pilot plant scale themselves and thus could not assume the responsibility of a pilot plant. With others, the profit margin is so slim that Quality Control is all that can be expected of them. At present, there is an extreme shortage of food engineers in Canada. Thus, although most Food Science Departments at Canadian universities would like to conduct research in food engineering, staff is lacking for this expansion.

The current lack of a food research pilot plant in any provincial or federal government laboratory precludes activity in this area. The need to up-scale new processes, to produce quantities of a new food for industrial or consumer testing, the need to prepare quantities of a new basic food ingredient so that its functional properties can be tested are all reasons for the establishment of a central food research pilot plant.

16.7 Recommendations

a. Areas in need of attention

The complexity of modern agricultural research is such that the multidisciplinary approach to the solution of problems is not only highly desirable but essential and, it is to be hoped, inevitable. The "evolution" of soil chemistry from a branch of agricultural chemistry to pedochemistry, a branch of geochemistry, carries with it the possibility of soil being divorced from agriculture and being regarded as a substrate for thermodynamic research rather than a source of nutrition for plants. Whether due to its youth or to other reasons, pesticide chemistry still appears to be closely wedded to agriculture. However, certain biological aspects of pesticide research appear to have been neglected; for example, studies of cytology and genetics in relation to herbicide action.

The Committee feels that pesticide research must go far beyond development of methods of analysis and field testing. The mechanisms of pesticide action at all levels: the soil, the water, the plant, the pest, and the higher animal that ingests it. Highly integrated, chemical, biochemical and biological research in depth is required.

When soils or pesticide chemistry is being considered in the light of knowledge on hand, the extent of current research, the need for expanded research effort, and the need for undergraduate and postgraduate training in universities, two aspects must be kept in mind: the domestic needs of Canada and the role that Canada will probably be called on to play in supplying teachers, extension specialists and researchers to underdeveloped countries. For this reason, and to this end, the Committee feels that the Science Council would do well to establish contact with the External Aid Office (Canadian International Development Agency) of the Department of External Affairs.

With the exception of milk from a lactating female, all food that humans consume is processed to a minor or major degree. The farmer has, therefore, become a supplier of raw materials to the food industry and his position now resembles that of the iron ore miner in the steel industry. Moreover, the farmer himself has now become a consumer of "store-bought", processed food.

Because of its mid position, the results of food research have input into the food processing industry as well as feed-back to the agricultural researcher. The term "Total Agriculture" has been used to describe the concern for food from the seed (animal or vegetable), through growth (nutrition and protection), harvesting, processing and consumption by the purchaser. Multidisciplinary research is needed, not merely because of the complexity of food research problems but, because so much biology is involved. Invoking biology when food is either dead or senescing material may appear strange but each food item is derived from living matter and the results of food research bear on numerous agricultural problems.

With the notable exception of wheat, and more recently rape, Canadian agriculture has been production-oriented and concerned with farm production only up to the farm gate. This restriction in thought has permeated the whole of agriculture: economics, production, marketing and research. Agricultural policy, as a result, has been designed primarily to influence production. Food has been considered as a by-product of agriculture and until recently concern for it has been limited to inspection and grading. Plant and animal breeding has been conducted with the ultimate consumer in mind but frequently the criteria used have not been based on the results of food research in combination with market research.

Contemporary food research can be said to be concerned with:

a. maintaining or improving the aesthetic and nutritive value of food;
b. reducing food wastage through improved preservation and storage;
c. increasing the efficiency of processing operations;
d. developing new foods, new processes and new primary foods.

This research is done in the full realization that until food is eaten it provides no nutrition and that, except in emergency, unattractive food will not be eaten. Furthermore, nutritional problems - overnutrition, undernutrition and malnutrition - are common to all countries. Thus, food research is concerned with the quantitative and the qualitative aspects of human nutrition.

Food research is multidisciplinary by nature. Natural products chemists investigate the color, flavor, aroma of foods and metabolically active substances and their products. Closely allied is the role of the specialist. The structural carbohydrate chemist, the protein chemist and the lipid chemist work at either the descriptive or the speculative level to determine the nature and functions of chemical compounds in relation to food quality. Texture and other aesthetic properties are measured instrumentally by engineers, physicists or physical chemists. In some cases, subjective assessment by taste-panels, soundly based on modern statistical analysis, is more sensitive and more precise than objective measurement. Food processing research is concerned with the invention of new foods and new processes, the improvement of the efficiency of existing processes or unit processes and with the development of new sources of food. To determine whether a new seed or grain or animal tissue can serve as a new source of food for humans requires that the food processor be fully supported by specialists. Team research is basic to food research and this team should include a market analyst.

The biochemist and the microbiologist are also important members of the food research team. Primary food is either dormant, senescing or dead and processing must include effective termination or close control of enzyme activity. Thus, often, the only life associated with a food is that supplied by the microorganisms that accompany it. Nevertheless, biochemistry is basic to food research in that knowledge of the mechanisms of senescence and paths by which microorganisms produce flavor, aroma and textural changes is essential to an understanding of food quality. The early, and readily justified, concern with food sanitation, has been supplemented by research on the ecology, genetics, serology and physiology of microorganisms.

Human nutrition is a complex function of the social, economic, religious, and political status of a country and depends markedly on the rate of population growth, on the general health of the population and on how far the country has evolved from subsistence agriculture. Nevertheless, the quantity and quality of food available to the people is the vital factor. If either is inadequate, nutrition is inadequate. Therefore, control of food wastage through proper storage and processing is an important factor in the nutritional status of a country. The impact of processing on the nutritive value of food is a vital consideration which is just starting to receive the attention that it deserves. Health aspects of nutrition are, very properly, the concern of the medical profession, a national department of health or the World Health Organization of the United Nations. All other aspects of nutrition are equally appropriate to food and agriculture, nationally or internationally as in the Food and Agriculture Organization of the United Nations.

The exploitation of new food sources also involves the nutritionist and food processor as a team. The nutritive value of the new food source must be determined as each step in the process is established by adjustments in process variables to meet nutritional requirements. Then, as the functional properties of the food are determined, additional nutritional and processing research is required. Because processing can increase as well as decrease the nutritive value of food, combined food processing-nutritional research is an area of major importance. This importance, moreover, will increase with time as urbanization and the changing role of farmers as consumers result in the consumption of increased amounts of processed food. The Committee is of the opinion that clear distinctions be drawn between the food production research of traditional agriculture and the food research conducted to convert agricultural produce into processed food. The volume of food production research is large, that of food research is small.

Product development research is an area best served by industry where the required close liaison with marketing experts is available. Where an industry cannot conduct its own product development R&D, it can hire consultants or request help from a government laboratory. Often, it is a trade association, rather than an individual company, that seeks help. To date, these requests for assistance from industry have not been numerous and government laboratories have engaged in product development work mainly to satisfy the individual researcher's curiosity. The up-scaling of the laboratory product development work has generally been left to industry to accomplish.

The role of the central (government) food research pilot plant is thus not to compete with industry in product development. Instead, it is to permit laboratory-scale experiments to be repeated on a sufficiently large scale to attract the serious attention of industry. New basic foods or new food processes are developed on a laboratory scale. There is then the need to produce the new food in quantity for large-scale testing of its functional properties, its consumer acceptance and its usefulness to industry as an ingredient. Canadian food research is seriously handicapped by the lack of such a facility.

Another area that could be strengthened in Canada is R&D to assist the inspection and grading of foods and the regulation of food quality. Food grading standards must be kept up to date to take advantage of changes in primary foods brought about by plant and animal breeding research and of developments in nutritional knowledge and analytical skills as well as changes in consumer needs. To a large extent, this research to put Quality Control on a sound basis will be covered by Committee 01 but the members of Committee 16 felt that they should direct attention to the need for additional research effort in this area.

b. Type and amount of support and sites of additional R&D activity

In making its recommendations, the Committee has before it the following considerations:

i The chemical component of agricultural and food research does not, nor is likely to, exceed 20% of the total effort as measured in man-years.

ii Agricultural and food research is by nature multidisciplinary.

iii Any recommended increase in chemical research must be accompanied by a corresponding increase in biologists to apply the new knowledge.

iv This required increase in biological man-years of research could come from the redirection of the research effort of existing biologists.

v Because of the success of non-agricultural sources of textiles, leather and protective coatings in replacing traditional materials and the uncertainty regarding the impact of non-agricultural food on world food supplies, the role of agriculture appears to be that of supplying food to the world.

vi The principal criterion for evaluating the adequacy of current and future agricultural and food research is whether the research is qualitatively and quantitatively adequate for helping Canada feed itself and fulfil its obligations to world feeding.

vii The complexity of agricultural problems and the frequent requirement of several crop years or generations for the testing of an hypothesis indicates the need for strong research centres which can supply continuity of research staff and a variety of disciplines under one strategic command.

viii The terms of reference of Committee 16 preclude its consideration of research in which chemistry is used as a tool in the solution of biological problems.

The chemical component of research on tobacco is currently confined to the curing processes and the products of the combustion of tobacco. In both cases, with the exception of flavor and aroma chemistry, the basic problems are principally biological. The Committee feels that private industry is the natural site for any increase in tobacco research and that existing means for obtaining government support for industrial research should continue to be adequate to meet demands.

Chemical research on fertilizers is principally in the area of fertilizer technology. The Committee feels that here again private industry is the proper site for R&D on fertilizer technology and that existing means for obtaining financial support for the research are satisfactory.

An analysis of soil research reveals the following:

(a) soil fertility classification and genesis employ chemistry as a tool in solving biological problems and as such are not for the consideration of Committee 16.

(b) soil minerology is covered by Committees 01 and 02.

(c) soil organic matter is the concern of Committee 04.

(d) soil microbiology is dealt with by Committee 17.

(e) research on the reactions in soil is covered by Committees 11 and 19.

As a result, Committee 16 would like to repeat its warning on the dangers of divorcing soil from agriculture. As in many divorce cases, both parties are at fault and traditional agriculture must assume a large portion of the blame for the lack of communication that preceeded the separation.

Traditionally, soil science embraced three topics: classification, genesis and fertility. Research effort was therefore categorized accordingly and this led in several instances to a loss of vigor. Thus, the exciting research became associated with other disciplines and departments, leaving the more pedestrian aspects of soil research to "agriculture".

Committee 16, while recognizing the limited concern that it has for soil research through its terms of reference, nevertheless would like to point out the obvious that soil is basic to agriculture. It would also like to call attention to the fact that soil problems that have been solved in Canada are current problems in less highly developed countries. Thus, if Canada is to lend technical assistance to these countries the supply and ability of its soil scientists must be maintained.

Pesticides cover such a wide range of compounds and reactions that a simple statement cannot deal adequately with the problem. In terms of technology, the situation is similar to that of fertilizers. There is, in addition, a laboratory R&D requirement and a strong role for non-regulatory government laboratories. The Committee is of the opinion that additional basic pesticide research on the mechanisms of interaction of pesticides with the soil and with organisms is required. Where indicated, this research should be at the cellular or molecular level.

The Committee feels that this R&D activity should be centred in a specialized government laboratory for the following reasons:

(a) The pesticide industry in Canada consists mainly of the Canadian subsidiaries of foreign-owned firms. The R&D activity is thus concentrated in central laboratories outside Canada. Moreover, the R&D is mainly developmental.

(b) The required basic R&D activity involves several disciplines and the efforts of the various contributors must be coordinated to the fullest extent of sound research management practice. Moreover, many of the problems are too difficult for post-graduate students to tackle successfully. Thus, unless a university were prepared to establish a multidisciplinary research department equivalent to a top-quality, non-regulatory, government laboratory, university chemistry or biology departments cannot provide the proper site for this R&D.

The Committee also recognizes the need for additional researchers in the field of basic research on pesticides. It therefore recommends that the possibilities be explored of increasing the use of post-doctorate fellows in this area. A corps of specialists is available in Canada to offer guidance to the fellows.

Food that reaches the consumer has been:

(a) produced by agricultural or non-agricultural effort involving fertilizers or other nutritients and pesticides or other control chemicals.

(b) processed, involving equipment, chemicals, additives

(c) inspected and graded

(d) packaged

(e) stored

(f) sold at the wholesale and retail levels.

Step (a) has been covered earlier in this section under non-food agricultural research. Step (b) involves industry and government. The equipment, chemicals and additives used in foods, except for the minor amounts supplied by Canadian firms, are all imported. Hence, the need for industrial chemical or chemical engineering R&D in this area is slight. The Canadian or Canadian-based "spice houses" should receive support for the research that they would like to undertake, however.

Government research on chemicals and additives is generally conducted in relation to devising standards for food composition or grading. Thus, governments are concerned simultaneously with steps (b) and (c). Within the past few years, and following the "Thalidomide incident", the laboratories of the Food and Drug Directorate of the Department of National Health and Welfare have received massive support. The Committee feels that, for the time being, a period of consolidation should preceed any further expansion of the laboratory facilities of the Directorate.

In marked contrast to the support given to its inspectors and enforcement personnel by the laboratories of the Food and Drug Directorate is the modest effort made by the Production and Marketing Branch of the Canada Department of Agriculture. Its laboratories are preoccupied almost completely with the routine analysis of food samples. Only a token effort is made to develop new methods of analysis and no attempt is made to study the properties of the food that is graded and inspected. In the Research Branch, analytical methods are developed on request by the Analytical Chemistry Research Service but no sustained research on food methodology is attempted. In the Food Research Institute, the properties of food are studied and analytical methods devised but the Institute's personnel are involved in research projects and are not available for sustained cooperation with the Production and Marketing Branch. The Committee suggests that possible means for increased support for the regulatory functions of the Canada Department of Agriculture be investigated.

At the provincial government level, the extent of research varies from nil to considerable activity in support of control functions. In several provinces cooperation between federal and provincial laboratories is effective. Because of the wide variation in need from province to province and the general concern with control functions only, the Committee feels that it cannot make recommendations regarding food R&D at the provincial government level.

To the Committee's knowledge, there is no university research directed to the support of regulatory functions. The Committee feels that this is an appropriate state of affairs.

Packaging research is conducted by the Department of National Defence to meet the unique requirements of the armed forces. Otherwise, packaging research is done by the major suppliers of packaging materials in cooperation with appropriate segments of the food industry. Because of the high cost of packaging research and the need for close cooperation between suppliers and users, the Committee sees no need to change the situation. Should any of the Canadian suppliers wish to conduct research beyond the ad hoc level, the Committee feels that fundamental research into the properties of the material should be supported. The Committee is of the opinion that the extensive research in the U.S.A. on the transmission to foods of plasticizers and other mobile components of packaging materials need not be duplicated in Canada.

During storage at the wholesale and retail levels, food can undergo changes such as the photo-induced oxidation of fat-containing foods and the denaturation of frozen tissue. During prolonged cold storage or during shipment from country of origin, fresh produce ripen or senesce. The changes involve both chemistry and biochemistry and are of concern to this Committee. So is the study of the factors that give aesthetic and nutritive value to foods.

The current state of the Canadian food industry and its immediate outlook suggests to the Committee that the industry will not be able to conduct more than a token amount of the research on the nature of quality in food, the reactions that it undergoes during storage and processing or even food technology research. The reason, stated earlier in more detail, is that the small firms cannot afford even government-subsidized research and the large firms are Canadian subsidiaries of foreign-owned corporations with central R&D laboratories.

The universities are logical sites for food research and each of the present seven departments of food science could make effective use of additional support for research. Currently, the departments lack undergraduate students and most of their graduate students are non-Canadian.

The average level of graduate research in food science, however, is more at the M.Sc. than the Ph.D. level. This present situation may be explained in terms of the quality of the graduate students, the quality of the staff and the complex nature of food research projects. Therefore, although the existing departments of food science could, through expansion, conduct more research, the Committee feels that there is also a need for centres of research where mature scientists can work in depth on difficult problems without a "Damoclesian" thesis hanging over them.

The Committee is of the opinion that the provincial or federal government food research centre has an important role to play in the Canadian food research scene. It is at these centres that research in depth can be accomplished. The scientist is mature and he can converse with and obtain cooperation from researchers in other disciplines. Programs of research with advanced but well-defined objectives can be established and pursued without interruption due to graduation or failure of students.

The Ontario Department of Agriculture and Food is unique among provincial departments in that both in name and practice it recognizes the relationship between food and agriculture. The change in name is more recent than its interest in food R&D. This research, however, has been concentrated on fruit and vegetable storage and processing and on wine making. The Committee feels that other areas of food research could be undertaken profitably provided full communication is maintained between the laboratories of the Department of Agriculture and Food and the new Food Science Department at the University of Guelph. The Committee is also of the opinion that in all provinces full communication between provincial research councils, universities and departments of agriculture must be maintained if food R&D is to be conducted effectively and efficiently.

The Committee recognizes that the role of the Departments of Agriculture and Fisheries is that of a supplier of raw materials to the food industry. Current levels of federal food R&D, however, appear to be based on the concept that food production or fish landing is an end in itself. The Committee feels, therefore, that, because the food industry is unable to perform its own food R&D and because many of the pressing problems are national rather than regional in scope, additional food research be undertaken by federal government laboratories. Research into the nature of quality in foods, the reactions that affect quality positively as well as negatively, the biochemistry of senescence of food tissues, the storage and processing of foods, the measurement of quality, the useful and harmful microorganisms, new sources of food are all areas in urgent need of additional support. One or more strong central food research centres are suggested to avoid fragmentation of effort.

c. The need for coordination

Research on agricultural and food problems competes for manpower and support with all other branches of research, and requests for additional agricultural and food R&D will probably be met only by diversion of support from other areas. Moreover, within the boundaries of food and agricultural R&D, competition will prevail. The need for broad strategic planning is self-evident.~~and the Committee merely suggests that when this planning is done, the role of agriculture and fishing as suppliers of food be the basis for the decisions.~~ The R&D activities of private industry, the universities and the government agencies should all be considered by the strategic planners. The ~~urgency~~ need to increase Canada's food R&D capability is so great that the Committee urges that both short-term and long-term planning be considered, not with the view of producing quick answers to ad hoc problems but with the objective of giving support to existing organizations that can benefit directly from increased support.

d. Mechanisms for funds and research manpower

The establishment of new industrial R&D laboratories is currently considered by the National Research Council and the Department of Industry to be a laudable objective. The Committee recognizes that

Canadian industry performs only a small amount of Canada's total research and that, in general, a larger share could be carried by industry. Nevertheless, the Committee requests that this general statement be applied with care to the structure of agricultural and food R&D. Canada must avoid a proliferation of small laboratories which would absorb manpower and funds but which, because of their isolation, contribute little beyond trouble-shooting. As stated earlier, the structure of the food and non-food components of Canadian agriculture- and fisheries-based industry will have to change markedly before R&D funds and personnel can be used effectively. Company management has yet to be convinced that R&D is other than a luxury that cannot be afforded. Many of the companies that can afford limited technical assistance employ consulting firms in the USA on an _ad hoc_ basis.

For these reasons, the Committee feels that increased support for currently effective laboratories, whether in industry, universities or government, would be the most effective way of improving agriculture and food R&D. For the large industrial laboratories, the present fund-granting systems appear adequate and sufficiently flexible to meet changes in requirements. Similarly, the various grants-in-aid of research available to university staff seem to meet needs, qualitatively if not quantitatively.

With the objective of sharpening the focus of the research, the Committee asks that government laboratories be allowed more post_doctorate fellows and expanded use of directed grants-in-aid of research such as the Extra-Mural Research Grants of the Canada Department of Agriculture. Agriculture and food research problems are complex and require the application of several disciplines for their solution. Moreover, their complexity requires that research effort be sharply focussed if a solution is to be achieved in finite time. The use of post-doctorate fellows and grants-in-aid of specific research projects would permit the required sharpness of focus.

As defined in the Questionnaires designed for this survey, "basic" chemical or chemical engineering research is almost inappropriate to agriculture and food because the substrates or systems are too complex for basic studies; researchers capable of conducting basic research are almost certain to select simpler systems. For this reason, "oriented basic" or applied research, as defined in the Questionnaires, are appropriate and essential for supplying knowledge for "development" research. The Committee is of the opinion that, for the foreseeable future, the agriculture and food industry will limit itself to "development" R&D with the occasional taste of "applied" research. Thus, university and government laboratories have the task of supporting industrial research through their "applied" and "oriented basic" research. The Committee, therefore, recommends that conditions favourable to sharply focussed, intensive, multidisciplinary research be established.