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# OPTIMIZATION OF DIETS WITH EQUAL QUANTITY OF PROTEIN DERIVED FROM FOOD LEGUME AND CEREAL FOR HARD WORKING RURAL POOR USING LINEAR PROGRAMMING APPROACH

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## ABSTRACT

Over 40 per cent Indian population needs to be attended for nutritional improvement. Traditional nutritious food resources though abundantly available but presently less used, if incorporated in the diets, can yield low-cost nutritionally balanced diets. The linear programming (LP) model was used for optimization of food resources to satisfy protein-energy requirements of hard working rural poor. Soybean- a highly nutritious food legume- available at reasonably low price was included alongwith chick-pea and pigeon-pea for comparison. The three cereals predominantly used in Indian diets -rice, wheat and sorghum- and three typical leafy vegetables namely, spinach, drumstick leaves and rajagira (Amaranths paniculantus) leaves were used for optimization. The contribution of food legume was restricted to supply only 50 per cent of daily protein requirement for maximum protein value. The quantities of other food stuffs namely, milk, sugar, tubers etc. were restricted to national per capita availability. The nutrition satisfaction levels in per cent RDA by the model are 149 - 250 for protein, 51 - 106 for fat, 134 - 362 for iron and 143 - 1158 for Vitamin- A. Quantities of food legumes, cereals and leafy vegetables ranged from 289 - 601, 3000 - 3700 and 360 - 1200 g/day respectively for a reference family of five hard working rural poor. Daily food resources cost ranged from US$ 0.6 to 1.0 for the family. Amongst food legumes, soybean based diet combinations provide maximum nutritional benefits at minimum cost indicating its suitability for wider adoption by hard working poor.

**Key Word** : Linear programming, Diet design, Nutrition satisfaction, Maximum protein value

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## INTRODUCTION

Nutritional improvement for growing population is the prime need for developing countries. Lack of purchasing power is the main hurdle in advocating suitable combinations of food stuffs to make the diets more meaningful. The only alternative, therefore, is to have an appropriate combination of less costly, locally available and nutritious food raw materials.

The diets which derive equal quantity of protein from legumes and other food components like cereals - vegetables give maximum protein value (Oke, 1975). In recent years, the linear programming (LP) technique has been adopted for diet designs (Shah, 1986) and optimiztion of food resources in formulating nutritious convenience foods (Bhole, 1992). The ICMR guidelines (ICMR, 1984) could be used in deciding the intake levels of food constituents.

Uncertain and low incomes coupled with inflation present the poor, a formidable problem of meeting their increased food demands on account of hard labour. Natural nutritious resources available rurally at reasonable price could find easy incorporation in daily diet.

An optimally balanced diet reasonable in cost and designed for varied consumption pattern followed in India may be useful for developing countries for their future food planning. The present study was therefore, takenup to optimize the diets using LP technique to have 50 per cent protein requirement met through legume source for maximum protein value at cost affordable by hard working rural poor from developing countries.

## MATERIALS AND METHODS

Approach followed for diet optimization based on 50 per cent protein requirement from food legumes includes identification of representative family, food material and their price pattern, social aspects and development of LP model.

**Representative Family**

Rural based poor family of hard working five members was considered. The details of family members were decided as per the normal family pattern. Nutritional requirement based on ICMR guidelines (Table 1) were used for development of a model for optimization of diet components.

**Food Materials**

Following facts were taken into account while selecting the food materials to form the diet of hard working rural poor family. i. Common food is prepared for all and thus no separate preparation is available for elders or children. Only quantity consumed by them varies. Sometimes children are given priority when limited food is available. ii. Different types of food dishes are normally not available. iii. Barring few occasions, the frequency of repetition of dietary articles is more due to financial constraints. iv. Choice is mainly guided by the cost of raw materials and not by their nutritive value. v. Normal tendency is to minimise the consumption of higher cost items for adjusting the food budget. vi. Cereal based foods form the major part of the diet which are supported by food legumes or leafy vegetables as complementary items.

Considering recommended intake of major food components (ICMR, 1984), national level availability of the commodity, general consumption pattern, price of food materials available through Government food supply system and rates in open market and social aspects, the nutritive food materials readily available at affordable price were selected. The quantities of different items were restricted to different levels (Table 2) to get 50 per cent of total protein requirement from legume source, to avoid abnormally higher allocation of the cheapest components and to have optimized allocations of all the desired food components. Nutritive values of selected food materials reported by Gopalan et al. (1981) were adopted for model.

**The LP Model**

A linear programming model was developed for formulating the least-cost nutritionally sound diet which can render 50 per cent of the protein requirement from food legume. The definition of variables used for the model are specified (Table 2). Thus, the objective function was as follows:

$$\text{Minimise } Z = \sum_{i=1}^{8} C_i X_i$$

where,
$C_i$ = Cost coefficient of $X_i$

The cereal component of the diet was not considered as a constraint in the model. The objective was to be met under the following constraints.

(a) Protein constraint

$$\sum_{i=1}^{8} P_i X_i \geq PT$$

where,
$P_i$ = Amount of protein available from $X_i$
PT = Total protein requirement

(b) Calorie constraint

$$\sum_{i=1}^{8} A_i X_i \geq CA$$

where,
$A_i$ = Amount of calories available from $X_i$
CA = Total calorie requirement

(c) Food legumes

$$FX_1 = FR$$

where,
F = Food legumes (Soybean, Bengal gram, Pigeon pea). Only one to be taken for each set.
FR = Quantity of food legumes meeting 50 per cent of total protein requirement

(d) Leafy vegetables

(i) $LX_3 \geq LR$

(ii) $LX_3 \leq MR$

where,
L = Leafy vegetables (Spinach, Drumstick leaves, Rajagira leaves). Only one to be taken for each set.
LR = Minimum quantity of leafy vegetables
MR = Maximum quantity of leafy vegetable.

(e) Fat/oil constraint

$X_4 = FA$

where, FA = Quantity of restricted fat intake

(f) Milk constraint

$X_5 = MA$

where, MA = Quantity of restricted milk intake

(g) Sugar constraint

$X_6 = SA$

where, SA = Quantity of restricted sugar intake

(h) Tuber constraints

$X_7 = TA$

where, TA = Quantity of restricted tuber intake

(i) Other constraint

$X_8 = OA$

where,
OA = Quantity of restricted intake of chilli / turmeric powder.

The Linear programming problem was solved using Linear Interactive and Discrete Optimisation Package (LINDO) on IBM PC/AT.

## RESULTS AND DISCUSSION

Optimum combinations of food components of economical diets have been worked out using LP model for hard working rural family consisting of five members. Food legume component in the diet would provide 50 per cent of the total protein requirement to give maximum protein value.

**Optimal Food Combinations**

Using the criteria and restricted quantities of food items (Table 2) the resulting solutions were able to overcome excess allocation of the cheapest food component (Table 3). The quantities of cereals, legumes and leafy vegetables allocated are respectively in the range of 3000 - 3700, 289 - 601 and 360 - 1200 g/day for a reference family. These food combinations were found to satisfy, the minimum consumption levels of main diet components, recommended for hard working people (ICMR, 1984). Quantities of food legumes, to meet 50 per cent of protein, require consumption of 58 g soybean or 120 g of Bengal gram or 113 g of pigeon pea respectively, per

head per day. All LP suggested legume intakes except soybean appear almost impossible to consume daily. A significant conclusion may thus be drawn that soybean is the only food legume, which can meet in normal quantities, the criteria of maximizing protein quality in vegan diets. Though the LP solution gives 27 variations of balanced diets (Table 3), only nine with 289 g/day soybean for a reference family as food legume source and 360 - 1200 g/day leafy vegetables and 3300 - 3700 g/day cereals appeared to be the most practical solution to get the maximum protein value. These nine solutions give a choice of at least three combinations in each cereal and provide practicable variation for making the diet more varied and convenient. However, normally, the adoption of an optimized diet suggested through LP with combination of one legume - cereal and vegetable becomes impracticable due to its monotonous nature. Athough all the 27 optimized diet combinations meet the protein and energy requirements fully, only nine solutions with soybean were found to be practical due to allocation of consumable quantity of food legume.

**RDA fulfilment**

Protein and energy malnutrition underlines the major need for attending nutritional problems in developing countries, yet it is imperative to look into the significance of fat, vitamins, minerals and essential amino acids. Proper selection of food components is necessary to meet these requirements (RDA) without unduly increasing the food budget. The typical 27 food combinations obtained through LP model showed the RDA satisfaction levels in per cent as 149 - 250 for protein, 51 - 110 for fat, 134 - 362 for iron and 143 - 1158 for vitamin-A. Inclusion of soybean gives maximum protein, fat, iron and vitamin-A at minimum daily food resource cost lower than a dollor (Table 3). Higher level supply of protein, fat, iron and vitamin-A leaves enough scope to cope with greater protein needs of children. They have smaller stomach capacity, require relatively higher protein intake than adults but are not normally provided with specially prepared food in socioeconomically poor segment. The projected levels of RDA fulfilment expressed as percentage for soybased diets ranged from 157 - 250 for protein, 76 - 110 for fat, 134 - 500 for iron, 146 - 1160 for Vitamin-A and for lysine 84 - 114. In case of other minerals, vitamins and essential amino acids, a good satisfaction level is indicated for almost all sets (Table 4). Moreover, all the suggested combinations provide in abundance, the nutrients which are not readily available to the poor. The related deficiency diseases and health problems can thus be avoided. These facts delineate the scope of an economical diet which can provide enough quantity of vitamin-A to avoid blindness, iron to avoid iron deficiency and protein and energy for proper nourishment. These soybased diets may go a long way in preventing the diseases caused due to malnutrition. Practical verification of recommendations would ensure the validity of such attempts for use in future food planning.

**Food Resource Cost**

The daily diet cost ranged from US$ 0.60 to 1.10 for 27 different nutritionally balanced combinations for each of the four sets appear to be highly reasonable (Table 3). The lower expenditure required to be incurred per day leaves enough scope to accommodate the seasonal price hikes. Moreover, the cost range obtained is valid for the regions where rice, sorghum and wheat form a major cereal option in the diets. Based on the preference of cereal, people of a particular region may derive a cost advantage. Recommendations of the model are expected to remain relatively unchanged with the increase in prices of variables other than cereals, food legumes and leafy vegetables. Results show that rice based combinations are costlier than wheat or sorghum for any given food legume. Fat, the costly constituent of diet is most scarce to the poor, in the Indian context. Although, combinations generally satisfy 51 to 101 per cent of fat requirement, soy based combinations provide 13 to 25 per cent more fat compared to Bengal gram and pigeon pea diets. This would mean a considerable saving for a reference family. Overall the soybean based diets are found to be the cheapest, adequately nutritious and practicable to consume compared to other optimized food combinations for getting 50 per cent of protein requirement through food legumes.

## CONCLUSIONS

The study showed that for hard working rural poor all the 27 combinations suggested through LP model provide

100 per cent requirement of calorie, 149 - 250 per cent for protein and 50 to 101 per cent of fat when food legumes contribute 50 per cent of total protein requirement. Besides these, requirement of micronutrients like vitamin - A and iron are abundantly met and that of others are adequately met. Out of 27 food combinations, only nine soybased ones meet the criteria of providing 50 per cent of required protein from food legume in a managable quantity one can consume daily. These nine contributions provide a variety of diets with maximum nutrition at comparatively lower cost and improved chances of adoption. Even if the prices are doubled, none of the dietary combinations exceed the food budget of a hard working individual or family. The approach and solutions appear to be feasible for attending the nutritional needs of poor and useful in future food planning based on locally available food resources in developing countries.

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Table 1. Recommended dietary intake and total requirement of nutritional components for a hard working family of five members

(ICMR, 1984)

| | | | | | | |
|---|---|---|---|---|---|---|
| A. Family breakup -> | Male | Male | Female | Male | Female | 5 |
| Age, yr -> | 60+ | 40+ | 40- | 15+ | 15- | .. |
| Work load ---> | Moderate | Heavy | Heavy | Heavy | Heavy | .. |
| B. Food component ↓ | | | | | | |
| Protein, g | 55.0 | 55.0 | 45.0 | 51.7 | 43.3 | 250.0 |
| Calorie, Kcal | 2800.0 | 3900.0 | 3000.0 | 2660.0 | 2360.0 | 14720.0 |
| Fat/oil, g | 38.0 | 38.0 | 38.0 | 38.0 | 38.0 | 190.0 |
| Minerals | | | | | | |
| Calcium, mg | 500.0 | 500.0 | 500.0 | 700.0 | 700.0 | 2900.0 |
| Iron, mg | 24.0 | 24.0 | 32.0 | 25.0 | 35.0 | 140.0 |
| Vitamines | | | | | | |
| Vitamin-A, ug | 3000.0 | 3000.0 | 3000.0 | 3000.0 | 3000.0 | 15000.0 |
| Thiamine, mg | 1.4 | 2.0 | 1.5 | 1.3 | 1.2 | 7.4 |
| Riboflavin, mg | 1.7 | 2.3 | 1.8 | 1.6 | 1.4 | 8.8 |
| Niacin, mg | 19.0 | 26.0 | 20.0 | 18.0 | 15.0 | 98.0 |
| Vitamin-C mg | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 200.0 |

Table 2. Quantities and prices of food stuffs fixed for optimization

| Variable | Definition | Quantity, g/day | Price, Rs./kg |
|---|---|---|---|
| $X_1$ | Food legumes | | |
| | Soybean | = 289 | 10.00 |
| | Bengal gram | = 601 | 10.00 |
| | Pigeon pea | = 561 | 17.00** |
| $X_2$ | Cereals | | |
| | Rice | * | 5.00** |
| | Wheat | * | 4.00** |
| | Sorghum | * | 3.00** |
| $X_3$ | Leafy vegetables | | |
| | Spinach | 360-1200* | 2.00 |
| | Drumstick leaves | 360-1200* | 0.50 |
| | Rajagira leaves | 360-1200* | 0.50 |
| | Others | | |
| $X_4$ | Fat/oil | 55 | 30.00** |
| $X_5$ | Milk | 250 | 8.00** |
| $X_6$ | Sugar | 50 | 8.00 |
| $X_7$ | Tubers | | |
| | onion | 75 | 3.00 |
| | Potato | - | 3.00 |
| $X_8$ | Chilly/turmeric | 30 | 30.00 |

* Open for optimization, ** Through ration shop and open market

Table 3. Optimised food combinations, their quantities(*) and costs

| | Rice | | | Wheat | | | Sorghum | | |
|---|---|---|---|---|---|---|---|---|---|
| | SP | DR | RA | SP | DR | RA | SP | DR | RA |
| Soybean | | | | | | | | | |
| Legume | 289 | 289 | 289 | 289 | 289 | 289 | 289 | 289 | 289 |
| Cereal | 3612 | 3320 | 3407 | 3655 | 3359 | 3445 | 3571 | 3282 | 3368 |
| L.veg. | 360 | 1200 | 1200 | 360 | 1200 | 1200 | 360 | 1200 | 1200 |
| Bengal gram | | | | | | | | | |
| Legume | 601 | 601 | 601 | 601 | 601 | 601 | 601 | 601 | 601 |
| Cereal | 3327 | 3034 | 3121 | 3366 | 3069 | 3157 | 3289 | 2999 | 3085 |
| L.veg. | 360 | 1200 | 1200 | 360 | 1200 | 1200 | 360 | 1200 | 1200 |
| Pigeon pea | | | | | | | | | |
| Legume | 561 | 561 | 561 | 561 | 561 | 561 | 561 | 561 | 561 |
| Cereal | 3430 | 3137 | 3224 | 3470 | 3174 | 3262 | 3391 | 3101 | 3187 |
| L.veg. | 360 | 1200 | 1200 | 360 | 1200 | 1200 | 360 | 1200 | 1200 |
| Raw material cost US$ | | | | | | | | | |
| Soybean | 0.90 | 0.84 | 0.86 | 0.78 | 0.74 | 0.75 | 0.65 | 0.62 | 0.63 |
| Bengal gram | 0.95 | 0.90 | 0.91 | 0.85 | 0.80 | 0.81 | 0.73 | 0.69 | 0.70 |
| Pigeon pea | 1.08 | 1.03 | 1.05 | 0.98 | 0.93 | 0.95 | 0.85 | 0.82 | 0.83 |

* Food materials Leafy vegetables :- SP : Spinach, DR : Drumstick leaves, RA : Rajagira leaves. * Quantities(g/day) of other food items fixed (Table 2).

Table 4. Nutrition satisfaction level (per cent of RDA met) for optimised food combinations(*) of food legumes(pulses), cereals and leafy vegetables determined by LP model (50 per cent protein from legume source)

| Combination) → | Soybean + RISP | RIDR | RIRA | WHSP | WHDR | WHRA | SOSP | SODR | SORA |
|---|---|---|---|---|---|---|---|---|---|
| Protein | 157 | 178 | 177 | 235 | 250 | 251 | 207 | 224 | 224 |
| Calorie | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 |
| Fat | 76 | 85 | 80 | 99 | 106 | 100 | 102 | 109 | 105 |
| MINERALS | | | | | | | | | |
| Calcium | 59 | 231 | 268 | 107 | 275 | 313 | 77 | 247 | 285 |
| Iron | 134 | 159 | 259 | 354 | 362 | 467 | 202 | 222 | 323 |
| VITAMINS | | | | | | | | | |
| Vitamin A | 146 | 554 | 1147 | 153 | 561 | 1154 | 157 | 565 | 1158 |
| Thiamine | 65 | 71 | 64 | 278 | 267 | 264 | 214 | 208 | 204 |
| Riboflavin | 55 | 49 | 76 | 101 | 91 | 119 | 83 | 75 | 102 |
| Niacin | 85 | 87 | 92 | 175 | 170 | 177 | 128 | 126 | 133 |
| Vitamin C | 60 | 1330 | 496 | 60 | 1330 | 496 | 60 | 1330 | 496 |
| AMINO ACIDS | | | | | | | | | |
| Isoleucine | 117 | 115 | 116 | 93 | 95 | 95 | 108 | 108 | 108 |
| Leusine | 165 | 163 | 160 | 143 | 144 | 141 | 257 | 241 | 245 |
| Lysine | 112 | 114 | 110 | 87 | 92 | 88 | 84 | 90 | 85 |
| Methionine | 92 | 89 | 87 | 65 | 67 | 63 | 70 | 71 | 68 |
| Cystine | 35 | 38 | 33 | 49 | 49 | 47 | 35 | 37 | 33 |
| Phen. | 165 | 165 | 157 | 163 | 163 | 158 | 172 | 171 | 165 |
| Tyrosine | 151 | 122 | 145 | 108 | 94 | 108 | 109 | 93 | 108 |
| Tryptophan | 54 | 56 | 53 | 49 | 51 | 48 | 49 | 52 | 49 |
| Valine | 137 | 136 | 133 | 111 | 114 | 110 | 128 | 129 | 126 |
| Threonine | 134 | 136 | 128 | 112 | 116 | 109 | 125 | 128 | 121 |
| CostUS$. | 0.90 | 0.84 | 0.86 | 0.78 | 0.74 | 0.75 | 0.65 | 0.62 | 0.63 |

| Combination) → | Bengal gram + RISP | RIDR | RIRA | WHSP | WHDR | WHRA | SOSP | SODR | SORA |
|---|---|---|---|---|---|---|---|---|---|
| Protein | 149 | 170 | 169 | 221 | 236 | 237 | 195 | 213 | 212 |
| Calorie | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 |
| Fat | 63 | 72 | 68 | 85 | 91 | 88 | 87 | 94 | 90 |
| MINERALS | | | | | | | | | |
| Calcium | 45 | 217 | 255 | 90 | 258 | 296 | 62 | 233 | 271 |
| Iron | 143 | 168 | 268 | 345 | 353 | 458 | 205 | 225 | 326 |
| VITAMINS | | | | | | | | | |
| Vitamin A | 143 | 551 | 1144 | 149 | 557 | 1150 | 153 | 561 | 1154 |
| Thiamine | 73 | 79 | 72 | 269 | 258 | 256 | 211 | 205 | 201 |
| Riboflavin | 53 | 47 | 73 | 95 | 85 | 113 | 78 | 70 | 98 |
| Niacin | 84 | 87 | 92 | 168 | 162 | 170 | 124 | 123 | 129 |
| Vitamin C | 63 | 1333 | 499 | 63 | 1333 | 499 | 63 | 1333 | 499 |
| AMINO ACIDS | | | | | | | | | |
| Isoleucine | 120 | 118 | 119 | 97 | 99 | 98 | 111 | 111 | 111 |
| Leusine | 167 | 165 | 162 | 146 | 147 | 144 | 253 | 237 | 241 |
| Lysine | 115 | 117 | 113 | 90 | 95 | 91 | 88 | 94 | 89 |
| Methionine | 92 | 90 | 87 | 66 | 68 | 65 | 71 | 73 | 69 |
| Cystine | 32 | 36 | 30 | 47 | 47 | 44 | 33 | 35 | 31 |
| Phen. | 167 | 167 | 160 | 165 | 165 | 160 | 13 | 172 | 167 |
| Tyrosine | 134 | 107 | 129 | 99 | 84 | 98 | 98 | 83 | 98 |
| Tryptophan | 51 | 54 | 50 | 47 | 50 | 47 | 47 | 50 | 47 |
| Valine | 135 | 134 | 131 | 111 | 114 | 110 | 127 | 127 | 125 |
| Threonine | 130 | 132 | 124 | 110 | 115 | 107 | 123 | 125 | 118 |
| CostUS$. | 0.95 | 0.90 | 0.91 | 0.85 | 0.80 | 0.81 | 0.73 | 0.69 | 0.70 |

| Combination) → | Pigeon pea + RISP | RIDR | RIRA | WHSP | WHDR | WHRA | SOSP | SODR | SORA |
|---|---|---|---|---|---|---|---|---|---|
| Protein | 152 | 173 | 172 | 227 | 241 | 242 | 200 | 217 | 217 |
| Calorie | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 |
| Fat | 51 | 59 | 55 | 73 | 80 | 76 | 76 | 82 | 79 |
| MINERALS | | | | | | | | | |
| Calcium | 48 | 220 | 258 | 94 | 262 | 301 | 66 | 236 | 274 |
| Iron | 129 | 155 | 254 | 338 | 346 | 451 | 194 | 214 | 315 |
| VITAMINS | | | | | | | | | |
| Vitamin A | 143 | 551 | 1144 | 149 | 557 | 1150 | 153 | 561 | 1154 |
| Thiamine | 69 | 75 | 68 | 271 | 260 | 258 | 211 | 205 | 201 |
| Riboflavin | 53 | 47 | 74 | 97 | 87 | 115 | 80 | 72 | 99 |
| Niacin | 88 | 90 | 96 | 174 | 169 | 176 | 129 | 128 | 134 |
| Vitamin C | 60 | 1330 | 496 | 60 | 1330 | 496 | 60 | 1330 | 496 |
| AMINO ACIDS | | | | | | | | | |
| Isoleucine | 108 | 107 | 108 | 87 | 90 | 89 | 101 | 102 | 102 |
| Leusine | 162 | 160 | 157 | 141 | 143 | 139 | 253 | 237 | 241 |
| Lysine | 123 | 124 | 120 | 95 | 99 | 95 | 93 | 98 | 94 |
| Methionine | 87 | 85 | 82 | 61 | 64 | 60 | 66 | 68 | 64 |
| Cystine | 30 | 34 | 28 | 46 | 46 | 43 | 31 | 34 | 29 |
| Phen. | 195 | 192 | 186 | 184 | 183 | 178 | 195 | 192 | 187 |
| Tyrosine | 135 | 108 | 130 | 98 | 84 | 98 | 98 | 82 | 97 |
| Tryptophan | 45 | 48 | 44 | 43 | 45 | 43 | 42 | 45 | 42 |
| Valine | 129 | 129 | 126 | 106 | 109 | 106 | 122 | 123 | 120 |
| Threonine | 127 | 129 | 120 | 107 | 111 | 104 | 120 | 123 | 115 |
| CostUS$. | 1.08 | 1.03 | 1.05 | 0.98 | 0.93 | 0.95 | 0.85 | 0.82 | 0.83 |

Recommended Dietary Allowances (RDA) for reference family of five persons: Protein(250g), Calorie(14720Kcal), Fat(190g), MINERALS Calcium(2.9g), Iron(140mg), VITAMINS Vit.A(15mg), Thiamine(7.4mg), Riboflavin(8.8mg), Niacin(98mg), Vit.C(200mg). AMINO ACIDS, g/16gN Isoleucine(4.2), Leusine(4.8), Lysine(4.2), Methionine(2.2), Cystine(4.2), Phenylalanine(2.8), Tyrosine(2.8), Tryptophan(2.4), Valine(4.2), Threonine(2.8).

* Food materials Cereals :- Ri : Rice, WH : Wheat, SO : Sorghum. Leafy vegetables :- SP : Spinach, DR : Drumstick leaves, RA : Rajagira leaves and other food materials.