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◇ Review ◇

The Constitution of Dietary Protein and Their Nutritional Effect in Korea

by

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韓國에 있어서 食餌蛋白質의 構成과 그 營養效果에 關하여

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Abstract

According to the intercombined review of chemical and biological investigation it has been noted that the metabolizable energy per gram dietary protein of mixed diet of daily intake patterned by Korean population has been found 3.4-3.6 Cal., which entails 10—12% level of the protein calorie percentage of total metabolizable energy, the biological value being fallen within the scope 63—73. The structure of dietary protein has revealed that the lysine and isoleucine were primary limiting amino acids and threonine secondary limiting as a general trend, however, it is assumed that the ultimate nutritional effect of dietary protein might be restricted uniformly among regions by the amount of lysine, since the lysine availability has been yielded as low as 72—82% level.

As for the net protein utillization NPUst falls in the range of 52—62 and the NPUop 47—58. In either part the mountainous region has demonstrated lowest value and the urban area highest, these trend being obviously associated with the ratio of animal protein relative to the vegetable origin.

The net dietary protein calorie percentage (NDpCal %) has been found within the range of 5—7 that may be capable of meeting the requirement for the maintenance of adult, though for the growth it is insufficient.

Present level of total caloric intake would not influence on the fate of protein value of prevailing regional diet in terms of caloric restriction, since the present intake of food energy is higher than the lower limit of caloric intake that would impair the biological performance of dietary protein fed ad libitum basis. Based on the protein efficiency, the adequacy of current level of protein inta-

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ke was analyzed in terms of utilizable protein, and it has been demonstrated that the 37.8g of utilizable protein in the fishery region and 38.2g in the mountainous region were bellow the FAO recommendation.

Accordin to the hematological study it may be interpreted that the anemic symptoms of the mountainous region has some possibility of being related to the inferior status of dietary protein in quality as well as in quantity.

1. Introduction

It is generally understood that the predominant use of cereals as staple food in Korea may apparently bring the problem of unbalanced nutrition among the populations. In this respect the foremost importance is on the practical evaluation of metabolizable food energy value and other relevant nutritional factors in the prevailling dietary pattern of local acceptance as well as of country-wide basis.

Of these the evaluation of protein value of diet in terms of elemental quality per se and practical nutritional value at such conditions as is influenced by the eating pattern and environment, and taking measures to improve the protein nutrition in the dietary regimen, is of critical importance in view of the growing evidence that there would be possible thread of protein crisis in some area on vulnerable situation according to the ever increasing magnitude of food demands.

In the evaluating of protein quality and nutritional value of dietary protein, it has been revealed that the chemistry would not always provide the knowledge on potential quality of protein and the biology, likewise, would not always be a sensible medium of detecting protein value. The empirical evidence has indicated that there were rather complex association between the data of chemical analysis and biological factors.[1]

There were numerous trials to observe the real value of food proteins, specially, the dietary protein of mixed daily diet has drawn a focus of attention on the part of utilizable ratio in the physiological channels.[2]-[9]

Sugimura(1970)[10]-[17] has given a comprchensive reviews on the plasma amino acid levels and other physiological behavior of amino acid in the body in an effort to observe the possibilities of being used as a yardstick for evaluating nutritional value of protein ingested; Payne (1958),[18] Miller et al (1961),[19] Cresta et al (1969)[20] and other numerous workers have contributed to the prediction of biological efficiency of proteins with chemical analysis.[21]-[30] It has been revealed, however, that the amino acid pattern itself may not always be a valid criteria on the measuring nutritional value of protein. In the practical nutrition the nutritive value of protein is a function of integrated total performance of component proteins in mixed diet derived by such intercombined effect as quantity, quality, concentration, daily intake and physiological and environmental conditions.

Autret et al (1968)[31] reported the results of extensive observations of protein value of different types of diet in the world. Ogawa et al (1958)[32] observed the biological performance of thinthetic mixed diet corresponding to the principal nutrients of the dietary pattern that has been observed by actual survey of several local places, and Morita et al (1961)[33] reported the essential amino acid intake in Japanese fishing villages. In a comparison of results obtained for protein value of U.K. diets using chemical and biological method, Drury et al (1959)[34] reported that, although the diets are ranked in a similar order, the chemical method gives higher value than the biological method, and it is considered that this is chiefly due to the inverse relationship between biological value and level of protein in the diet, e.g. even Reference Protein would not be completely utilized for anabolism in diet containing more than 4% protein. Narasinga et al (1969)[35] have given some recommendation for the increased supply of calories rather than the protein itself according to the evidence shown by their actual survey in India.

Author has hereon tried to evaluate practical potency of nutritional value of dietetary protein of Korean diet through the combined detection by chemical and biological procedure that might be expected to give an associated significance in conjunction. In an attempt to judge the realistic value of food proteins as eaten by populations which could be assumed appreciable deviation from the theoretical figures, the actual survey data of food consumption obtained by the Ministry of Health and Social Affairs[50] has been cited in this work as a standard of sample diet preparation. And this work is largely based on the previous author's work done at the Tokyo University of Agriculture in 1975. [78]

2. Metabolizable Food Energy of Regional Intake

It is known that the metabolizable food energy is the product of gross energy value(combustion energy) and absorption ratio. The method of determination of energy value has been developed through historical progress with numerous trials.[37]-[44] The absorption ratio of the protein and fat in this work was determined by rat experiments and that of carbohydrate was derived from Atwater's recommendation.[36]

At the estination of metabolizable protein energy, the energy of unmetabolized urinary sustances, 1.25 Cal/grm of protein was taken into account.

The potential energy of organic acid[46] and alcohol [46] has not been incorporated in this work.

The data of metabolizable energy of diets as representative to the regional dietary pattern are given in Talbe 1. Figures are shown as determined with the dried mixture.

It has been observed that the metabolizable food energgy value as determined with Korean diet demonstrated significant deviation from the Atwater's calculation. This differences may be mainly attributed to the lower digestibility of food.

Table 1. Energy value of representative diet(dried preparation)

Items	Urb.	Agri.	Fish.	Mount.	C'wide
Moisture(%)	6.28	6.36	6.25	6.22	6.32
Nitrogen(%)	1.64	1.92	1.80	1.45	1.80
Protein (% N×6.25)	10.24	12.02	11.21	9.07	11.33
-Digestibility	85.4	83.5	82.6	83.0	84.0
-M.E. (a)/g	3.58	3.47	3.42	3.44	3.50
-M.E./100g food	36.7	41.7	38.3	31.2	39.7
(Atwater's value)	(41.0)	(48.1)	(44.8)	(36.3)	(45.3)
Total metabolizable calorie	309.9	367.4	325.5	303.9	355.2
Protein Cal%	11.84	11.35	11.77	10.27	11.18

(a) M.E.=Metabolizable energy

3. Chemical and Biological Factors of Dietary Protein at Each Regional Intake

a. Amino acid composition of regional diet and availability of lysine.

The chemical scores were found varied magnitude among regions ranging 58-67, the limiting amino acid being primarily lysine or isoleucine.

The threonine and total sulfur containing acid are also important factors receiving attention in Korean diet, since these amino acids are located closely to the limiting position. Therefore when an effective program of improving protein quality is to be formulated, these amino acids must be born in mind so as not to be limiting immediately after primary or secondary limiting amino acids have been supplemented.

The lysine availability representing available percentage of total lysine were ranging from 72 to 82. This relative low value of lysine availability may be mostly due to the structure of the foods, cooking procedure and preserving conditions. It is generally accepted that a part of the lysine in foods can be turned out unavailable by reactions of the free ε-NH_2 group

with reactive components of the food, i.e. with aldehydes as in the case of maillard reaction.

In respect to the lowest yield of available lysine in fishery region diet, there has been no sufficient evidence to allow precise conclusion to be drawn except attributing it to the autoxidized fish and the empirical evidence obtained through the experiment of Carpenter et al (1957).[47] They observed that the heat damage of total lysine of fish fillets amounted 11% being accompanied by losses in available lysine as much as 40%.

b. Net Protein Utilization (NPU)

NPU representing the proportion of food nitrogen retained and expressed in a single index both the digestibility of protein and the biological value of the amino acid mixture absorbed from the intestine, has been investigated according to the method of rat experiments recommended by Miller and Bender(1955).[48]

If the measurement is made under standardized conditions, with the protein intake at or below maintenance levels, the value is termed "NPU standardized" (NPUst),[49] values determined under any other conditions have been termed "NPU operative" (NPUop). These two different expressions are based on the endeavours to make one recognize that in the process of protein evaluation of diet, a distinction has to be made between protein quality which is an attribute of the protein per se and the efficiency of utilization which is dependent both on the quality of the protein and the conditions under which it is eaten.

The results of rat experiment for NPU assay carried out on the five different test diets are given in Table 2. The urban area diet was found highest in NPU, as expected from the dietary pattern. in which animal origin has been incorporated at the level of second highest preceded by the fishery region, whereas the NPU of moutainous region has demonstrated lowest.

The relatively low value for NPU in fishery region where the highest incorporation of animal origin was observed, may be attributed to the low value for lysine availability.

Table 2. NPU of Korean Diet

Classification	Urb.	Agri.	Fish.	Mount.	C-wide	Remarks
NPUst	62	56	53	52	59	35.7** 5.99=F0.01
NPUop	58	48	47	49	53	16.9** 5.99=F0.01

The NPUop, is of paramount importance in the practical evaluation of dietary protein. In this connection FAO (1965)[51] recommended that the protein should be supplied in varied amouts according to the value for NPUop of protein; if the protein has NPUop 50 the amount needed is necessarily doubled the amount of NPUop 100.

Platter & Miller (1959)[52] has termed the product of NPUop X protein content (food N X 6.25) NDpV (Net dietary protein value). This term represesents utilizable protein in the mixture and is a function of both quality and quantity.

Judging from the Korean regional diet in this connection, in urban area, the daily intake of protein is 79.5g and this figure has yielded 46.1g of utilizable protein (NDpV). This amount is slightly exceeded the safety level recommended by FAO.

Illustrating another sample, the mountainous region has had the protein intake per day 78.0g wherefrom the utilizable protein has been yielded as low as 38.2g which ranks apparently below the safety line.

In an attempt to find out the method of predicting NPUop from the chemical data or from the NPUst, author has tried to compare the value observed by biological experiment with the data calculated by Miller & Payne[19] method and the device of Morrison et al (1963)[53]

It was noted that the value obtained by Miller & Payne formula based on the chemical score has given some deviation from those observed by biological experiment. It has been demonstrated, however, that the NPUop of Miller & Payne based on the NPUst show well agreement with those observed, the value of Morrison et al being characterized by showing no distinction among regions as a whole.

4. Factors Affecting on the Protein Nutrition and the Analysis of Protein Intake Adequacy

a. NDpCal % (Net dietary protein calorie %)

The NDpCal % was estimated according to the method suggested by Platt et al (1961)[54] and can be expressed as the percentage of calories derived from protein, corrected for efficiency of protein utilization.

$$\text{NDpCal } \% = \frac{\text{Protein Calories}}{\text{Total metabolizable Calories}} \times \text{NPUop} \times 100$$

This figure represents the efficiency and concentration of dietary protein in conjunction, and shows the magnitude of total utilizable protein in the diet in terms of metabolizable energy.

It has been recently reviewed that the protein calorie deficiency occurs at all ages but incidence is greatest in the weaning and immediate post-weaning periods; deprived of high quality protein food, the child is not old enough to fend for himself in the family circle and is particularly subject to dietary taboos and prejudices. These findings are of value receiving attention, particularly, in Korea, though any serious syndromes of Kwashiorkor or Marasmus which are principal attribute of protein deficiency have not been observed so much as Scrimshaw (1956)[55] has pointed out through his extensive survey of underdeveloped parts of the world, in view of the fact that the NDpCal % of regional diets may be considered insufficient for the children and adolescent, for the maintenance of adult, though, being satisfied.

In evaluating the general picture of NDpCal % of regions, it may be important to consider that the NDpCal % is a fixed value of given diet; that is to say, unless otherwise there is a specific recipe for children or lactating women, the ad libitum diet will always provide lower value of NDpCal % than the requirement.

In Korea it is still a pending problem that for majority of people the specially prepared baby food or nutritious recipe for lactating wamen or adolescent would scarecely be available. The NDpCal %, in consequence, may yield sam value for all of those who are eating in same table:the children, adolescent, male and female, old and young are mostly in same dietary condition in practical sense.

b. Influence of caloric intake on the protein value of regional diets

In has been generally known that protein malnutrition in man is frequently associated with the shortage of metabolizable caloric intakes. This is based on the physiological evidence that the energy requirement are always satisfied preferentially to protein requirement.

Under conditions of caloric restriction, the protein value of diet will be the product of energy available for protein anabolism rather than that of known factors as protein concentration and internal quality potential.

Miller and Payne (1961)[56] has reported that in any given diet there is a range of food intakes over which NDpCal% is constant and below which it falls with the caloric intake, and recommended following formulas for the estimation of protein value when fed insufficient calorie of the diet:

$$\text{NDpCal } \% = \frac{100}{E}\left(1 - \frac{Cb}{C}\right) \quad \cdots\cdots(A)$$

where E is the calories required for the synthesis of 1 Cal of protein, C the caloric intake and Cb calories required for basal metabolism. According to the empirical evidence the requirement of Cb is 70 Cal per day per kg of body weight to the power of 0.73, and E is for 6. Thus, above equation is simplified as:

$$\text{NDpCal } \% = \frac{100}{6}\left(1 - \frac{70W^{0.73}}{C}\right) = 17 - \frac{1190W^{0.73}}{C} \quad \cdots\cdots(B)$$

where W is the body weight.

In this connection author has tried to utilize equation (B) in finding out the lower limit of caloric intakes of each region, below which the NDpCal% falls with the caloric intake and over which it is constant.

Into the equation (B) 60kg of body weight which is the weight of Korean reference man is inserted so as to replace W with 60, and taking NDpCal % as Y bar against the caloric intake X. the curvilinear equation is, thus,

$$Y = 17 - \frac{1190\ (60^{0.73})}{X} \quad \cdots\cdots(C)$$

The curvature of this equation is shown in Fig. 1.

Marking the value of respective NDpCal % obtained by preceding biological assay on ad libitum basis on the curvature, the lower limit of caloric intake can be read off at a glance.

Illustrating the urban area diet, Y value (NDpCal %) is taken for 6.9 as previously obtained by rat experiment, and it is possible to read out the relative X value at this point, i.e. 2,341 Cal, the limiting caloric intake per day at this NDpCal %.

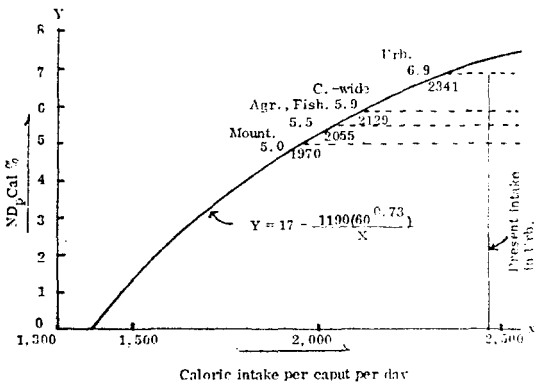

Fig. 1. Influence of caloric restriction on the protein value of each region

According to the evaluation in this way, the general view of the possible influence of caloric intake on the protein value can be expressed as; in all regions the present caloric intakes of adults are not fallen in the range of caloric-restricted situation that may influence on the fate of respective protein value in the diets.

Finally it may be concluded that in the estimation of protein value of each region, the NDpCal % obtained by feeding ad libitum, 6.9 for urban area, 5.5 for agricultural and fishery region, 5.0 for mountainous region and 5.9 for country-wide average, were not injured by present caloric intake.

c. Analysis of protein intake adequacy

In the evaluating of the adequacy of protein intake, the primary factor to be considered is the estimation of protein requirements for intake groups. The estimation of protein requirements, however, may not be done in a simple process in view of the fact that human beings need in their food many different types of nutrient, and defficiency states, as they occur in practice, are usually multiple in origin.

In fact it has been well recognized that previous estimates of the incidence of protein deficiency were only based on the simple criterion of whether the diet fulfilled an accepted requirement for protein, regardless of other relevant factors.[57-59] If it may be shown that a large proportion of the incidence of protein deficiency is an indirect result of low energy intake, any policy to close the protein gap by laying great emphasis on the production and use of effective protein sources regardless of the energy content will need to be critically reviewed.

It is general view that, as for the figures pertaining to adult, the protein intakes will meet or exceed the requirement as a whole if the given caloric requirement[60] were fulfilled, and at present the agriculture, fishery and mountainous region are somewhat below the required level and, particularly, in mountainous region the protein quality is also not satisfactory; the NDpCal % of this region has been yielded only 5.0.

In most cases for the adults, in cereal eating regions, the protein malnutrition has not been so serious, since the problem on the protein nutrition in adults may be connected mainly to the amount of protein rather than the quality itself. In fact for the adults, unlike children, the protein requirement for the normal health is only dependent on the magnitude of obligatory losses of nitrogen according to the physiological process for the living activities. This obligatory losses of nitrogen involves the loss in faces, cutaneous and urinery excretion.

In Korean diet the evaluation of protein nutrition of children and adolescent is more important than that of adults, particularly because, in the vulnerable groups of social level the quality of protein of children's diet is likely to be inferior because of lack of variety acceptable for the children's preference.

In the analysis of protein intake adequacy, the nutritional status of the population must be interpreted in conjunction with the dietary intakes.

It would be general principle that uncomplicated protein deficiency probably never occurs in man. The disease syndrome of kwashiorkor first described by Williams (1933)[61] is believed to be due primarily to protein deficiency but it occurs to varying degrees in conjunction with other factors. For this reason the present trend is to speak of protein-calorie malnutrition

rather than kwashiorkor or marasmus.[62]

In Korea no serious clinical symptoms of disease caused by protein malnutrition have been observed. There are, however, some questions that is needed receiving careful attention, e.g. in the mountainous region it has been revealed that the statue in growing or maturing stage of the population groups is inferior to that in urban area. It could be assumed that the latent or subcl inical incidence of protein malnutrition might have already been started in this area, as is hypothesized from the lowest value of utilizable protein, and the predominant frequency of t e incidence of anemia would acertain above fact, even though it is taken into account that, as a whole, the animea may be partly caused by parasites.

5. Possible Range of Improvement of Protein Quality and its Utilizable Value

Fig. 2-3 indicate the improvement of protein value by supplementing regional diet with the effective protein sources. For the effective protein sources pork and soybean were selected in view of their popularity in Korea.

NPUop in Fig. 2-3 were gained by Miller & Payne method[19] with chemical score basis, though this method would yield appreciable deviation from the observed value as has been indicated. The general view of comparative value among regional diets obtained by Miller & Payne method, however, is considered

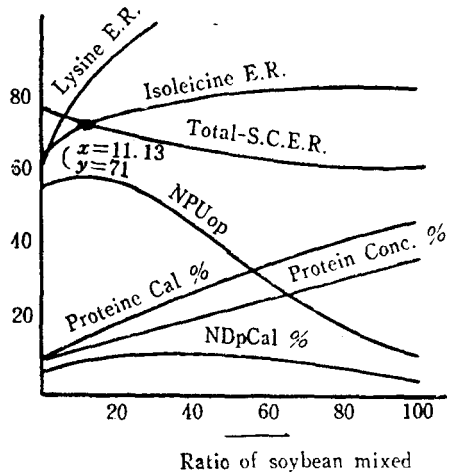

Fig. 2. Change of protein value by supplementing mountainous region diet with soybean

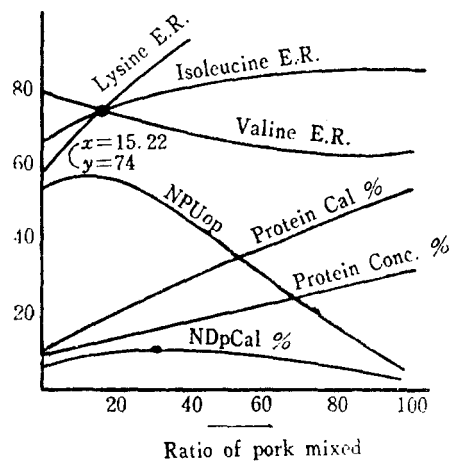

Fig. 3. Change of protein value by supplementing mountainous region diet with pork

available in approximating the practical value of dietary protein. Particularly, in the urban area and country-wide average diet the Miller and Payne value is almost identical to the observed value.

The NPUop values obtained were curved mode with negative slope; as the pork supplement is increased the NPUop is, reversely, decreased. This views are well known fact that the net protein utilization is generally decreased by the increase in protein concentration. In this respect Mitchell and Barnes et al[63,64] have observed the effect of different protein concentration in the diet on the biological value, though has not been thoroughly explored in quantitative aspects of this concept. Forbes et al (1958), however, have reported the detailed data in terms of quantitative category through their comprehensive experiments with the subject of young albino rats.

The line of NDpCal % in Fig. 2-3 which represents both the amount of utilizable protein and quality of dietary protein itself is showing that by the supplement of pork to the base diet the NDpCal% is capable of being raised as much as the level of around 11.0. Thus, it may be quite feasible that the increase of NDpCal% is fully achieved in any required level by adjusting the amount of pork supplement into the base diet, and it may be concluded that 5—10% sup-

plementation with pork protein and 5—7% with soybean protein are in the range of satisfactory for the growth of toddler; for the adolescent, 8—13% with pork protein or 10—12% with soybean protein are necessary. Beyond these level only brings the unnecessary passage of nitrogen through physiological channel for energy purpose, and is uneconomical.

6. Hematological Corrobolation on the Effect of Protein Quality and Intercombination Between Protein Intake and Anemic Symptoms

Korean population have shown remarkable ratio of amemic symptoms, especially in the mountainous region, it has been revealed that as much as 23% of population above 20 years of age are being suffered from anemia.

This phenomenon so far has been interpreted as a heavy parasitic attack to population accelerated by the extensive use of uncooked vegetables according to traditional food habit in Korea, however, through numerous studies pertaining to causative factors of anemia[65)-72)] in essence it has come to understand that anemias come from diversified origin because anemia is a condition in which there is a reduction of the number or size of the red blood cells, or of the quantity of hemoglobin, or both. Accordingly, it results in a decreased ability of the blood to carry oxygen to the tissues.

In hematological sense anemias may be caused by blood loss, decreased production of blood, or by increased destruction of blood. Faulty nutrition either occasioned by failure to provide essential nutrients, such as iron and protein, or by poor utilization of dietary constituents may lead to anemia, the type being dependent upon the initiating defect.

In view of abundant intake of iron in Korea, the hemoglobin formation may not be hindered by the deficiency of iron itself, however, the fact that hemoglobin is a protein which is composed of an organic iron compound, heme, and the protein, globin, the latter being a sulfur-bearing protein which makes up 96 percent of the molecule and that the formation of hemoglobin is dependent principally on adequate dietary supplies of iron and of protein,[73,74] provides uncertainty whether the dietary intake of iron be fully utilized under the condition of protein intake in poor quality and insufficient amount as observed in mountainous region.

The experiment has been carried out to investigate blood indices in such a way as to compare the control rat groups fed with the mixture of dietary pattern of mountainous region with the rat groups fed by same diet plus additional protein sources of pork and soybean, so as to observe hematological abnormalities if any in the mountainous region diet as compared with the supplemental diet.

The supplemented diets subjected to this experiments were satisfactory in nutritional sense of protein in quantity as well as in quantity. And these supplemental diets were taken as the sustenance giving normal growth and maintenance.

According to the normal hematological state in rats so far has been described[75,76] the number of red blood cell is spread in fairly wide range of 8—10millions, nevertheless the rats are growing in normal state. If it is taken for 6 millions, the lower limit of forgoing data, the observed number of 4.8—5.5 millions in rat groups fed with mountainous region diet is slightly lower than normal, of which whether the conclusion could be drawn on the anemic state is debatable. It is obvious, however, that the red blood cell obtained in the mountainous region diet is significantly lower than that obtained in supplemented diet which demonstrated around 8 millions. If the pattern of 8 millions of erythrocytes is considered normal in these rat groups the findings of 4.8—5.5 millions in mountainous region diet are far bellow the standard, and it is highly probable that the insufficiency of protein in mountainous region diet could be a possible root to give some influence on iron metabolism or formation of globin protein.

As for the hemoglobin level the rat groups in unsupplemented diet have given 77—78% performance of the supplemented diet. Since it has been known that the hypochromic anemic state is beginning at 70% of normal in hemoglobin level[77] above ratings are not so pessimistic as being afraid of danger. However, it could be interpreted as a tangible result that the pro-

tein level and quality in mountainous region diet is not considered as well-rounded and satisfactory in nutritional aspect, and it may be concluded that the prolonged intake of this poor diet would bring the possible anemic state even though no outward syndrome has been demonstrated.

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