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Comparative Nutritional and Mineral Analysis of Raw and Processed Eggs from Local and Genetically Modified Birds in Plateau State, Nigeria

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ABSTRACT

This study investigates the nutritional composition of eggs from local and genetically modified birds, focusing on moisture, protein, fiber, fat, ash, carbohydrate, and mineral content in raw and boiled samples. Findings reveal notable variations between local and genetically modified bird eggs, with local bird eggs showing superior crude protein and fiber levels, while genetically modified eggs exhibited higher moisture, calcium, and zinc levels. Specifically, raw local bird eggs had lower moisture (71.51±0.08) but higher protein (15.98±0.06) compared to genetically modified eggs, aligning with prior research. Conversely, boiled genetically modified eggs contained the most moisture (78.30±0.05), suggesting heat-resistant moisture retention. Mineral analysis showed genetically modified eggs with higher calcium, zinc, and magnesium levels, essential for eggshell strength and hormone regulation, whereas local eggs contained greater iron, beneficial for immunity. These findings highlight nutritional disparities between local and genetically modified eggs, informing dietary choices based on specific nutrient needs.

KEYWORDS: Nutritional composition. Mineral content, Eggs and Birds.

1. INTRODUCTION

Food nutrition, the study of how food and its nutrients impact the health and function of the body, is a complex but essential aspect of human health, directly influencing physical, mental, and emotional well-being (Muscaritoli, 2021). The nutrient composition of foods varies based on factors like species, ecological conditions, post-harvest handling, preservation, and storage techniques. Nutrient content determines whether foods are considered healthy or unhealthy (Adewoyin, 2023; FAO, 2013). Adequate nutrition is vital for health, and factors such as poverty, disease, inadequate policies, poor nutrition education, and adverse climatic changes contribute to hunger and malnutrition (Adeyeye *et al.*, 2023).

Addressing global malnutrition and poverty requires strategies to combat nutrition-related diseases. Food-based and agriculture-based approaches are employed, with animal-source foods, such as meat and eggs, offering sustainable solutions to multiple deficiencies (Talukder and Anik, 2016; FAO, 2013). Research shows that food biodiversity can help combat food insecurity and malnutrition (FAO, 2013). Different breeds and varieties of foods can significantly impact nutrition and health outcomes. Promoting the use of biodiversity for food and nutrition requires specific data, and while crops provide 95% of dietary energy and protein, animal-source foods contribute essential micro and macro-nutrients (Gunte, 2023; FAO, 2007). Exploring more animal sources, such as eggs, fish, snails, and insects, is crucial for improving food security and narrowing the protein gap in low and middle-income countries.

Protein is an essential nutrient required for the growth, maintenance, and repair of all body cells. A lack of adequate protein intake can lead to various severe health issues, including Kwashiorkor, muscle wasting and shrinkage, marasmus, edema, organ failure, impaired mental health, and a weakened immune system (Khan et al., 2017; Obayelu et al., 2022). Consuming sufficient high-quality protein is vital for achieving optimal health. The World Health Organization (2007) recommends a Dietary Allowance (RDA) of 133 mg of nitrogen per kg of body weight per day or 0.83 g of protein per kg of body weight per day to meet the requirements of a healthy population, regardless of age. This intake accounts for 10 to 39 percent of daily calories.

Eggs are highly nutritious due to their nutrient content, bioavailability, and chemical characteristics. They are considered nutraceutical food products with multifunctional properties (Kijowski *et al.*, 2013). Eggs are rich in phosphorus, calcium, and potassium, with moderate amounts of sodium, making them a relatively cheap and accessible source of essential nutrients consumed by humans for centuries. According to Pamplona-Roger, egg protein has a biological value (BV) of 1, serving as a reference standard for comparing proteins from other sources (Onyenweaku *et al.*, 2018). Egg consumption includes raw and cooked forms, with raw eggs consumed for perceived health benefits. Egg components are highly digestible, though a small amount of egg protein is not assimilated, particularly when consumed raw (Evenepoel *et al.*, 1999; Ramalho *et al.*, 2006). Cooking increases protein digestibility due to structural denaturation, facilitating enzyme action, although some proteins, such as ovomucoid and ovalbumin, resist heat (Stanciuc *et al.*, 2018).

Recent studies have been made to enhance egg content in polyunsaturated fatty acids, selenium, and phenolic antioxidants through hen feed (Grela *et al.*, 2020). Nutrient content in eggs is directly related to the feed of laying hens. Egg quality, including freshness, depends on factors like age, sex, breed, feeding, and housing systems of birds (Hanusova *et al.*, 2015). The fatty acid profile of eggs can be modified by changing the hen's diet (Secci *et al.*, 2018). Significant changes in cholesterol content and lipid profile were observed in eggs from hens fed with insect proteins instead of soy protein, and in triacylglycerol and phospholipids when different diets and rearing conditions were used (Campos *et al.*, 2016).

The mineral composition of eggs can be altered by the quality of feed, the rearing system, and the genetic traits of hens (Heflin *et al.*, 2018). Eggs are rich in phosphorus, chlorine, potassium, sodium, sulfur, calcium, magnesium, and iron, with trace levels of elements like zinc, iodine, copper, and selenium (Saha *et al.*, 2021). Consuming an egg provides about 10% of the daily requirement for many elements (Bhat *et al.*, 2013). Increasing consumer awareness of food quality and safety reflects the growing interest in foods produced without genetically modified ingredients and from free-range animals. This study aims to evaluate the nutritional and mineral content of raw and processed eggs from local and genetically modified birds.

2. MATERIALS AND METHODS

2.1 Sample Collection and Identification

Fresh eggs from genetically modified birds were purchased from poultry within Jos-South Local Government Area in Plateau State, Nigeria while eggs from local birds were purchased from local farmers in Barkin Ladi Local Government Area of Plateau State, they were then transported to the laboratory for preparation and analysis.

2.2 Raw Egg Preparation

The shells of the fresh eggs were cleaned, and broken, and the contents were emptied into clean, labelled glass beakers. The raw egg content was then homogenized and frozen at -40°C. The homogenized raw egg samples were lyophilized using a freeze-drier (Onyenweaku *et al.,* 2018).

2.3 Processed (Boiled) Egg Preparation

The fresh eggs were cleaned, labelled, and boiled by placing them in clean water already boiling at 100°C. The boiling water was sufficient to cover the eggs in the pot. The eggs were left to boil for 10 minutes, immediately after which they were removed and allowed to cool in tap water at room temperature. The different eggs (from local and genetically modified birds) were boiled separately and then shelled off after they had cooled. The boiled eggs were placed in clean, labelled beakers and sealed with parafilm prior to undergoing freeze-drying. The boiled, whole eggs were mashed and then freeze-dried with a freeze-drier. All freeze-dried samples were milled to a fine powder using a laboratory miller (Breville Kitchen Wizz BFP650). Milling was done under very low temperatures. After milling, 50 g of each sample (raw and boiled freeze-dried samples) were refrigerated in labelled, air-tight sample glass bottles until ready for analysis (Onyenweaku *et al.,* 2018).

2.4 Proximate Analysis

The moisture content, ash, crude fat, crude protein and fibre of the eggs were determined using methods of the Association of Official Analytical Chemists (AOAC, 2018).

2.5 Estimation of Mineral Elements

The mineral elements were determined using sample digests prepared by digesting completely 5 g of the samples in perchloric and concentrated nitric acid, diluted with deionized water in a 50 ml volumetric flask. Calcium (Ca), phosphorus (P) iron (Fe), zinc (Zn) and magnesium (K) in the digest were estimated using the Perkin Elmer Atomic absorption spectrophotometer (Model 306, UK) (AOAC, 1990).

2.6 Statistical Analysis

Data generated were subjected to the Statistical Package for Social Sciences (SPSS) version 16.0 for Windows, using a one-way analysis of variance (ANOVA). Results were expressed as Mean -Standard Deviation.

3. RESULTS AND DISCUSSION

3.1 Results

The proximate compositions of egg samples from local and genetically modified birds used in this study are presented in Table 1. For the raw eggs sample, the moisture content of local bird eggs was lower (71.51±0.08) compared to genetically modified bird eggs (74.24±0.04). The crude protein content was significantly higher in local bird eggs (15.98±0.06) than in genetically modified bird eggs (13.76±0.04). Both the local bird eggs and the genetically modified bird eggs had no crude fibre content (0.00±0.00),

and a lower lipid content for both birds eggs (7.64±0.04 and 8.29±0.01 respectively). The total ash content was higher in local bird eggs (1.59±0.04) than in genetically modified bird eggs (0.72±0.02), while the carbohydrate content was slightly lower (0.02±0.01 and 0.09±0.01 respectively). The metabolized energy in local bird eggs was lower (132.76±0.06) compared to genetically modified bird eggs (190.40±0.40). For the boiled eggs sample, local bird eggs showed significantly lower moisture content (70.19±0.01) compared to genetically modified bird eggs (78.30±0.05). The crude protein content was slightly higher in local bird eggs (14.95±0.02) than in genetically modified bird eggs (13.50±0.03). Both the local bird eggs and the genetically modified bird eggs had no crude fibre content (0.00±0.00), and a significantly higher lipid content of both birds eggs (9.77±0.02 and 4.67±0.01 respectively). The total ash content in local bird eggs was slightly higher (0.85±0.03) than in genetically modified bird eggs (0.74±0.01), while the carbohydrate content was also slightly higher (0.03±0.01 vs. 0.01±0.01). The metabolized energy in local bird eggs was significantly higher (147.85±0.02) compared to genetically modified bird eggs (96.07±0.02).
The results of the mineral analysis of egg samples from local and genetically modified birds used in this study are presented in Table 2. For the raw eggs sample, the calcium content in local bird eggs was lower (0.75±0.03) compared to genetically modified bird eggs (0.90±0.10). The phosphorus content was slightly higher in local bird eggs (0.02±0.01) than in genetically modified bird eggs (0.01±0.01). Local bird eggs contained more iron (86.60±0.31) compared to genetically modified bird eggs (64.30±0.20), but less zinc (58.10±0.10 vs. 77.10±0.10). The magnesium content was lower in local bird eggs (1.82±0.02) than in genetically modified bird eggs (6.70±0.20). For the boiled eggs sample, the calcium content in local bird eggs was lower (0.65±0.02) compared to genetically modified bird eggs (0.77±0.02). The phosphorus content was lower in local bird eggs (0.01±0.01) than in genetically modified bird eggs (0.02±0.01). The iron content was higher in local bird eggs (60.40±0.40) compared to genetically modified bird eggs (58.41±0.01), but the zinc content was lower (38.60±0.20 and 64.23±0.03 respectively). The magnesium content was higher in local bird eggs (6.57±0.03) compared to genetically modified bird eggs (4.50±0.10).

Table 1: Proximate analysis of raw and processed eggs samples from local and genetically modified birds, weight (g) per 100 grams of samples.

Sample	Moisture (%)	Crude protein (%)	Crude fibre (%)	Lipids (%)	Ash (%)	M.E (Calories)	N.F.E (%)
Raw sample							
Local bird	71.51±0.08	15.98±0.06	0.00±0.00	7.64±0.04	1.59±0.04	132.76±0.06	0.02±0.01
Genetically modified bird	74.24±0.04	13.76±0.04	0.00±0.00	8.29±0.01	0.72±0.02	190.40±0.40	0.09±0.01
Boiled sample							
Local bird	70.19±0.01	14.95±0.02	0.00±0.00	9.77±0.02	0.85±0.03	147.85±0.02	0.03±0.01
Genetically modified bird	78.30±0.05	13.50±0.03	0.00±0.00	4.67±0.01	0.74±0.01	96.07±0.02	0.01±0.01

Table 2: Mineral analysis of egg samples from local and genetically modified birds (mg/L)

Sample	Calcium (ppm)	Phosphorus (ppm)	Iron (ppm)	Zinc (ppm)	Magnesium (ppm)
Raw sample					
Local bird	0.75±0.03	0.02±0.01	86.60±0.31	58.10±0.10	1.82±0.02
Genetically modified bird	0.90±0.10	0.01±0.01	64.30±0.20	77.10±0.10	6.70±0.20
Boiled sample					
Local bird	0.65±0.02	0.01±0.01	60.40±0.40	38.60±0.20	6.57±0.03
Genetically modified bird	0.77±0.02	0.02±0.01	58.41±0.01	64.23±0.03	4.50±0.10

3.2 Discussion

The raw sample from the local bird had a lower moisture value (71.51±0.08) compared to the genetically modified bird, which had the highest moisture value (74.24±0.04). This aligns with the findings of Ezenwosu *et al.* (2023). In contrast, the boiled sample from the genetically modified bird recorded the highest moisture value (78.30±0.05), while the local bird had the lowest value (70.19±0.01). This finding is consistent with the reports of Babangida *et al.* (2006) and Ezenwosu *et al.* (2023), indicating that the moisture content of boiled eggs was not affected by heat.

Crude protein content was highest in the local bird for both raw and boiled egg samples (15.98±0.06 and 14.95±0.02, respectively), corroborating the findings of Fraga *et al.* (1989) and Ezenwosu *et al.* (2023). The genetically modified bird had the lowest crude protein content in both raw (13.76±0.04) and boiled (13.50±0.03) eggs, which is consistent with Ezenwosu *et al.* (2023). This study suggests that consuming local bird eggs, whether raw or boiled, is more beneficial in terms of crude protein content.

Crude fibre content was not found. This finding aligned with Ezenwosu *et al.* (2023), who reported that animal-based products like eggs do not contain fibre.

Fat content data revealed that raw egg samples from the local bird had the lowest fat content (7.64±0.04), while the genetically modified bird had the highest (8.29±0.01), aligning with Babangida *et al.* (2006) but contrasting with the reports of Mine (2007) and Ezenwosu *et al.* (2023). The boiled egg sample from the local bird had the highest fat content (9.77±0.02), while the genetically modified bird had the lowest (4.67±0.01), which agrees with Ezenwosu *et al.* (2023). Boiled eggs contained significantly less crude fat than raw eggs, likely due to lipid oxidation during boiling. Research indicates that lipid oxidation, requiring increased activation energy provided by heat exposure, commonly occurs at temperatures above 66ºC (World's Healthiest Foods, 2014).

Regarding ash content in both raw and boiled egg samples, the local bird recorded the highest values (1.59±0.04 and 0.85±0.03, respectively), while the genetically modified bird had the lowest (0.72±0.02 and 0.74±0.01, respectively). This finding agrees with Isidahomen *et al.* (2013) and Ezenwosu *et al.* (2023), who reported lower ash values in genetically modified bird eggs and higher values in local bird eggs, potentially due to environmental factors and feed type.

The carbohydrate content in both raw and boiled egg samples from the local and genetically modified birds were relatively low (0.02±0.01 and 0.03±0.01, and 0.09±0.01 and 0.01±0.01, respectively), as egg carbohydrates are distributed between the egg yolk and egg white. This finding contrasts with Ezenwosu *et al.* (2023).

Calcium is essential for the formation and maintenance of bones, muscles, and nerves. It also plays a crucial role in egg production, as eggshells are primarily composed of calcium. Birds have high calcium requirements to produce eggshells strong enough to ensure viability. The calcium content in both raw and boiled egg samples of local bird eggs showed lower values (0.75±0.03 and 0.65±0.02, respectively) compared to genetically modified bird eggs, which recorded higher values in both raw and boiled egg samples (0.90±0.10 and 0.77±0.02, respectively).

Phosphorus, although present at low levels in the eggshell, is important for replenishing the hen's medullary bone. Adequate dietary phosphorus is necessary to assimilate calcium into the bone matrix. The phosphorus content was slightly higher in raw local bird eggs (0.02±0.01) than in genetically modified bird eggs (0.01±0.01) and lower in boiled local bird eggs (0.01±0.01) compared to genetically modified bird eggs (0.02±0.01).

Iron is crucial for increasing energy and boosting the immune system. The raw egg samples of local birds contained more iron (86.60±0.31) compared to genetically modified bird eggs (64.30±0.20). Similarly, the iron content was higher in the boiled egg samples of local bird eggs (60.40±0.40) than in genetically modified bird eggs (58.41±0.01).

Zinc acts as a cofactor for the enzyme carbonic anhydrase. A deficiency of zinc in layer and breeder diets can lead to lower levels of carbonic anhydrase, resulting in shell defects and a higher incidence of broken eggs and pigmentation defects. The raw egg samples of local birds contained less zinc (58.10±0.10) compared to genetically modified bird eggs (77.10±0.10). Similarly, the boiled egg samples of local bird eggs had lower zinc levels (38.60±0.20) compared to genetically modified bird eggs (64.23±0.03).

Magnesium helps balance fertility hormones, such as progesterone and estrogen, and controls follicle-stimulating hormone (FSH), which stimulates the ovaries. The raw egg samples of local birds contained lower magnesium (1.82±0.02) compared to genetically modified bird eggs (6.70±0.20). However, the boiled egg samples of local bird eggs had higher magnesium levels (6.57±0.03) compared to genetically modified bird eggs (4.50±0.10).

CONCLUSION

This comparative analysis underscores that local bird eggs provide higher levels of protein and fiber, making them preferable for individuals seeking these nutrients, while genetically modified eggs excel in calcium and zinc, crucial for bone health and eggshell quality. The study reveals that boiling affects fat content, reducing levels significantly across both bird types, likely due to lipid oxidation. The differences in mineral composition suggest that genetically modified eggs may offer advantages for calcium and zinc intake, while local bird eggs are richer in iron and magnesium. These insights can guide consumers toward eggs that meet their specific dietary needs, demonstrating that egg type selection can have meaningful health implications. Further research could explore how feed and environment contribute to these nutritional differences, enhancing our understanding of egg composition and quality.

REFERENCES

1. Adewoyin, O. B. (2023). Pre-Harvest and Postharvest Factors Affecting Quality and Shelf Life of Harvested Produce. In *New Advances in Postharvest Technology*. IntechOpen.
2. Adeyeye, S. A. O., Ashaolu, T. J., Bolaji, O. T., Abegunde, T. A., & Omoyajowo, A. O. (2023). Africa and the Nexus of poverty, malnutrition and diseases. *Critical Reviews in Food Science and Nutrition*, *63*(5), 641-656.

3. AOAC (1990). Official methods of analysis. 15th Edition, Association of Official Analytical Chemists, Washington DC.
4. AOAC (Association of Official Analytical Chemistry) (2018). Official Method of Analysis of the AOAC (W. Horwitz Editor Eighteen Edition, Washington; D. C., AOAC).
5. Babangida, S., Isidahomen, E. C., & Igebuike, J. U. (2006). A comparison of egg quality parameter of some poultry species in Maiduguri, Nigeria. *Journal of research in Agriculture*, *3*(2), 37-39.
6. Bhat, Z. F., Kumar, S. U. N. I. L., & Kumar, P. A. V. A. N. (2013). Production of designer eggs. *Animal products technology*, 543-568.
7. Campos, A. M., Ricardo, F., Alves, E., Reis, A., Couto, D., Domingues, P., & Domingues, M. R. M. (2016). Lipidomic investigation of eggs' yolk: Changes in lipid profile of eggs from different conditions. *Food Research International*, *89*, 177-185.
8. Evenepoel, P., Claus, D., Geypens, B., Hiele, M., Geboes, K., Rutgeerts, P., & Ghoos, Y. (1999). Amount and fate of egg protein escaping assimilation in the small intestine of humans. *American Journal of Physiology-Gastrointestinal and Liver Physiology*, *277*(5), G935-G943.
9. Ezenwosu, E., Osita, C. O., & Kingsley, A. (2023). Comparative Nutritional Evaluation of Eggs From Some Poultry Species in Nigeria. *Journal of Agriculture, Food, Environment and Animal Sciences*, *4*(1), 62-77.
10. Food and Agriculture Organisation (FAO). (2007). The state of the world's animal genetic resources for food and agriculture. Barbara Rishchowsky and Dafydd Oilling, FAO, Rome.
11. Food and Agriculture Organisation (FAO). (2013). Combating micronutrient deficiencies: Food-based approaches. In: Thompson, B. and Amoroso, L., Eds., Food and Agriculture Organisation of the United Nations.
12. Fraga, L.M., Valdivie, M., Berrio, I., & Pertez, P. P.C. (1989). Naked neck genes are useful in the tropics. Misset International Poultry. *An international Magazine on poultry*, *5*(94), 26-27.
13. Grela, E. R., Knaga, S., Winiarska-Mieczan, A., & Zięba, G. (2020). Effects of dietary alfalfa protein concentrate supplementation on performance, egg quality, and fatty acid composition of raw, freeze-dried, and hard-boiled eggs from Polbar laying hens. *Poultry science*, *99*(4), 2256-2265.
14. Gunte, K. E. (2023). Nutritional and environmental impacts of livestock production systems in Canada: a food systems perspective.
15. Hanusová, E., Hrnčár, C., Hanus, A., & Oravcová, M. (2015). Effect of breed on some parameters of egg quality in laying hens. *Acta fytotechnica et zootechnica*, *18*(1), 20-24.
16. Heflin, L. E., Malheiros, R., Anderson, K. E., Johnson, L. K., & Raatz, S. K. (2018). Mineral content of eggs differs with hen strain, age, and rearing environment. *Poultry Science*, *97*(5), 1605-1613.
17. Isidahomen, C. E., Njidda, A. A., & Olatunji, E. A. (2013). Egg quality traits of indigenous and exotic chickens as influenced by specific genes. *Journal of Biology, Agriculture and Healthcare*, *3*(1), 53-58.
18. Khan, A., Khan, S., & Jan, A. (2017). Health complication caused by protein deficiency. *J. Food Sci. Nutr*, *1*, 645-647.
19. Kijowski, R., Blankenbaker, D. G., Munoz del Rio, A., Baer, G. S., & Graf, B. K. (2013). Evaluation of the articular cartilage of the knee joint: value of adding a T2 mapping sequence to a routine MR imaging protocol. *Radiology*, *267*(2), 503-513.
20. Mine, Y. (Ed.). (2008). *Egg bioscience and biotechnology*. John Wiley & Sons.
21. Muscaritoli, M. (2021). The impact of nutrients on mental health and well-being: insights from the

literature. *Frontiers in nutrition*, *8*, 656290.

22. Obayelu, O. A., Adeyeye, A. I., Adepoju, A. O., & Ayanboye, A. O. (2022). Protein food consumption among students in a Nigerian university: A demand modelling. *Agricultura Tropica et Subtropica*, *55*(1), 83-91.

23. Onyenweaku, E. O., Ene-Obong, H. N., Williams, I. O., & Nwaehujor, C. O. (2018). Comparison of nutritional composition of bird egg varieties found in Southern Nigeria: A preliminary study. *Food and Nutrition Sciences*, *9*(7), 868-879.

24. Onyenweaku, E. O., Ene-Obong, H. N., Williams, I. O., & Nwaehujor, C. O. (2018). Comparison of nutritional composition of bird egg varieties found in Southern Nigeria: A preliminary study. *Food and Nutrition Sciences*, *9*(7), 868-879.

25. Onyenweaku, E., Oko, G., & Fila, W. (2018). Comparative Evaluation of Some Bioactive Compounds in Raw and Boiled Egg Varieties: Eggs, Potential Nutraceuticals?. *International Journal of Biochemistry Research & Review*, *22*(4), 1-7.

26. Ramalho, H. M., Santos, V. V., Medeiros, V. P., Silva, K. H., & Dimenstein, R. (2006). Effect of thermal processing on retinol levels of free-range and caged hen eggs. *International journal of food sciences and nutrition*, *57*(3-4), 244-248.

27. Saha, S. K., Pathak, N. N., Saha, S. K., & Pathak, N. N. (2021). Mineral nutrition. *Fundamentals of animal nutrition*, 113-131.

28. Secci, G., Bovera, F., Nizza, S., Baronti, N., Gasco, L., Conte, G., ... & Parisi, G. (2018). Quality of eggs from Lohmann Brown Classic laying hens fed black soldier fly meal as substitute for soya bean. *Animal*, *12*(10), 2191-2197.

29. Stănciuc, N., Creţu, A. A., Banu, I., & Aprodu, I. (2018). Advances on the impact of thermal processing on structure and antigenicity of chicken ovomucoid. *Journal of the Science of Food and Agriculture*, *98*(8), 3119-3128.

30. Talukder, R. K., & Anik, A. R. (2016, January). Food Security and Nutrition Sensitive Agriculture in Bangladesh: Challenges and Opportunities. In *15th national conference and seminar of Bangladesh Agricultural Economist Association*.

31. World Health Organisation (WHO) (2007). Dietary reference intakes for energy, carbohydrate, fibre, fat, fatty acids, cholesterol, protein and amino acids (macronutrients). World Health Organisation (WHO); Geneva, Switzerland: 2007. WHO Technical Report Series 935, Report of a Joint WHO/FAO/ UNU Expert Consultation.