Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences
Department of Food Science

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Entomophagy, nsenene, kwashiorkor and marasmus in East Africa

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Abstract

Insects have been eaten by humans since around 10000 years and they are still eaten nowadays by humans in most cultures around the world. Insects are a good source of protein and also have other nutritional values. Production of insects as food does not require so much resources as for example meat production. Hence, insects are cheap, rich of nutrients and environmental friendly.

Children in poor areas in developing countries often eat an undiversified diet which leads to a nutrient deficiency, like kwashiorkor or marasmus. It has been known that kwashiorkor and marasmus are diseases caused by protein deficiency. More current research proved that kwashiorkor and marasmus are not necessarily caused by protein deficiency, but instead that it is caused by deficiency in any of the so called type II nutrients, of which protein is one of them.

This study investigated whether nsenene (East Africa grasshoppers) can be a source of nutrient that can cure or prevent the malnutrition diseases kwashiorkor and marasmus. It was found that nsenene can not cure those diseases, because treating a child with the wrong nutrients, like for example protein, can lead to death. A child suffering from kwashiorkor or marasmus needs a very special diet. The consumption of nsenene would, however, contribute to varying the diet of a poor child so that kwashiorkor and marasmus could be prevented by including nsenene in the diet.

Keywords: Entomophagy, Kwashiorkor, Marasmus, Nsenene, Malnutrition, Prevention, Cure, East Africa

Sammanfattning

Människor har ätit insekter sedan ungefär 10 000 år tillbaka och äts fortfarande av människor i de flesta kulturer. Insekter är en bra källa till protein och andra näringsämnen. Produktion av insekter som livsmedel kräver inte lika mycket resurser som till exempel köttproduktion. Sammanfattningsvis är insekter billiga, näringsrika och miljövänliga.

Barn i fattiga områden i utvecklingsländer har ofta en ensidig kosthållning vilket leder till näringsbristsjukdomar som till exempel kwashiorkor och marasmus. Det har varit känt att kwashiorkor och marasmus orsakas av proteinbrist. Aktuell forskning har dock visat att dessa sjukdomar inte nödvändigtvis orsakas av proteinbrist, men att sjukdomarna istället orsakas av en brist på så kallade typ II-näringsämnen, av vilka protein är ett.

Denna studie har med hjälp av en litteraturgenomgång undersökt om nsenene (Östafrikansk gräshoppa) kan vara en näringskälla som kan bota eller förebygga näringsbristsjukdomar som kwashiorkor eller marasmus. Det visade sig att nsenene inte kan bota sjukdomarna, eftersom barn kan dö om man behandlar det med fel näringsämnen, som till exempel protein. Ett barn som lider av kwashiorkor eller marasmus måste ha en speciell kost. Intag av nsenene kan bidra till att variera ett fattigt barns kosthållning, så att kwashiorkor eller marasmus kan förebyggas genom att inkludera nsenene i dieten.

Nyckelord: Entomophagy, Kwashiorkor, Marasmus, Nsenene, Malnutrition, Prevention, Cure, East Africa

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1 Introduction

Around 10 000 years ago, humans gathered insects in order to survive. In some cultures, insects are still staple food (Ruggia et al. 2004, Banjo et al. 2006). For example, nsenene (grasshopper) in East Africa, especially Uganda and Tanzania, is a cultural food for special occasions. The technical term for eating insects is entomophagy (FAO 2013).

Since insects contain protein (Payne et al. 2016), insects could be a source of protein for people in developing or developed countries and could even prevent malnutrition. In the academic literature, edible insects have slowly been introduced as a source of protein, especially for developing countries. Edible insects as a food product have also been introduced in developed countries as eco-friendly protein source (Ruggia et al. 2004).

It has been in the news lately (Erbentraut 2015) that insects are an environmental friendly source of protein, since production of insects does not consume so much resources, and thereby does not contribute as much to global warming as for example meat production. Since insect production does not use so much economic resources, the insects could be an alternative protein source for poor malnourished children in developing countries (Premalatha et al. 2011).

This year alone, Unicef is making plans to treat 2 million children in Africa. In southern and eastern Africa 36 million people are expected to suffer from malnutrition in year 2016. In Ethiopia, 3.6 million children are not able to participate in school in year 2016 because of drought (Graham-Harrison 2016).

Two, of many, forms of malnourish diseases are kwashiorkor and marasmus (Atri et al. 2010). There is a common misunderstanding (Millward 2013, Golden 2010) in the literature, from 1933 (Williams 1933, 1935) until today (Bain et al. 2013, Black et al. 2008) suggesting that those diseases are because of lack of protein (Williams 1933) alone. Also outside the academic world, the view is that the cause of kwashiorkor and marasmus is solely due to protein and energy deficiencies (Wikipedia 2016a, 2016b).

In some African cultures livestock is usually only slaughtered during special occasions, perhaps once a year (Chege et al. 2015). Even if an animal is slaughtered, there is in some cultural ethnic groups a negligible chance that a child would get the meat (Chege et al. 2015, Longhurst et al. 1995). This, since that the right to the meet follows a successional process, where the men have the right to eat the best parts (flesh meat), and the women will get the bad parts (intestines). If anything is left of the animal, the children may get a small part (FAO 2000). The animals are also highly valued as a status symbol for family wealth. It might happen that a family keeps a healthy animal until it dies by itself (Chege et al. 2015).

The East African nsenene is an example of insect which may help to prevent malnourish diseases. Nsenene is the Ugandan name of a grasshopper collected in Uganda. The scientific name of the nsenene is *Ruspolia differens* (Matojo 2013). The nsenene is between 40 to 65 mm in body length excluding the antennas. The nsenene exist in at least six sympatric colour forms. The most common colours are the green which are predominantly females and the brown males which are predominantly males. The rare nsenene are purple suffused or have purple stripes on their green or brown body.

Nsenene is caught for commercial or domestic use (Kasambula, personal conversation, Appendix 1).

For the domestic use, the simplest method is to catch the current demand during day light from grass and tree branches (Nalwoga et. al., personal conversation, Appendix 2). A more advanced method for domestic use is to spread a white cloth over the grass, so that the brightness from the cloth attracts the nsenene so that they are unable to fly.

For commercial use, the nsenene are collected during night with artificial electric LED light, roof sheet metal and metal drums. The light attracts the nsenene, so that they fall on the sheet metal and then slide into the drums.

The direct advantages of collecting nsenene are economic income from nsenene business, nutritional if used as meal, animal feed as well as preservation of crops, since nsenene eat crops. The nsenene business also has indirect advantages, since government tax is collected from the professional business. In addition, nsenene has also brought some infrastructure to the rural areas like expansion of electricity, development of roads and hotels for the nsenene traders.

Nsenene can not be eaten uncooked. Before cooking, the wings are removed and then they are washed in water. Fresh nsenene can be fried in their own fat, which means that expensive cooking oil is not needed. Nsenene can be boiled, sundried or smoked. The nsenene can for example be fried together with spices then eaten as a crispy snack. Onions and tomatoes can also be added, to make a proper meal eaten with other staple food like cassava or yams (Nampewo 2013).

Nsenene is said to taste like a cross between chicken and shrimps (Viral Crackle 2016) and is as delicious as any other food. Perhaps it can even prevent or cure kwashiorkor or marasmus.

This study aims to find out if insects could help to prevent malnourish diseases kwashiorkor and marasmus or cure children suffering from these diseases, which commonly exists in poorer areas in developing countries (Müller et al. 2005).

2 Theory

The human body needs protein and other nutrients in order to function. If the nutrients are not sufficiently absorbed by the body, malnutrition diseases can emerge. A few diseases are associated with protein deficiency and two of them are kwashiorkor and marasmus. Since the 1930's, there has been more or less a common view among experts in the subject that kwashiorkor is caused by protein deficiency and marasmus is caused by protein and energy deficiency (Millward 2013, Golden 2010). According to the common view, the cause of marasmus is "inadequate intake of protein and calories" and the cause of kwashiorkor is "inadequate protein intake" (Bain et al. 2013, Wikipedia 2016a, 2016b).

Apart from protein, insects contain other nutrients. Hence, in this study a distinction between protein and other nutrients was made since they have different effects on the body. Also, prevention and cure must be distinguished since accomplishing prevention and accomplishing cure might need to be carried out in different ways. A distinction between kwashiorkor and marasmus needs to be made, since the diseases are likely to have different causes.

The hypotheses to test are:

- Nsenene protein or other nsenene nutrients can prevent or cure kwashiorkor or marasmus in poorer areas in developing countries

- There is sufficient nsenene in a typical rural area in order to supply its habitants' nutritional demand

3 Methodology

This study is a literature search in scientific databases and food databases. It focused on research newer than 1995 and mostly review articles. This study follows a deductive approach.

3.1 Definition of the Diseases

The diseases were first defined as accurate as possible, through review of academic literature.

3.2 Limitation

This study focused on poorer areas in developing countries, since people from those areas have the highest utility of nutrients from insects.

Regarding the choice of insect, the study limited to nsenene (grasshopper) since it is edible and available in some developing countries (FAO 2013).

Since malnutrition is more common among younger children than others (Manary et al. 2009), the study concentrated on children of age from birth up to 10 years.

3.3 Finding the Nutrient Requirement of the Body.

In order to understand if the collected nsenene could be enough for a child, the study investigated how much protein and other nutrient a child needs by consulting research articles about nutrient requirements.

3.4 Supply of Nutrients from Insects

The protein and other nutrient value of nsenene were taken from research articles. The findings were compared with the equivalent values in beans, fish and meat by consulting research articles and food databases.

Interviews with three nsenene collectors were conducted on the collecting methods by email and telephone conversation (see Appendix 1-2). Questions about benefits and challenges to the society collecting nsenene were made in order to gather important answers that were not asked specifically. Questions were made regarding how much, as a quantity in weight, nsenene a producer can collect during collecting seasons for the whole year. The interviews made it possible to understand which seasons nsenene can be collected and how it can be stored.

4 Results

4.1 Definition of the Diseases

It has lately been proved that kwashiorkor is not directly caused by protein deficiency (Millward 2013). It has also been shown that treatment of children suffering from kwashiorkor or marasmus by giving protein is dangerous and can lead to death. Such treatment has caused many unnecessary deaths among malnourished children since the 1930's until now (Golden 2010). The first evidence for this came in 1968 and has after that been confirmed 1989, 2006 and 2007 (Golden 2010, Heikens et al. 2009), and now many researchers have better knowledge about the causes of kwashiorkor and marasmus

The new consensus is that kwashiorkor is not because of protein deficiency but due to deficiency in any of a specific set of nutrients, including protein (Heikens et al. 2009). However, there are still researchers, not specialized in kwashiorkor, incorrectly believing that protein and energy unbalance is the cause of kwashiorkor (Kwena 2016, Black et al. 2008).

There are two different types of nutrient deficiencies (Golden 1995, Heikens et al. 2009), which are called type I deficiency and type II deficiency. The specific nutrients associated with the two deficiencies are presented in Table 1.

The type I deficiency, is a deficiency where the child can continue growing and consume the body stores. A type I deficiency will give specific symptoms depending on the specific nutrient deficiency (Heikens et al. 2009). For example, a deficiency of iron may cause fatigue through anaemia (Yip et al. 1998). Iodine deficiency may cause exacerbating learning capacity and productivity (UNICEF 2008). Fluorine deficiency may cause dental caries (Selwitz 2007) or osteoporosis (Kleerekoper 1998). Clearly, type I deficiencies give very different symptoms depending on which of the type I nutrients is deficient.

The type II deficiency, is a deficiency where the child stops growing (stunting) and starts conserving nutrients in the body tissue (wasting). A type II deficiency will not give a specific symptom depending on the specific nutrient deficiency.

The main symptoms of a child with a type II deficiency are the same (Heikens et al. 2009), independent on if there is a deficiency in zinc, magnesium or any other type II nutrient (Golden 1995). The direct cause of the stunting and wasting is loss of appetite. The direct cause of loss of appetite is a deficiency in any of the type II nutrients. A loss of appetite will lead to further nutrition deficiency (Emery 2005). Eating an unvaried diet may lead to a vicious circle where loss of appetite is increasing over time until the child gets kwashiorkor or marasmus.

The deficiency of a type II nutrient may cause a liver disease. This disease causes a higher level of ferritin. The ferritin gives an antidiuretic effect which gives the oedema in kwashiorkor. Marasmus does not lead to oedema (Golden 2010).

Since kwashiorkor and marasmus are caused by deficiency in type II nutrients, this study’s further focus was on deficiency in type II nutrients. Kwashiorkor and marasmus are not caused by deficiency in type I nutrients and therefore the study does not focus on type I nutrients.

Table 1. *Type I nutrients with nutrient specific deficiency symptoms and type II nutrients with stunting and wasting deficiency symptoms*

TYPE I nutrients	TYPE II nutrients
Iron	Potassium
Copper	Sodium
Manganese	Magnesium
Iodine	Zinc
Selenium	Phosphorus
Calcium	Protein
Fluorine	Carbohydrates
Thiamine	Fat
Riboflavin	
Pyridoxine	
Nicotinic acid	
Cobalamin	
Folate	
Ascorbic acid	
Vitamin A (retinol)	
Vitamin E (tocopherol)	
Vitamin D	
Vitamin K	

Source: Golden 1995

A type II deficiency occurs when any of the type II nutrients are limited in the diet. Since the type II nutrients are fundamental for all biological processes, both animals and plants, they have somewhat similar concentrations in all organisms. This means that if a diet is deficient in one of the type II nutrients, it is likely to be deficient in the other type II nutrients as well (Golden 1995). However, eating a varied diet increases the probability of consuming additional type II nutrients, since concentrations actually do differ between different organisms.

4.2 Requirement of Type II Nutrients

A newborn infant needs 1.41g protein per kilo per day (Millward 2013, Table 2) and the protein requirement will decrease rapidly until two years of age to 0.79g/kg per day (WHO 2007a, Table 2) and after that the protein need will remain more or less constant (Millward 2013). Assuming that the distribution of the age of children is equal in a village, a child in a village between 0 and 10 years of age on average needs 16.95 g protein per day, given a normal weight curve for a child. In other words, 16.95 g protein per day is the expected value of the requirement for a random child in the village population, although the younger children in this age interval need much less protein and older children need much more protein. The expected value calculated is called a safe level requirement (Table 2).

In order to calculate the average safe level requirement for a child (16.95g protein per day), different types of requirements of protein for the body at different ages were investigated (Table 2). The two main types of requirements are maintenance requirement and growth requirement, which sum up to a total requirement. The maintenance requirement is the amount of protein which the body needs in order to maintain its basic functionality without wasting. The growth requirement is the amount of protein that the body needs in order to continue growing by depositing protein in the body. The body deposition is the amount of protein intake that will actually be absorbed and deposited in the body tissue. Notice that the growth requirement is larger than the body deposition, which is because in order to deposit protein into the tissue an excess of protein is needed because of the efficiency of the depositing process (WHO 2007a).

The total requirement is the sum of the maintenance and growth requirement and is the minimum amount of protein, which the body needs in order to maintain and grow. In order to be on the safe side, WHO created a safe level, which is higher than the total requirement. The total requirement is not constant over time, and since it varies over time a standard deviation can be calculated. The total requirement is actually the average value of the varying total requirement. The safe level is the upper limit of the 95% confidence interval, which is calculated by the average total requirement plus 1.96 times the standard deviation of the total requirement (Table 2, WHO 2007a, Englund 2012). The safe levels are levels of nutritional intake where 97.5% of the children are safe from any diseases caused by deficiencies (Reeds et al. 2003).

This way the safe level protein-mass per body-kilo per day, for each age, was calculated. By multiplying the median weight of each age by the safe level protein-mass per body-kilo, the safe level protein mass per day for each age was calculated. Assuming that the distribution of age in a village is equal, so that each age in the population contains an equal amount of children, an average of the protein mass per day per child could be calculated, which is 16.95g per child.

The findings were in line with the expectations of the study. The study expected the body total requirement in g per kg per day to be higher for an infant than for a 10-year old and that the safe level in g per day to increase slowly and to increase at the same speed as the body weigh at older age.

A safe level of 16.95g per day per child, is in line with the recommendations from other sources (DRI, USDA 2016b).

Table 2. *Requirement of protein per day for a child*

Age	Median weight	Body deposition	Body maintenance requirement	Body growth requirement	Body total requirement	Safe level (+1.96SD)	Safe level
(years)	(kg)	Protein (g/kg per day)					Protein (g per day)
0					1.41		
0.5	7.9	0.266	0.66	0.46	1.12	1.31	10.3
1	9.6	0.168	0.66	0.29	0.95	1.14	10.9
1.5	10.9	0.108	0.66	0.19	0.85	1.03	11.2
2	12.1	0.075	0.66	0.13	0.79	0.97	11.7
3	14.3	0.039	0.66	0.07	0.73	0.90	12.9
4	16.3	0.020	0.66	0.03	0.69	0.86	14.0
5	18.3	0.016	0.66	0.06	0.69	0.85	15.6
6	20.5	0.035	0.66	0.04	0.72	0.89	18.2
7	22.9	0.048	0.66	0.08	0.74	0.91	20.8
8	25.4	0.053	0.66	0.09	0.75	0.92	23.4
9	28.1	0.053	0.66	0.09	0.75	0.92	25.9
10	31.2	0.051	0.66	0.09	0.75	0.91	28.4
Average 0 to 2 years		**0.181**				**1.160**	**10.840**
Average 2 to 10 years		**0.043**				**0.903**	**18.986**
Average requirement per child							**16.950**

Source: Protein requirement at 0 age (Millward 2013), protein and amino acid deposition (WHO 2007a) and requirement (WHO 2007a), median weight 0.5 to 5 years (WHO 2006), median weight 6 to 10 years (WHO 2007b)

The other type II nutrient requirements for children between 0 to 10 years of age are presented in Table 3, which are recommendations from United States Department of Agriculture (Golden 1995, DRI USDA 2016b). Table 3 also contains nutrient content from selected diets, discussed below.

Important to note is that the recommendations are higher than a level that will cause kwashiorkor or marasmus. The recommendation may also be much higher than a level which may cause kwashiorkor or marasmus. It is not known apart from for protein, at which levels (Golden 1995, 2010) of the type II nutrients, kwashiorkor or marasmus may occur, but the recommendations are of course higher than the level at which the diseases may occur. By saying that, this study can only prove levels where the child cannot become ill in kwashiorkor or marasmus, but it can not prove levels where the child will become ill in those diseases.

Since the safe levels are only 1.96 standard deviations higher than the sum of maintenance and growth requirements it is argued that the safe levels for protein are very close to the biological requirement and that a level below the recommended intake may cause some illness (Reeds et al. 2003). However, this study argues that the level which causes the specific diseases kwashiorkor and marasmus is not proved and may very well be far below the safe level for any of the type II nutrients. Therefore, this study defines deficiency as an unknown level that will cause kwashiorkor or marasmus, and this deficiency level may very well be far below the safe level.

4.3 Supply of Type II Nutrients

A poor African child usually eats an undiversified diet. If a family has access to cassava, the diet may be cassava and porridge (Nungo et al. 2012). The poorer the family, the more undiversified the diet (Golden 2010). If any of the type II nutrients are deficient in the diet, which is likely to happen if eating food with low variation, the child may get kwashiorkor or marasmus.

In Table 3, the supply of type II nutrients from selected diets, are presented next to the type II nutrient requirements of a child. The nutrient values from diets are presented in mg nutrients per 100g of fresh weight food. Assuming that an average child eats between 100g to 500g per day depending on which food, it was investigated which diets would satisfy the type II nutrient requirements. The satisfying levels are presented in bold text in Table 3. The satisfying levels are safe levels, recommended by USDA, which may possibly be much higher than a deficiency level that may cause kwashiorkor or marasmus.

If eating only cassava, the child will only satisfy the carbohydrate requirement, but may be deficient in potassium, sodium, magnesium, zinc, phosphorus, protein, and fat (Table 3). If eating cassava and nsenene, the child will satisfy magnesium, zinc, phosphorus, protein and carbohydrates, but may be deficient in potassium, sodium and fat. If eating nsenene and yams, the child may only be deficient in sodium and fat.

The nutrient which the child is deficient in, at such low level that it will cause kwashiorkor or marasmus, is called the limiting nutrient of the diet (Golden 2010). Zinc is the most frequently limiting type II nutrient and after zinc come phosphorus and magnesium as limiting nutrients. After those nutrients, protein follows as limiting nutrient and after protein comes potassium and the rest of the type II nutrients as limiting. The more varied the child can eat, the less likely it is that it will suffer from kwashiorkor or marasmus.

It can be assumed that a poor family has access to cassava or yams and would by those foods satisfy the recommended intakes of carbohydrates and partly satisfy potassium. By adding nsenene to the diet, all type II nutrients except from fat, sodium and possibly potassium reach the recommended safe level. However, fat and carbohydrates are interchangeable considering kwashiorkor and marasmus. Also, potassium is supplied from cassava and yams, and at least partly covering the recommended safe level, and possibly fully cover the limiting level. Collecting nsenene will clearly at some extent prevent kwashiorkor and marasmus.

Table 3. *Requirement of type II nutrients for a child and supply from selected diets*

Type II nutrients	Child requirement (mg per day)	Nsenene	Cassava	Yams	Sweet potato	Mango	Guava	Peanut
		(mg/100g fresh weight)						
Potassium	**3 162**	230	271	**816**	337	168	**417**	**705**
Sodium	**1 038**	104	14	9	55	1	2	18
Magnesium	**120**	**196**	21	21	25	10	22	**168**
Zinc	**4.5**	**10**	0.3	0.2	0.3	0.1	0.2	**3.3**
Phosphorus	**555**	**185**	27	55	47	14	40	**376**
Protein	**16 950**	**21 400**	1 360	1 530	2 090	820	2 550	**25 800**
Carbohydrates	**121 923**	5 100	**38 060**	**27 880**	**20 120**	**14 980**	**14 320**	**16 300**
Fat	**30 077**	5 500	280	170	50	380	950	**49 240**

Source: Type II Nutrients (Golden 1995), Child Requirement (DRI, USDA 2016b), nsenene nutrients potassium (Si-rimungkararat 2010), sodium, magnesium, zinc (Blasquez 2012), phosphorus, carbohydrates, fat (Lukiwati 2010), protein (FAO 2013), cassava nutrients potassium, sodium, magnesium, zinc, phosphorus, carbohydrates (Montagnac 2009), protein, fat (NND, USDA 2016a), yams, sweet potato, mango, guava, peanut nutrients (NND, USDA 2016a)

Note: Requirement and supply satisfying requirement (for an average child assumed to eat 100-500g fresh weight) in ***bold*** *text. Dry weight nutrient supply for nsenene was converted to fresh weight using a dry weight factor of 32.6% (Nakagaki 1991). An average value was calculated for different species of nsenene (Blasquez 2012).*

A comparison between nsenene, beans, fish and beef meat shows that nsenene has even better nutritional composition than other common protein rich food (Table 4). This study did not expect nsenene to have better nutritional values for most of the nutrients than the other selected foods. The important magnesium and zinc concentrations are much higher for nsenene than for meat, fish and beans. In a poorer area, the availability of nsenene and beans are higher than the availability of fish and meat. Because the nutritional values are higher for nsenene than for beans, the nsenene is clearly the best alternative for a poor child.

It would be best to vary the diet, not only by eating for example cassava, yams, bananas, peanuts and nsenene, but also by eating beans, meat and fish. However, it would not be an option for a poor child in a developing country to eat meat or fish, if any, since it often goes to older family members or is sold on the local market. There is also no guarantee that any excess nsenene will go to the children. However, the more richness in any food, the more likely it is that the children will get more food, so collecting nsenene is likely to improve the supply of type II nutrients.

Most important would be to combine a diet including nsenene, cassava and yams. Such diet would to some extent prevent kwashiorkor and marasmus.

Table 4. *Comparison of type II nutrients supply from selected protein rich foods*

	Nsenene	Beans	Fish	Meat
	(mg/100g fresh weight)			
Potassium	230	211	86	367
Sodium	104	6	**318**	82
Magnesium	**196**	**25**	1	**19**
Zinc	**10**	0.2	0.1	**7.7**
Phosphorus	**185**	38	30	**187**
Protein	**21 400**	1 830	2 000	**19 250**
Carbohydrates	5100	6 970	400	230
Fat	5500	220	600	3 680

Source: Type II Nutrients (Golden 1995), nutrients potassium (Sirimungkararat 2010), sodium, magnesium, zinc (Blasquez 2012), nsenene phosphorus, carbohydrates, fat (Lukiwati 2010), protein (FAO 2013), beans, fish and meat nutrients (NND, USDA 2016a)

Note: Supply satisfying requirement (for an average child assumed to eat 100-500g fresh weight) in ***bold*** *text. Dry weight nutrient supply for nsenene was converted to fresh weight using a dry weight factor of 32.6% (Nakagaki 1991). An average value was calculated for different species of nsenene (Blasquez 2012).*

Below is the calculation of how many children can be fed by a family collecting nsenene in order to at some extent prevent kwashiorkor and marasmus, assuming that they have sufficient access to cassava or yams.

The protein content of 100 g grasshopper is 21g. A family can collect 50-70 kg fresh weight of grasshoppers weekly (FAO 2013). The interviewee did a rough estimate that the collected nsenene could be around 20 kg fresh weight per week (Kasambula personal conversation, Appendix 1). For the model a collection of 70 kg per week was chosen, as the maximum value given in the article. The measurement in the article might be more accurate than the estimate of the interviewee, however the answer from the interviewee was in line with the FAO article. This means that a family during nsenene season of 7 weeks (Nalwoga et. al. personal conversation, Appendix 2) can collect up to $7 \times 70\ 000g = 490\ 000g$ nsenene in a year or $\frac{490\ 000g}{365} = 1\ 342g$ grasshoppers per day or $1\ 342g\ \times \frac{21g}{100g} = 281.82g$ protein per day. Since a child on average requires 16.95 g protein per day (Table 3) one family can supply up to $\frac{281.82g}{16{,}95g} \approx 17$ children at safe level if collecting 70 kg grasshoppers weekly or 12 children if collecting 50 kg grasshoppers weekly.

In a similar way, the number of children which could be supplied by the other type II nutrients were calculated (Table 5). Because of the low density of potassium, sodium, carbohydrates and fat in nsenene, children need alternative diets, because a child cannot eat so much nsenene that it will be satisfied in those nutrients.

Phosphorus seems to not be sufficient for a large family, so for that nutrient, there might as well be a need for a complementing diet.

However, these requirements are recommendations from USDA. When the amounts of supplied nutrients are so high that they satisfy the requirements, the child will not become ill in kwashiorkor or marasmus. However, if less is supplied, the child does not necessarily get kwashiorkor or marasmus. So for all these nutrients, more children than presented in the table may be supplied without the children necessarily get those diseases. The number of children in the table are safe level amounts where the children for sure will not get kwashiorkor or marasmus.

Table 5. *Number of children which can be supplied type II nutrients satisfying safe level requirements, through nsenene collected by family*

Number of children supplied	50 kg catch	70 kg catch
Potassium	0.9	1.2
Sodium	1.2	1.7
Magnesium	**20**	**28**
Zinc	**27**	**38**
Phosphorus	**4**	**5.7**
Protein	**12**	**17**
Carbohydrates	0.5	0.7
Fat	2.2	3.1

Note: Supply satisfying requirement (for an average child assumed to eat 100-500g fresh weight) in ***bold*** *text. For the values not in bold, the nsenene has too low density of the nutrient and a complementing food is needed in the diet.*

4.4 Sustainability and education

Nsenene in Uganda are collected during rainy seasons spread out over the year summing up to around 7 weeks in total (FAO 2013, Nalwoga et al. personal conversation Appendix 2). They are stored for the whole year by drying, salting, smoking or roasting them. The dried nsenene and other insects may be contaminated with fungal infection, bacteria or pesticide residues, which may reduce their nutritional value (van Huis 2013, Mujuru et al. 2014). To maintain quality, the nsenene can be quickly dried and subsequent stored in cool and dry conditions.

Some storage techniques may be more technically difficult than others. If knowledge about optimal storage techniques is insufficient, education might be helpful, especially if storage techniques are developed further than the knowledge. By storing the nsenene, the availability of type II nutrients can be spread out over the whole year. Thereby the requirement can be met at all times and then nsenene collection will be a sustainable method of supplying type II nutrients to the children.

Other educational subjects could be the importance of the type II nutrients, the causes of the diseases, treatment and prevention of the diseases (Musgrove 1993). If government could develop and offer educational seminars in the villages, people would get knowledge about the diseases and better methods of collecting, preserving and storing nsenene. This study does not know about any existence of governmental nsenene farming education in East Africa.

Since nsenene is collected only during 7 weeks in a year, the storing and preservation is really the weak link in a sustainable contribution of nsenene to prevent kwashiorkor and marasmus. Children need a continuous supply of type II nutrients over the whole year.

Storing nsenene will also contribute to a stable supply of type II nutrients when there are temporary decreases in other type II nutrient sources, like for example beans when there is prolonged drought. This year alone 36 million people in eastern and southern Africa will suffer from drought (Graham-Harrison 2016). This is also important for villages in distant rural areas where the access to type II nutrient sources, like for example fish, is limited.

Since nsenene eat crops, collecting nsenene reduces the amount of nsenene in the local environment so that crops might be preserved (Kasambula personal conversation, Appendix 1). The collectors benefit from nsenene and the farmers may get an increased yield of crops. Crops and nsenene have different densities of different type II nutrients. Collecting nsenene increases the supply of nsenene and perhaps the supply for crops. This might increase the amount of type II nutrients and widen the spectrum of type II nutrients.

With a continuous supply of type II nutrients, children will have energy to live the life of a normal child. Children can for example participate in school, which contributes to give them a sustainable life in higher welfare. This year 3.9 million children in Ethiopia have truncated education because of the drought (Graham-Harrison 2016).

Fewer children will need resources from the hospitals if the number of children ill in kwashiorkor and marasmus decrease. This year Unicef is making plans to treat 2 million children for malnutrition diseases. Unicef explains that “more than 10 million people need food aid” (Graham-Harrison 2016).

The increased welfare from nsenene may lead to a sustainable society where children can not only survive, but also live a healthy life.

4.5 Other insect eating cultures

Caterpillars are collected in some countries in central Africa (Göhler et al. 2004). They are sold fresh on the market. Around 40 % of the animal protein consumed in the Democratic Republic of the Congo comes from caterpillars (Latham 2003). Like nsenene, caterpillars come only seasonally during rain. The collecting season is usually an uninterrupted four-month period. Depending on which geographical region, the period starts at different months (FAO 2013). In central African countries, caterpillar is the main insect consumed by the population.

In Thailand and Vietnam, a large variation of insect species is collected in different time periods of the year. This maintains a steady supply of type II nutrients throughout the year (Viwatpanich 2005). In Thailand over 30 species are eaten and some of them are grasshoppers, ants, beetles, bugs, termites, crickets, spiders, wasps and scorpions.

The variation of insects eaten in Thailand is quite large compared to in central and eastern Africa. Because of this the population in Thailand can obtain a continuous supply of type II nutrients throughout the year, while for example the population of the Democratic Republic of the Congo only obtain type II nutrients from insects during a few months in a year.

In Uganda, termites are also eaten and their nutritional value is so high that they are given to malnourished children (van Huis 2003). If more types of insects could be eaten in East Africa, the important Type II nutrient requirement can be satisfied over the whole year. However, this may be difficult, because even if the East African environment might have a similar variation of insect species as in Thailand, the culture of eating additional types of insects may not yet have been developed. So first of all, it is better to focus on nsenene and the other insects currently eaten in East Africa.

5 Discussion

Since only three collectors were interviewed and none of them had measured the weight of the collected nsenene and only one of them could make an estimation of the weight, the knowledge of the supply is vague. However, it seems like the interviewees' estimations are in line with the research article (FAO 2013). But it is still difficult to see if the collected nsenene is enough to satisfy the requirement of the type II nutrients of the children, because of lack of collection measurements. However, the method used can be extended with more interviews and on field measurements in different areas in developing countries. Different areas are likely to have different density in populations and different amount of nsenene. Even though it has been reported how much a family can gather, it is not clear if the nsenene in the area will be enough if a whole village gather nsenene at the same time.

6 Conclusion

The current research proved that kwashiorkor and marasmus are not necessarily caused by of protein deficiency. Kwashiorkor and marasmus are due to deficiency in any one of the so called type II nutrients, of which protein is one. Poor children in developing countries often eat such an unvaried diet, that a deficiency in any of the type II nutrients can occur. This deficiency decreases the appetite so that the body starts stunting and wasting. The decrease in appetite leads in turn to further deficiency in type II nutrients, which leads to a vicious circle until the child gets kwashiorkor or marasmus.

It was found that nsenene contain the required type II nutrients which poor children in the developing countries usually miss. Kwashiorkor and marasmus could at some extent be prevented by including nsenene in the diet and every family could, on average, supply themselves with enough nutrients by collecting nsenene in combination with other staple foods like yams or cassava root. The diet would be more varied if the children ate nsenene as staple food.

Some children in poor areas in developing countries miss type II nutrient rich food because it may be sold on the market or consumed by older family members with higher cultural status. Perhaps an increased wealth in nsenene could supply children with a more varied diet containing more type II nutrients.

By storing and preserving nsenene properly, a continuous supply of type II nutrients can meet the requirement for the whole year. Education in the importance of the type II nutrients, the causes of the diseases, treatment and prevention of the diseases, collecting technologies and storage technology may lead to a sustainable health among children.

Nsenene can not cure kwashiorkor or marasmus, because treating a child with the wrong nutrients, like for example protein, can lead to death. A child suffering from kwashiorkor or marasmus needs a very special diet.

7 Further Research

7.1 Breeding of Nsenene

It would be possible to do research about developing a new method of breeding nsenene, so that it could be reproduced and available all over the year. Insects can breed more quickly than other protein sources. Perhaps a special indoor facility could make them breed faster and throughout the whole year.

7.2 Crossbreeding of Nsenene

Cross breeding, which would be faster for insects than for plants or higher animals, could optimize the nutritional output per time period. This would increase the utility for the children.

7.3 Proper Storage of Nsenene

Live nsenene is only seasonally available. By developing proper storage methods, the nsenene could be available for a larger part of the year. Some examples are; electricity cooling, underground cooling, sun drying, salting and better packaging like vacuum packaging or canning could be developed. Furthermore, a better infrastructure, like for example electricity could be used for both cooling and collecting. Other infrastructure improvements could be roads for transport during rainy seasons, which could improve the handling of the insects.

7.4 Final Remarks

It would be valuable to compare the production costs of nsenene with other nutritional sources like meat, fish or beans.

Nsenene could be promoted through consumer marketing it in both developing countries and developed countries. The nsenene could be packaged in an attractive way, with a list of nutritional contents, so that people understand why it is important to eat nsenene. It could also be promoted so that it is eaten as staple food and not only as a cultural dish or a snack. It could also be promoted to politicians and established manufacturers of food.

If humans start consuming more nsenene, there might be a change in the ecological system. There might be a reduction in nsenene so that other animals will suffer. Since nsenene eat the harvest and other plants, the harvest might suffer less from a reduction in nsenene and the humans will gain from more crops. The ecological food chain is complicated and could be researched.

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Appendix

1 Interview with Sadyq Kasambula

A personal conversation was performed with Sadyq Kasambula the May 5 2016.

1.1 Methods of collecting nsenene

Q: "Please explain the method(s) used for catching nsenene?"

A: “The methods used for catching nsenene are depending on the purpose, for example if it’s for a domestic use or if it is a business. If it’s for domestic use, one can use cloth spread of the grass in order to attract nsenene so that they lose their ability to fly during day light. If you are collecting nsenene for business you need artificial light which is very strong also known as LED light. You place the light to attract nsenene by night and the heat of the light weaken them and they fall into a bucket. With LED you get many during nsenene season.”

Q: "What are the advantages for collecting nsenene for you and the society?"

A: “The advantages are both economical and nutritional for those who need it most. Catching nsenene helps to preserve crops, because nsenene are the insect which eats almost any green crops.”

Q: "What are the challenges you are facing while collecting nsenene?"

A: “If collecting nsenene during the day, there is a chance of coming in contact with a poisonous snakes, since both snakes and nsenene are locate in the grass during the days. With LED light, there is a chance of damaging the eyes, since the LED is very strong.”

1.2 Quantity of collected nsenene in an area

Q: "How much nsenene can you gather for the whole year?"

A: “For economical use it’s possible to catch 1 tonne per week, while for domestic use 20 kg a week during season.”

Q: "Have you measured the weight of the collected nsenene in kg or can you estimate how much it can be in kg?"

A: “No I have not measured it”

1.3 Equipment

Q: "Please explain the equipment you use while catching the nsenene? "

A: “Strong LED light, cloth and smoke which make the nsenene too weak to fly, so that they fall and are easy to collect.”

2 Interview with Deborah Nalwoga and Edward Serwanja

A personal conversation was performed with Deborah Nalwoga and Edward Serwanja the May 5 2016.

2.1 Methods of collecting nsenene

Q: "Please explain the method(s) used for catching nsenene?"

A: “Hand picking method when using hands to pick the current demand from grass and on tree branches. Hand picking during daylight is cheaper than during night [because of electricity during night], but relatively few are collected compare to the method using light during night. These light attract nsenene at night and a huge amount is collected. With the strong light method, roofing sheets are used with water drums [water containers without water] for collecting the catch [for the nsenene not to fly up again]. The sheets are put on to the empty drums with a strong light up and when the nsenene come from light they slid off the iron sheet into the drum where it’s collected and put into sacks for selling.”

Q: "What are the advantages for collecting nsenene for you and the society?"

A: “Source of income. Provide meal by eating them as food. Use as animal feed, for example feeding of chicken and pigs. Source of revenue to the government since it collects taxes from nsenene traders. Tourist attraction where people from different parts of the world come to have a look at nsenene where government gets revenue, hence development. Nsenene has led to expansion of electricity in rural areas, since it´s one of materials used for catching them. There has been development of infrastructure like roads and hotels in places like Masaka where nsenene traders stay during its period, hence development.”

Q: "What are the challenges you are facing while collecting nsenene?"

A: “Electricity get off at night. They are seasonal so not dependable. Then nsenene seasons are spread out during the year and they are in total around 7 weeks. Poor road to transport them to the market, hence when they delay they get spoilt. Heavy taxes collected from traders by government. Poor government policy of not planning for nsenene traders like creating market. Expensive to preserve since they need cold room to keep them fresh. Accidents caused by electricity shocks which leads to loss of lives.”

2.2 Quantity of collected nsenene in an area

Q: "How much nsenene can you gather for the whole year?"

A: They don’t know.

Q: "Have you measured the weight of the collected nsenene in kg or can you estimate how much it can be in kg?"

A: They have not.

2.3 Equipment

Q: "Please explain the equipment you use while catching the nsenene? "
A: See method