

# How linear programming can help improve diets and foods

*Cost Action FoodMC  
Lisbon, March 2017*



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# MS-Nutrition



-Start'up founded in February 2014



-Located in Marseille

-Hosted in a research laboratory of nutrition, in the faculty of medicine La timone (Marseille)



-Technology transfert: rent of informatic license



-Our partners: public research institutes and universities, private stakeholders



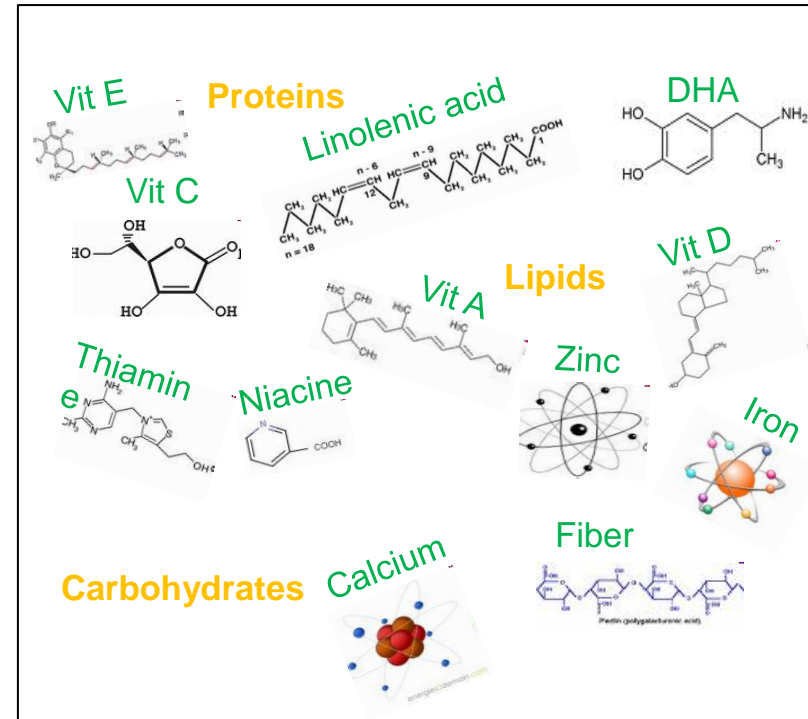
# Background

We eat FOODS...



BUT

We need nutrients



=> Recommended dietary allowances

=> Maximum Recommended Values  
for saturated fats, free sugars, sodium

# Background

We eat FOODS...



BUT

We need nutrients

## Nutrition Facts

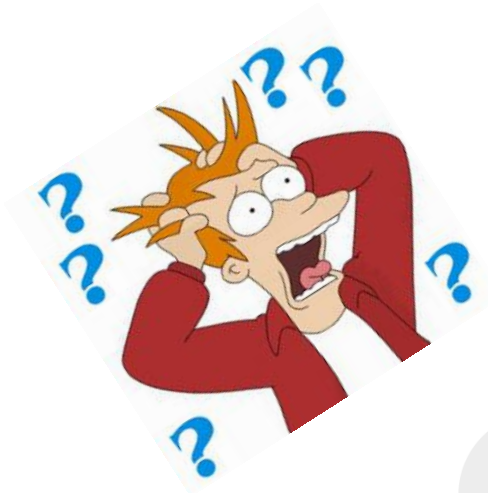
Serving Size 1 muffin

Servings Per Container 2

**Amount Per Serving**

**Calories 250**    **Calories from Fat 110**

	% Daily Value*
<b>Total Fat 12g</b>	<b>18%</b>
Saturated Fat 3g	15%
<b>Cholesterol 30mg</b>	<b>10%</b>
<b>Sodium 470mg</b>	<b>20%</b>
<b>Total Carbohydrate 31g</b>	<b>10%</b>
Dietary Fiber 3g	12%
Sugars 5g	
<b>Protein 5g</b>	



How help people to improve the nutritional quality of their diets?

# Levers of change: make healthier food choices

## Nutrient profiling

*science of classifying or ranking foods according to their nutritional composition for reasons related to preventing disease and promoting health*

WHO website

Food labeling



Promotion of food



Food (re)formulation



## Food based dietary guidelines

*advice on foods, food groups and dietary patterns to provide the required nutrients to the general public to promote overall health and prevent chronic diseases.*

FAO website



# No bad foods, only bad diets

## Relationship of nutrient profiling to food-based dietary guidelines

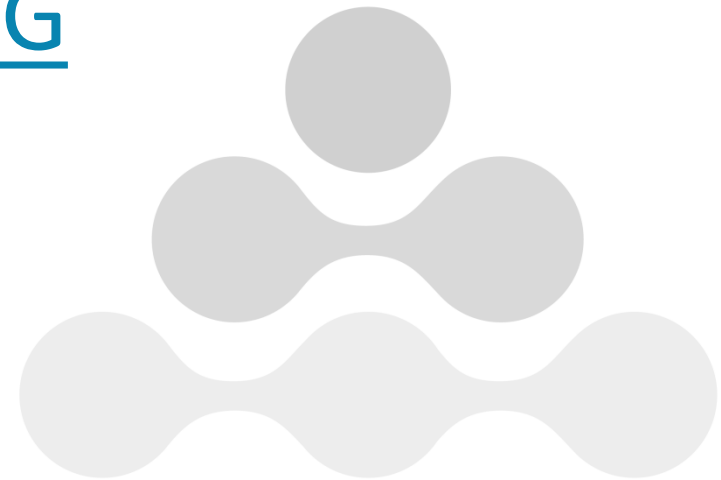
**Food-based dietary guidelines** are recommendations for **healthy eating, framed in terms of foods and food patterns**. **Nutrient profile** models **classify foods based on their nutrient composition**, and this information can be used to help in achieving dietary recommendations. Thus, **nutrient profile models need to complement and support food-based dietary guidelines in the regions or countries in which they are applied.**

*World Health Organisation, 2010*

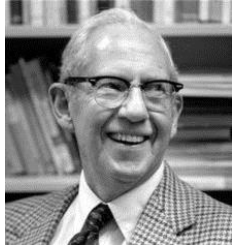
« the total diet or overall pattern of food eaten is the most important focus of healthy eating. **All foods can fit within this pattern** if consumed in moderation with appropriate portion size and combined with physical activity ».

*Academy of Nutrition and Dietetics, 2014*

# Why linear programming is a well adapted tool to derive and validate nutrient profiles and FBDG

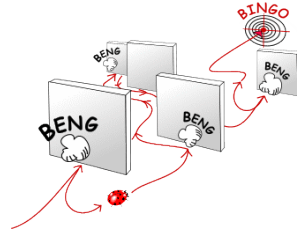


# Linear programming was born to solve a problem related to nutrition



“How much of 77 foods should be eaten on a daily basis so that a man’s intake of nine nutrients will be at least equal to the recommended dietary allowances (RDAs) with the cost of the diet being minimal?”

*George Stigler, the cost of subsistence, 1945*



Stigler diet problem  
Use of trial and errors method  
**39.93\$/year**



1947:discovered the simplex method (the heart of linear programming) and applied it to define a low cost diet that would meet the nutritional needs of a GI soldier



Application of the simplex algorithm to the Stigler diet problem (Laderman, 1948)  
**39.69\$/year**



# Principle of Linear Programming in diet modelling

## 1. Foods and Data = Variables

- List of 77 foods 
- Nutritional composition (8 nutrients), energy, price

## 2. Targets = mathematical constraints

- On **nutrients**:
  - nutrient-based recommendations RDA

## 3. Specific question = objective function

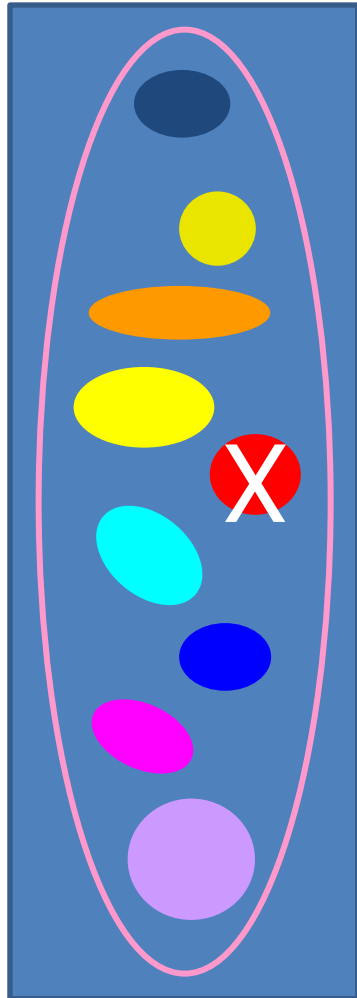
Minimum Diet cost?

## 4. OPTIMISATION

selection of foods and their weight to achieve all constraints:



# Evolution of diet modelling in the 70's-Minimizing the departure from an existing diet (The thrifty food plan)



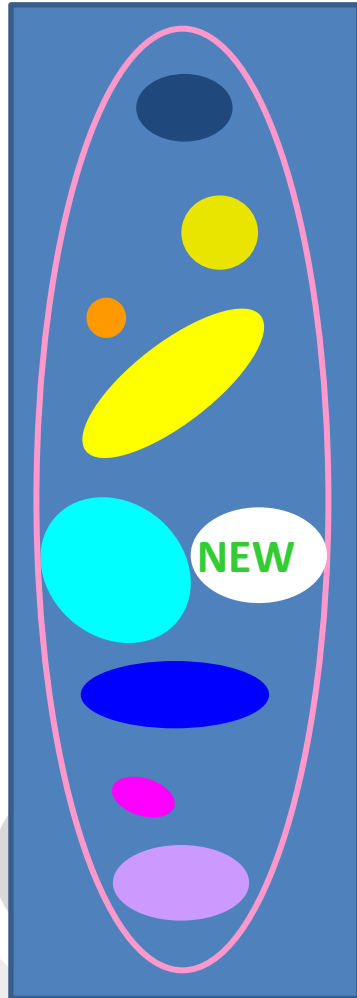
**Observed diet**

current average consumption of low-income Americans

**Variables**  
Consumed foods and their quantities,  
New foods if needed

**Constraints**  
Iso Energy  
Nutrient recommendations  
Maximal quantities of foods and food groups, and max total diet weight  
Cost, and/or any other food-related characteristic

**Objective function & optimization**  
Minimal departure from the observed diet




**Optimized diet**

nutritionnally adequate & socially acceptable

# Evolution of diet modelling in early 2000- incorporating additional information

## 1. Foods and Data = Variables

- List of foods 
- Nutritional composition (more than 30 nutrients), price
- toxicological content, carbon impact...

## 2. Targets = mathematical constraints

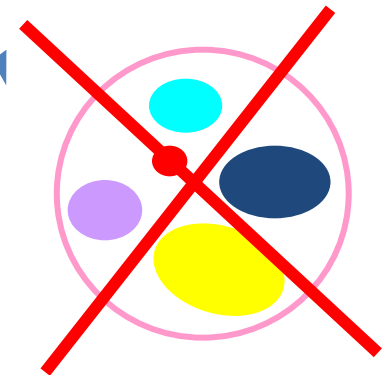
- On **nutrients**:
  - nutrient-based recommendations as EARs or RDAs
- On **foods** :
  - food-based recommendations as MyPyramid
  - dietary habits at individual or population level (maximal amount, portion size, balance between food-groups...)
- Others :
  - diet cost, total weight, total energy ...

## 3. Specific question = objective function

Minimum Diet cost? Minimum energy needed? Minimum deviation from an existing food basket?

## 4. OPTIMISATION

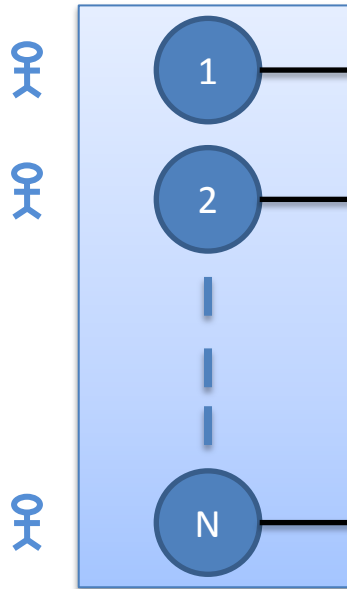
selection of foods and their weight to achieve all constraints:



Solution may be infeasible ....

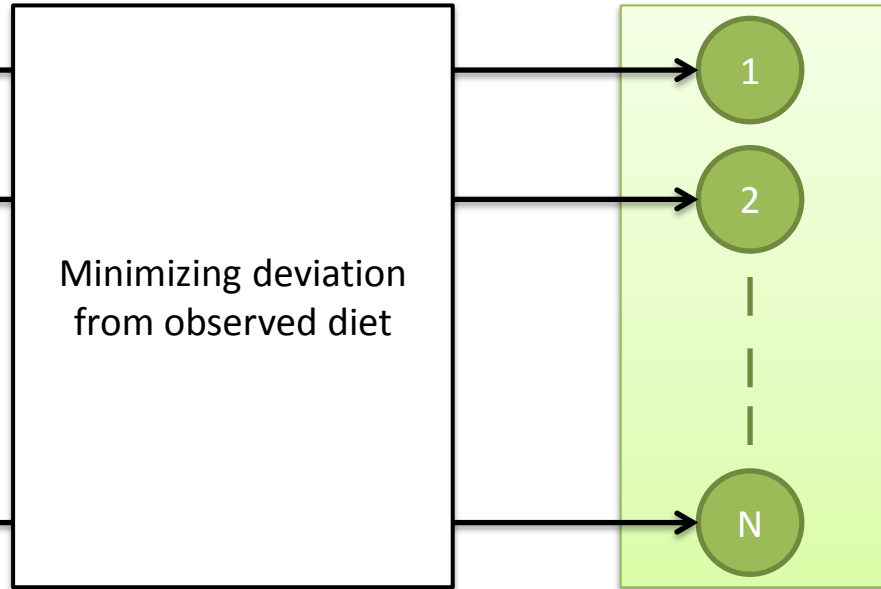
# Evolution of diet modelling in early 2010- individualisation

Individual observed diets

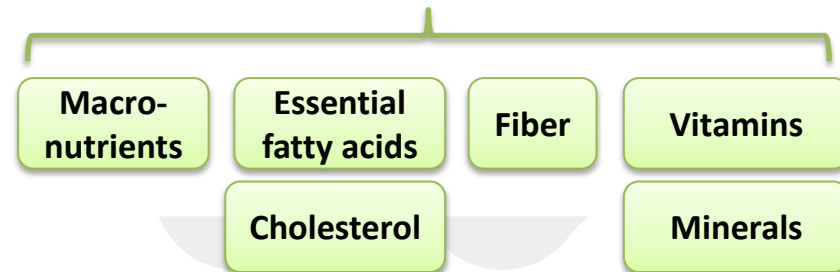


*Inadequate intakes*

Individual optimized diets



*Adequate intakes*



# Illustrations of how LP can be used to:

## ➤ Develop dietary guidelines

Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices<sup>1-3</sup>

*Matthieu Maillot, Florent Vieux, Marie Josèphe Amiot, and Nicole Darmon*

## ➤ Test nutrient profiling systems

Quantifying the contribution of foods with unfavourable nutrient profiles to nutritionally adequate diets

Matthieu Maillot<sup>1,2</sup>, Adam Drewnowski<sup>3</sup>, Florent Vieux<sup>1,2</sup>, and Nicole Darmon<sup>1,2\*</sup>

## ➤ Identify the role of a given food in a healthy diet



*Article*

**Role of Young Child Formulae and Supplements to Ensure Nutritional Adequacy in U.K. Young Children**

Florent Vieux<sup>1,\*</sup>, Chloé M. C. Brouzes<sup>2</sup>, Matthieu Maillot<sup>1</sup>, André Briend<sup>3,4</sup>, Régis Hankard<sup>5</sup>, Anne Lluch<sup>2</sup> and Nicole Darmon<sup>6</sup>

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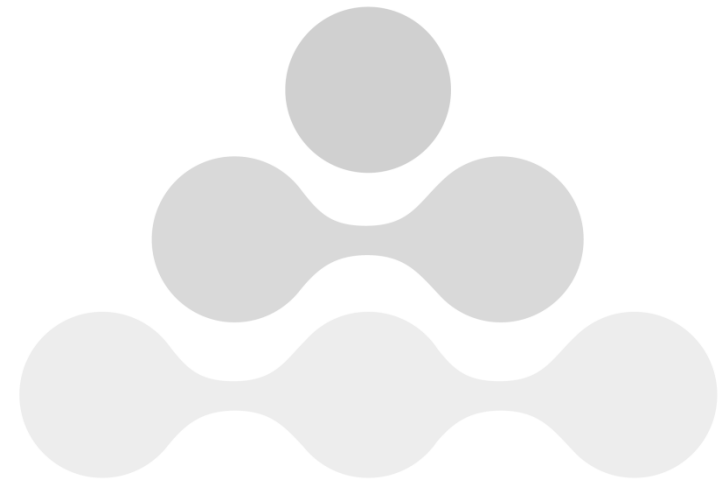


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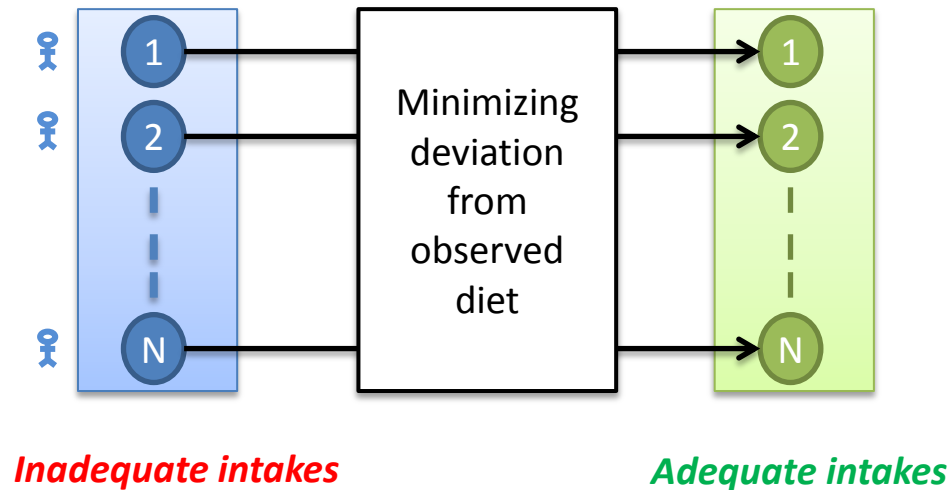
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What kind of foods are needed to reach  
nutrient goals ?



# Method

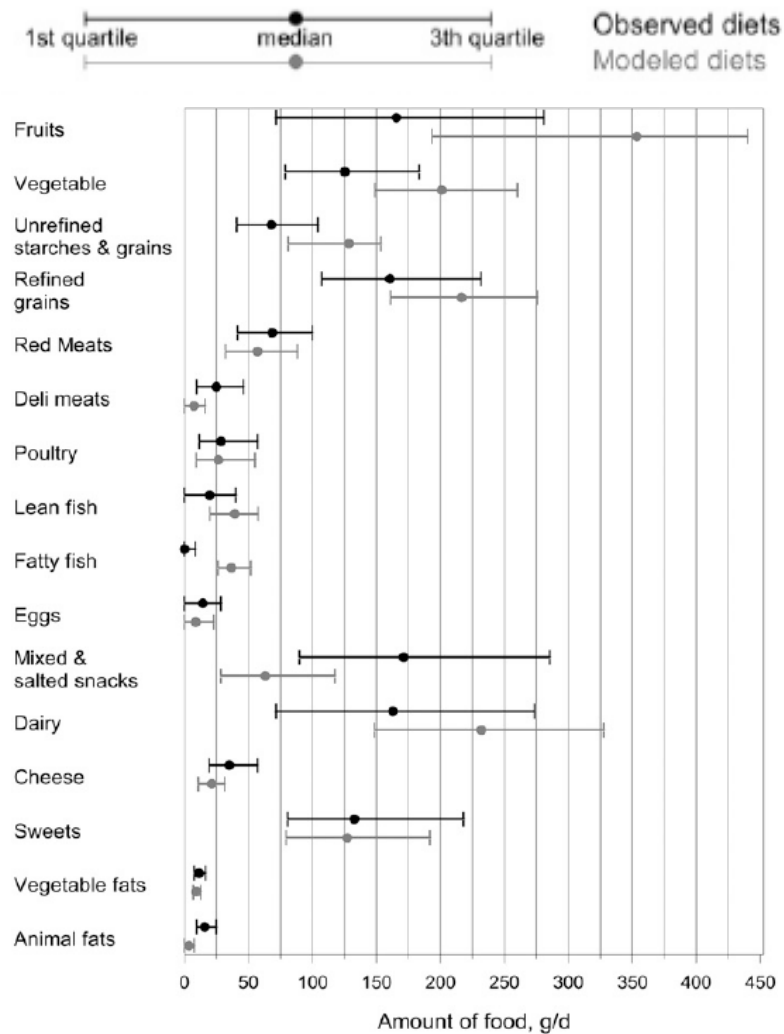
Application of individual diet modelling to a national representative sample of French adults



Comparison of the quantities of foods between observed and optimized diets



# Results



There are as many different optimized diets as the number of observed diets (here n= 1171)

General tendencies: Increase in **Plant-based foods, fish and fresh dairies** and decrease **deli meat, cheese & animal fats**

In accordance with food based dietary guidelines

Added value: take individual preferences into account -> better adherence by the population

# Illustrations of how LP was used to:

- Develop dietary guidelines

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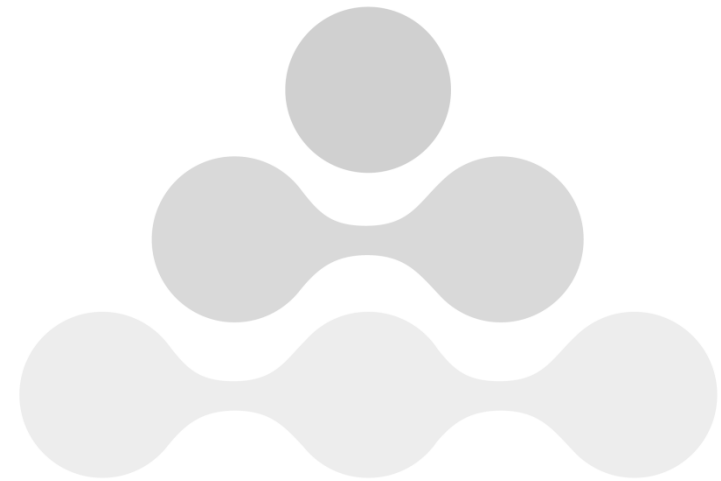


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# How foods with different nutrient profiles fit in nutritionally adequate diets?



# Individual Diet Modelling and Nutrient Profile

## SAIN, LIM system

Darmon et al. AJCN 2009

SAIN  
(%/100kcal)

$$SAIN_i = \frac{\sum_{p=1}^{p=5} ratio_{ip}}{5} \times 100$$

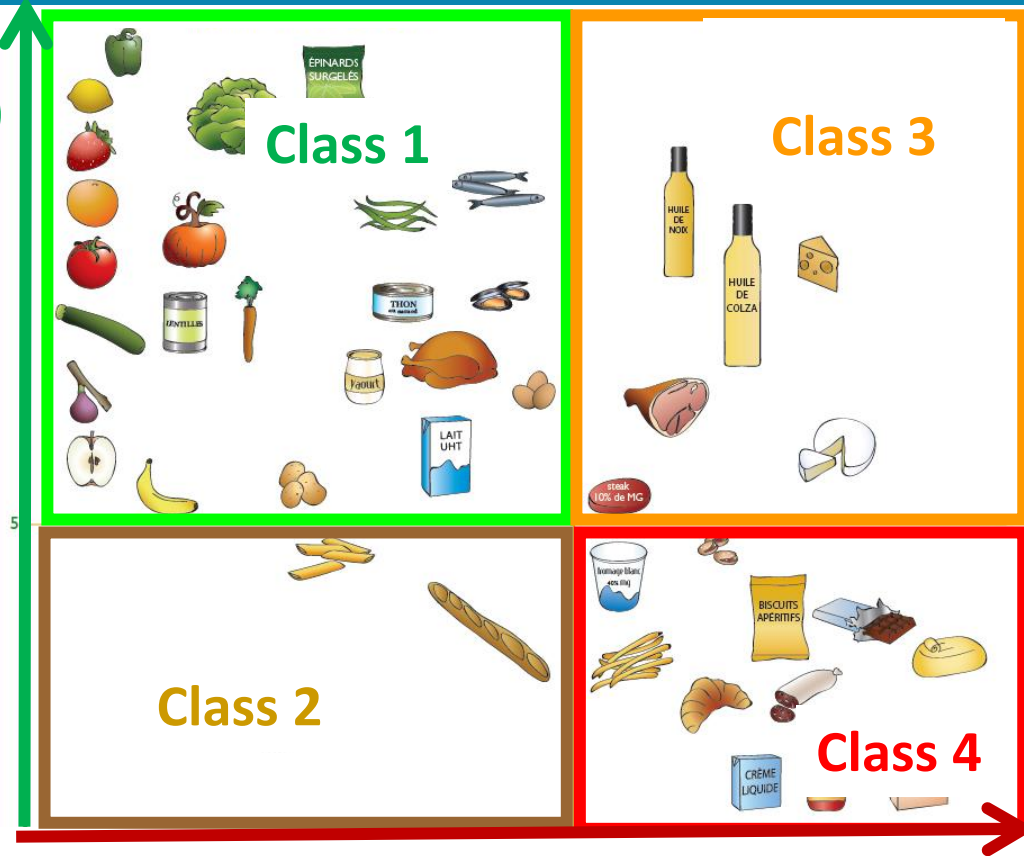
$$ratio_{ip} = \frac{nutrient_{ip}}{Recommended\ Value_p} \times \frac{100}{E_i}$$

-> Reflects the positive aspects of foods

$$LIM_i = \frac{\sum_{l=1}^{l=3} ratio_{il}}{3}$$

$$ratio_{il} = \frac{nutrient_{il}}{Maxi\ Recommended\ Value_l} \times 100$$

-> Reflects the negative aspects of foods

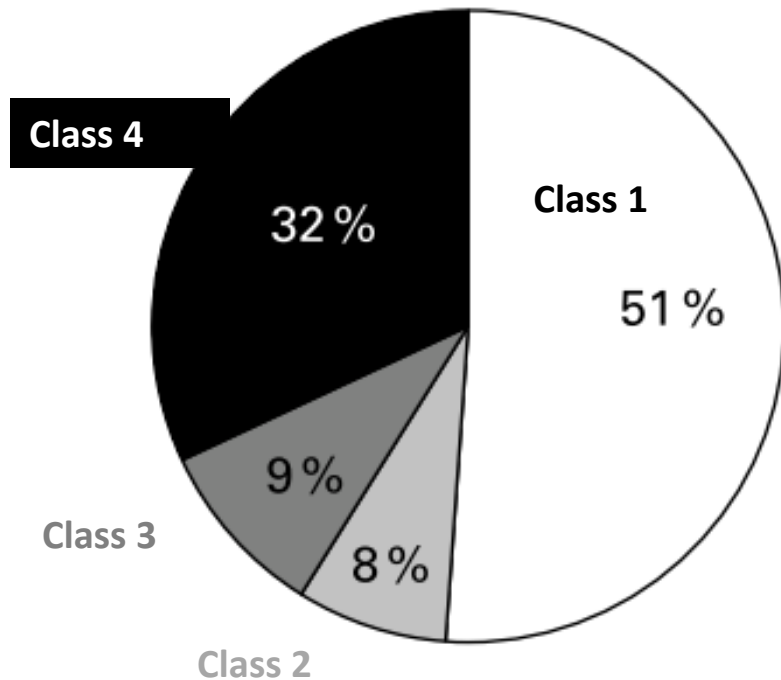


LIM  
(%/100g)

# Individual Diet Modelling and Nutrient Profile

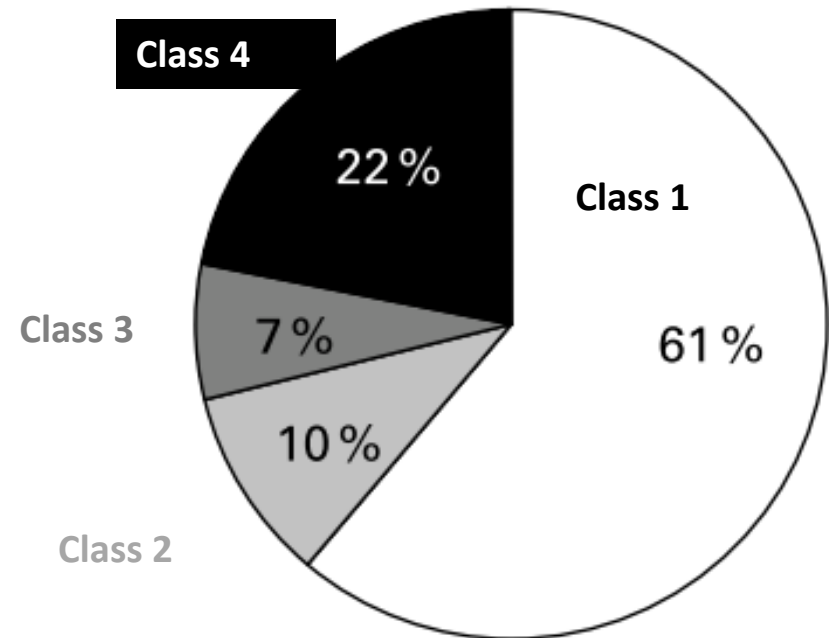
## How foods fit in a nutritionally adequate diet

(b) Observed diets



**Contribution to total weight, %**

Optimised diets



**Contribution to total weight, %**

# Illustrations of how LP was used to:

- Develop dietary guidelines

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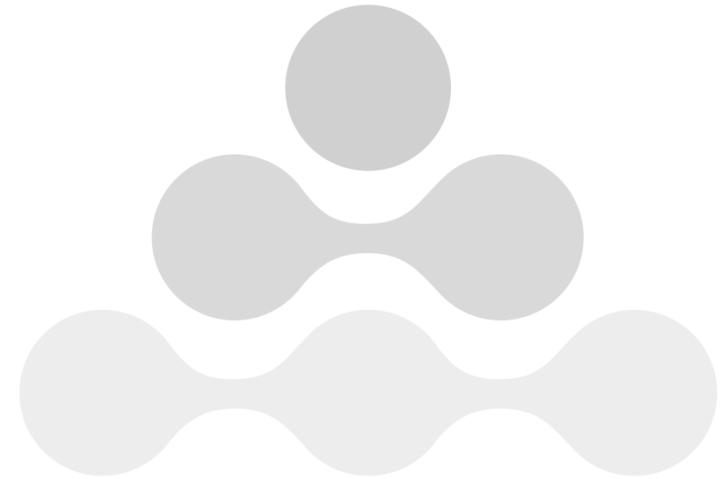
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# What role for young child formulae (YCF) in nutritionally adequate diets?



# Background:

In the UK, more than 60% of 12-18 months old young children do not consume neither young child formulae, nor supplement

Consumption of...		...young child formulae (YCF)?	
		Yes	No
...Supplement?	Yes	YCF & Suppl (3%)	no YCF Suppl (5%)
	No	YCF no Suppl (30%)	no YCF no Suppl (62%)

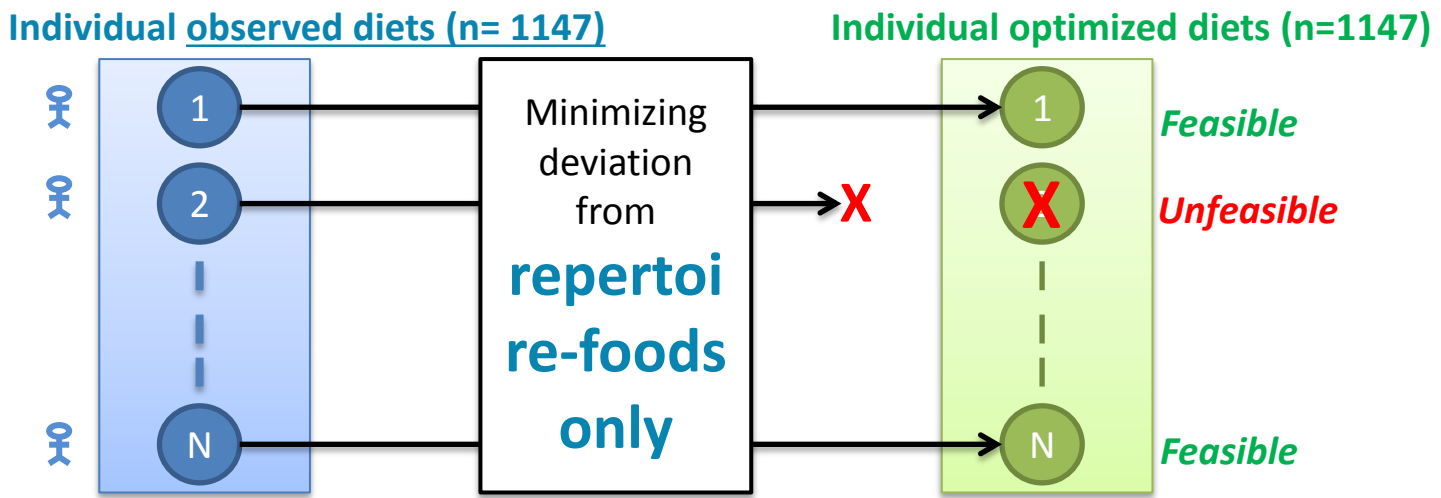


In this context,

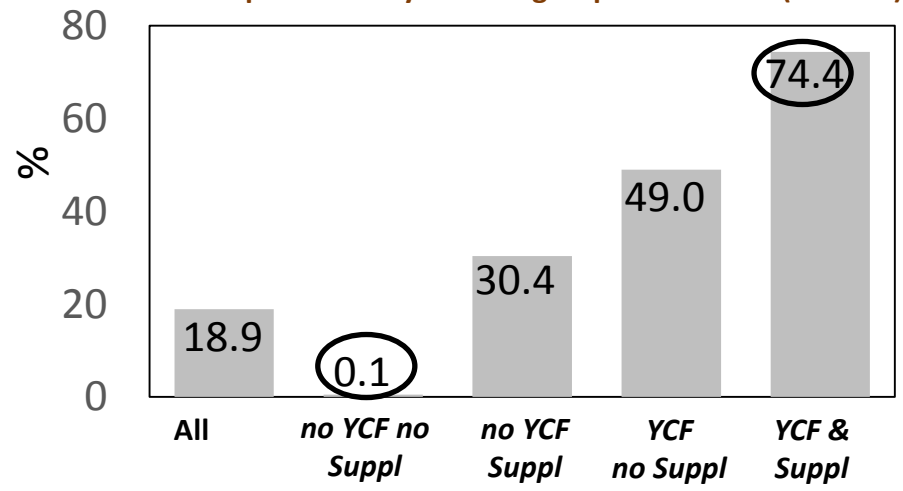
- Is the consumption of YCFs and/or supplements strictly necessary to ensure nutritional adequacy?
- What are the dietary changes needed to meet nutritional adequacy?



# Use of individual diet modelling to estimate the role of YCF for meeting nutrient adequacy



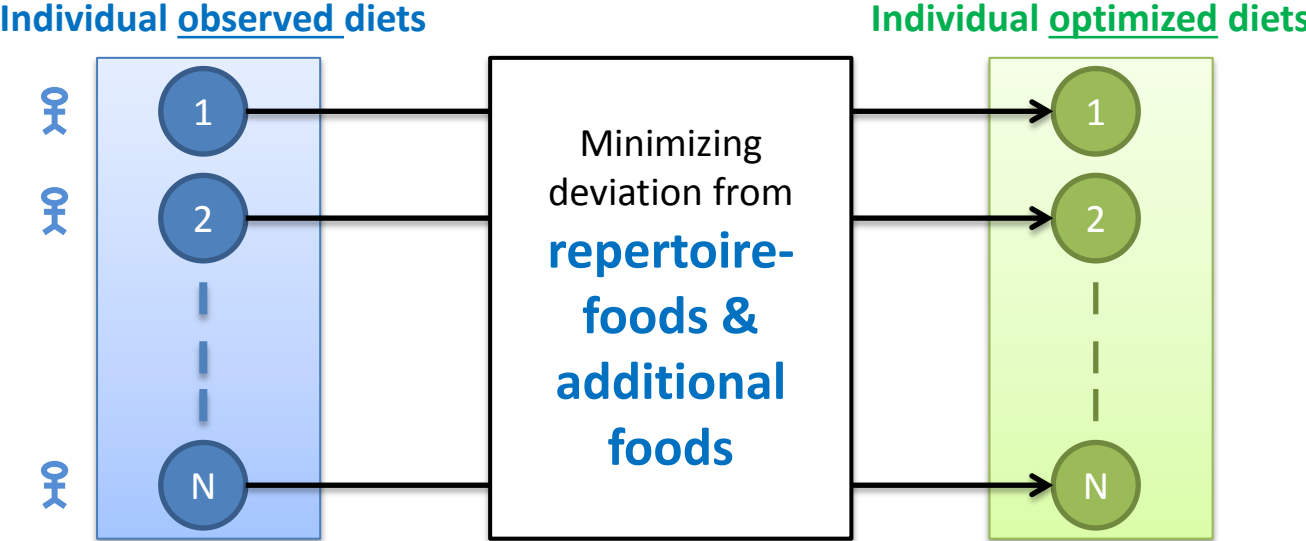
Percentage of children for whom it is possible to model a nutritionally adequate diet from their food-repertoire only in the 4 groups of children (N=1147)



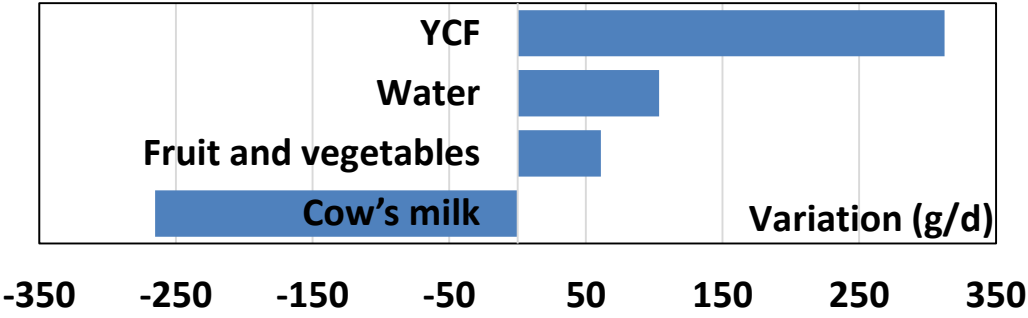
Only 1 children out of the 707 'no YCF no Suppl' could meet nutrient requirements with his/her repertoire-foods only (without introducing YCF or Suppl)

YCF and/or supplement consumption increased the feasibility of modelling a nutritionally adequate diet

# Use of individual diet modelling to estimate the role of YCF for meeting nutrient adequacy



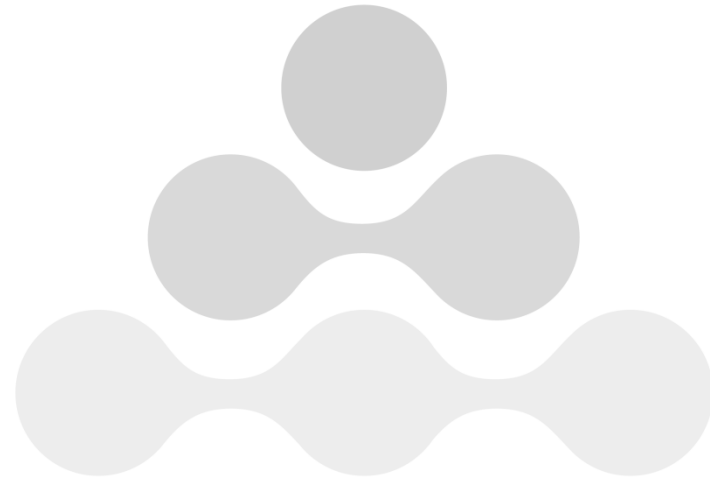
Main mean variations between modelled and observed diets in the 'no YCF no Suppl' group of children (N=707)



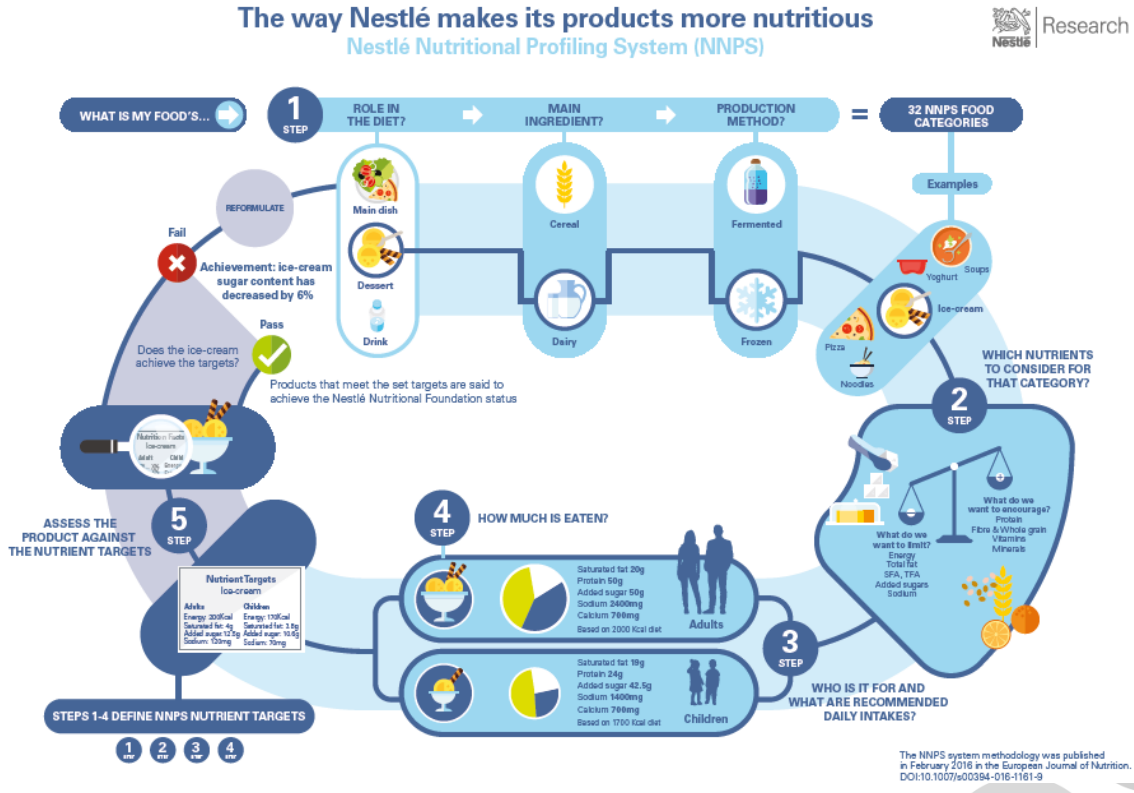
With access to all foods, **all nutrient recommendations could be met for all children** (ie, 100% feasibility)

**In the No/No group**, in average, **313g/d of YCF** and **0.82g/d of supplements** were needed to meet nutrient requirements; as well as a **decrease of 265g of cow's milk** and an **increase of 61g of fruit&veg**.

# How to apply LP at the food level in order to improve nutritional quality of the offer?



# Example: The Nestlé Nutritional Profiling System for reformulation of food products



It looks like a trial and errors methodology... Does it remind something to you?

The Stigler approach!

Would it be possible to use LP?

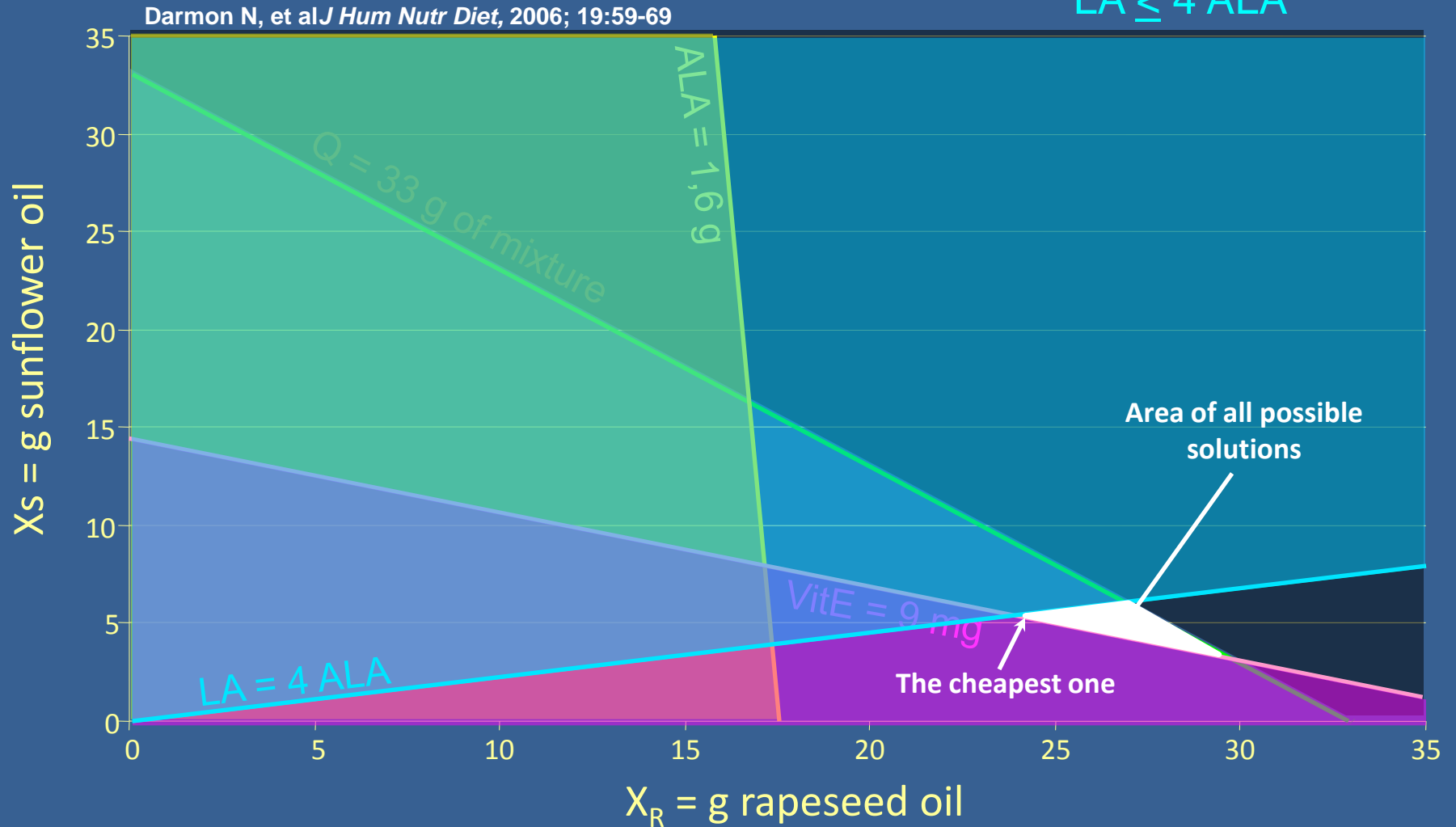
# Graphical illustration of an oil mixture

$$Q \leq 33 \text{ g of mixture}$$

$$ALA \geq 1.6 \text{ g}$$

$$\text{Vit E} \geq 9 \text{ mg}$$

$$LA \leq 4 \text{ ALA}$$



# Reformulation of foods (for humans) is not so simple

Cost  
Quality and consumer acceptance  
Taste  
Food safety  
Processing  
Nutritional composition of ingredients

**We are at the very beginning of the work on this subject**

**Any help is welcome!**

# Discussion

Linear programming was found to be a powerful tool  
to solve the historical « diet problem »  
to help in public health nutrition

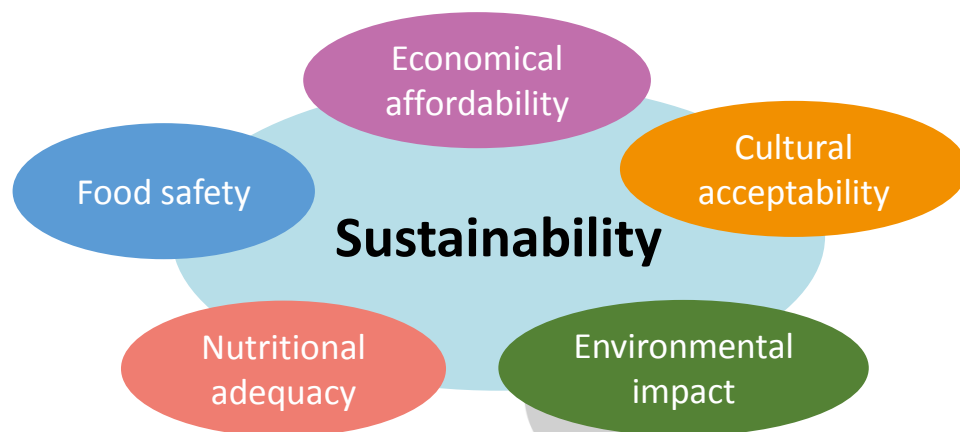
It evolved with the rise of information on food consumption (**dietary surveys**) and on  
**nutrient content**

It is able to take many dimensions into account:

**Toxicological contents**

**Carbon footprint**

**Price...**



I would be happy to discuss the way of applying LP (or an other approach) in the field of  
food reformulation

# Thanks for your listening



Nicole Darmon, PhD



Matthieu Maillot, PhD



Marseille

