Mycoprotein:
The Food for the Future?

Andy T. Kusumo PhD
Director of Science and Technology
MONDE NISSIN SINGAPORE PTE LTD
1998

Collapsing Currencies
(Against USD; July 1, 1997=100)

- Thailand
- Korea
- Indonesia
- Philippines
- Malaysia
- Taiwan
- Singapore

Time and chance

1998

Purdue University
BSc in Chem. Eng.

Cornell University
Master of Engineering in ChE (Bioeng.)

MSD
Pharmaceutical

AMGEN
Biopharmaceutical

Carnegie Mellon University
PhD in ChE

Monde Nissin
Food / Biotechnology
In October 2015, Monde Nissin purchased the Quorn Foods business. I am incredibly proud of this. The vision of Monde Nissin is to build a business respectful of our planet as well as contributing to improved public health and food security. Quorn will play a big part in this journey. We want to increase availability of Quorn products around the world, investing in further improving their outstanding sustainable qualities. We are confident that by making meat reduction easier for consumers, there will be a continual shift toward healthier options especially in countries where consumption levels are unsustainable. In essence, we’re passionate about bringing leadership and commitment to the sustainable food community.

Henry Soesanto, CEO Monde Nissin Corporation
Today

1. Humankind: Our Food journey

2. Mycoprotein Story

3. Our Future
Humankind: Our Food Journey
Population and GDP

World Population
Projected world population until 2100

1990: 5.3 billion
2015: 7.3 billion
2030: 8.5 billion
2050: 9.7 billion
2100: 11.2 billion

Source: United Nations Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2015 Revision
Produced by: United Nations Department of Public Information

World GDP Per Capita

Data Source: The World Bank
Population and Supply of Animal Protein

Indexed

400

300

200

100


Meat Supply

Population

FAO 2012a, UN 2012
Global Demand for Animal Protein

2005 vs. 2050
(in tonnes)

Source: Food and Agriculture Organization of the United Nations, ESA Working Paper No. 12-03, p. 131
Growth of Animal Protein Consumption

- Faster growth for rising economy (Brazil, China, Indonesia, etc)
Meat consumption vs. GDP per capita, 2013

Average meat consumption per capita, measured in kilograms per year versus gross domestic product (GDP) per capita measured in 2011 international-$s. International-$s corrects for price differences across countries. Figures do not include fish or seafood.
Stress on Natural Resource

Land

When it comes to land use around the world, cows are the real hogs. They use 86% of the energy from agricultural land but account for only 8% of the food we eat.

Cows are the real hogs.

Water

- 650 Liters of water for 1 kg of Wheat
- 7000 Liters of water for 1 kg of Steak

“...raising meat takes a great deal of land and water and has a substantial environmental impact. Put simply, there’s no way to produce enough meat for 9 billion people”

- Bill Gates, Future of Food (2013)
Stress on Planet

Livestock production being the second highest contributor to greenhouse gases

https://www.scientificamerican.com/slideshow/the-greenhouse-hamburger/
Growing Obesity

Prevalence of obesity in adults by region

The prevalence of obesity in adults, measured as the percentage of adults aged 18 years and older (both male and female) with a body-mass index (BMI) greater than 30 kilograms per metre squared.

Source: UN Food and Agricultural Organization/WHO

OurWorldinData.org/obesity/ • CC BY-SA
Obesity in Asia

Overweight populations in Southeast Asia

Overweight prevalence (%) for adults of both sexes (BMI of > 25 kg/m²)

Cambodia 12.1
Indonesia 21
Laos 13.3
Malaysia 44.2
Myanmar 18.4
Philippines 26.5
Singapore 30.2
Thailand 32.2
Vietnam 14.1

Source: WHO Non-Communicable Diseases Country Profiles, 2011

Growing Diabetes

The Unrelenting March Of Diabetes
% prevalence and number of adults with diabetes by WHO region in 1980 and 2014*

Region of the Americas
- 1980: 5.0% (18m)
- 2014: 8.3% (62m)

Eastern Mediterranean Region
- 1980: 5.9% (6m)
- 2014: 13.7% (43m)

European Region
- 1980: 5.3% (33m)
- 2014: 7.3% (64m)

Western Pacific Region
- 1980: 4.4% (29m)
- 2014: 8.4% (131m)

South-East Asia Region
- 1980: 4.1% (17m)
- 2014: 8.6% (96m)

African Region
- 1980: 3.1% (4m)
- 2014: 7.1% (25m)

Total
- 1980: 4.7% (108m)
- 2014: 8.5% (422m)

* Millions of people and % of total regional population
Source: World Health Organization

Complications
- Amputation
- Blindness
- Heart Attack
- Kidney Dialysis
- Diabetic Coma
- Stroke

Table 1. Top 10 Countries in Asia With the Highest Number of Persons With Type 2 Diabetes and Impaired Glucose Tolerance in the Age Group 20 to 79 Years in 2007 and Projected Data in 2025a

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>40 850</td>
<td>69 882</td>
<td>35 906</td>
<td>56 228</td>
</tr>
<tr>
<td>China</td>
<td>39 809</td>
<td>58 270</td>
<td>64 323</td>
<td>79 058</td>
</tr>
<tr>
<td>Japan</td>
<td>69 78</td>
<td>71 71</td>
<td>12 891</td>
<td>12 704</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>38 48</td>
<td>74 16</td>
<td>68 19</td>
<td>10 647</td>
</tr>
<tr>
<td>Korea</td>
<td>30 74</td>
<td>41 63</td>
<td>32 24</td>
<td>42 40</td>
</tr>
<tr>
<td>Thailand</td>
<td>3 162</td>
<td>4 660</td>
<td>1 896</td>
<td>2 399</td>
</tr>
<tr>
<td>Philippines</td>
<td>30 55</td>
<td>55 72</td>
<td>4 410</td>
<td>7 582</td>
</tr>
<tr>
<td>Indonesia</td>
<td>28 87</td>
<td>51 29</td>
<td>14 144</td>
<td>20 597</td>
</tr>
<tr>
<td>Malaysia</td>
<td>15 30</td>
<td>27 43</td>
<td>2 915</td>
<td>4 442</td>
</tr>
<tr>
<td>Vietnam</td>
<td>12 94</td>
<td>25 00</td>
<td>1 175</td>
<td>1 902</td>
</tr>
<tr>
<td>Subtotalb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Pacific</td>
<td>66 993</td>
<td>99 401</td>
<td>111 898</td>
<td>142 693</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>46 549</td>
<td>80 341</td>
<td>45 169</td>
<td>70 525</td>
</tr>
<tr>
<td>Grand total Asiab</td>
<td>113 536</td>
<td>179 742</td>
<td>157 067</td>
<td>213 218</td>
</tr>
</tbody>
</table>

aSource: International Diabetes Federation.2 All values are in thousands.
bIncludes numbers from Asian countries not shown here.

Diabetes in Asia Epidemiology, Risk Factors, and Pathophysiology

Juliana C. N. Chan, MBChB, MD; Vasanti Malik, MSc; Weiping Jia, MD, PhD; et al; Takashi Kadowaki, MD, PhD; Chittaranjan S. Yajnik, MD, PhD; Kun-Ho Yoon, MD; Frank B. Hu, MD, PhD

JAMA. 2009;301(20):2129-2140. doi:10.1001/jama.2009.726
Diabetes: Thailand and Singapore

**Thailand**

<table>
<thead>
<tr>
<th>Prevalence of diabetes and related risk factors</th>
<th>males</th>
<th>females</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>9.1%</td>
<td>10.1%</td>
<td>9.6%</td>
</tr>
<tr>
<td>Overweight</td>
<td>27.7%</td>
<td>35.4%</td>
<td>31.6%</td>
</tr>
<tr>
<td>Obesity</td>
<td>6.1%</td>
<td>12.1%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Physical inactivity</td>
<td>12.8%</td>
<td>16.4%</td>
<td>14.6%</td>
</tr>
</tbody>
</table>

http://www.who.int/diabetes/country-profiles

**Singapore**

1 in 3 Singaporeans has a lifetime risk of developing diabetes

Singapore has the second-highest proportion of diabetes among developed nations

Estimated by 2050, as many as a million Singaporeans may suffer from diabetes - that would mean 1 in 6 Singaporeans
Childhood obesity is one of the most serious public health challenges of the 21st century.

The prevalence has increased at an alarming rate.

Almost half of all overweight children under 5 lived in Asia and one quarter lived in Africa.

Globally, in 2016 the number of overweight children under the age of five, is estimated to be over 41 million.

Overweight and obese children are likely to stay obese into adulthood and more likely to develop noncommunicable diseases like diabetes and cardiovascular diseases at a younger age.
Ischaemic heart disease and stroke are the biggest killers

http://www.who.int/mediacentre/factsheets/fs310/en/)
Risks

According to the World Health Organization...

Eating **50g** of processed meat a day - less than two slices of bacon - increased the chance of developing colorectal cancer by **18%**.

Source: IARC/WHO

© Global News
Pressure on Government

Impact on global GDP\textsuperscript{1}

- $2.1$ trillion
  - Smoking
- $2.1$ trillion
  - Armed violence, war, and terrorism
- $2.0$ trillion
  - Obesity
- $1.4$ trillion
  - Alcoholism

\textsuperscript{1}In 2014 dollars at purchasing-power parity.

Source: Literature review; World Health Organization global burden of disease (GBD) database; McKinsey Global Institute analysis
Investment in Meatless Space

https://www.cbinsights.com/research/future-of-meat-industrial-farming/
Consumer Trend

### FOOD & DRINK TRENDS 2017

#### Sticking with tradition
Consumers are seeking the recognisable not revolutionary, longing for safe, traditional products that are easily recognisable.
- 37% of French consumers like the appeal of authentic flavours
- 36% of Polish consumers like the appeal of authentic flavours
- 33% of Danish consumers like the appeal of authentic flavours

#### Time is precious
2017 will place emphasis on "time saved" by purchasing the particular product.
Mintel GNPO revealed that global food and drink launches that include "slow" in the product description grew nearly 214%.

#### Plant Power
The number of global food and drink launches with "ON THE GO" claims increased by 54%.

#### Sustainability
2017 will see more consumer awareness and consideration of global food waste.

- 51% of US adults are open to buying less-than-perfect vegetables
- 1/3 of food produced for human consumption is lost or wasted
- 55% of UK adults include vegetables in meals
- 25% super foods incorporated in UK adults meals

*between September 2016 – August 2017 and September 2015 – August 2016. Sources: Mintel Global Food & Drink Trends 2017 & Mintel GNPO*
Mindful Choices: The Key Food Driver for 2018, says Innova Market Insights (PRNewsfoto/Innova Market Insights)
Shrinking World – Transportation & Communication

RISING POPULATION
Hectares of available land per person

1900: 7.91
1950: 5.15
1987: 2.60
2005: 2.02
2050: 1.63

http://init.planet3.org/2008/06/ww2my-little-world-revisited.html
Mycoprotein Story
1960's
Malthusian predictions receded in the face of “The Green Revolution”

Norman Borlaug
Agricultural Scientist

Norman Ernest Borlaug was an American agronomist, humanitarian and Nobel laureate who has been called "the father of the Green Revolution", "agriculture's greatest spokesperson" and "The Man Who Saved A Billion Lives". Wikipedia

Wheat yields in developing countries, 1950 to 2004, kg/HA. The steep rise in crop yields in the U.S. began in the 1940s. The percentage of growth was fastest in the early rapid growth stage. In developing countries maize yields are still rapidly rising.[6]
A man with an idea

1964

Carbohydrate (Plenty)

- 3000 microorganisms
- 1967 – *fusarium venenatum*, mycoprotein
  - Safety
  - Organoleptic
  - Nutrition content
  - Scalability

Protein (Scarce)
Continuous Fermentation Technology

- Continuous fermentation to efficiently convert glucose to protein
- Heat shock – stop growth, reduce RNA to meet WHO limit
- Centrifuge to harvest biomass
CERTIFICATE OF FREE SALE 
IMPORTATION OF FOOD PRODUCTS

The Ministry of Agriculture, Fisheries and Food hereby certify that the product 'Quorn' Mycoprotein may lawfully be sold in the United Kingdom of Great Britain and Northern Ireland, subject to the provisions of the Food Act 1984.

Signed:

Mr L B Linley

For and on behalf of the Ministry of Agriculture, Fisheries and Food

DESCRIPTION OF FOOD PRODUCTS

The product named 'Quorn' Mycoprotein is produced by cultivation of Fusarium graminearum CHI45625 in aerobic conditions using food grade raw materials and subsequently processed to reduce its Ribonucleic Acid (RNA) content to a level suitable for human consumption.

150 gram 5.28 oz £

Approved by the Vegetarian Society
Extensive database to establish safety of mycoprotein

• Analytical data (identity, composition, potential impurities)
• Manufacturing process
• In vitro test
  • Determine that mycoprotein is non-mutagenic
• Animal studies
• Digestibility and nutritional evaluation
• Human studies
• Historical consumption
## Animal Studies – Subchronic Studies

Four studies in rats, one study in dogs, one study in baboons

<table>
<thead>
<tr>
<th>Species</th>
<th>Study Duration</th>
<th>Dietary Concentration of Mycoprotein</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rats</td>
<td>22 weeks</td>
<td>26 or 52%</td>
<td>No effects in histology and clinical pathology were observed.</td>
</tr>
<tr>
<td>Rats</td>
<td>13 weeks</td>
<td>17.5 or 35%</td>
<td>No toxicologically significant adverse effects in growth, food and water consumption, clinical condition, or clinical pathology, or histopathology.</td>
</tr>
<tr>
<td>Rats</td>
<td>90 days</td>
<td>5, 10, or 20%</td>
<td>No toxicologically significant adverse effects in growth, blood parameters, organ weights, histopathology, or mineral balances were observed.</td>
</tr>
<tr>
<td>Rats</td>
<td>90 days</td>
<td>20 or 40%</td>
<td>No differences in pregnancy and litter parameters were observed. Rats receiving 40% mycoprotein exhibited a slightly lower liver weight, attributed to a slight decrease in food consumption. No toxicologically relevant differences in body weights, haematology, and urinalysis were observed.</td>
</tr>
<tr>
<td>Dogs</td>
<td>90 days</td>
<td>20 or 40%</td>
<td>No differences in weight gain, gross or histopathological findings, or organ weights were observed. No toxicologically significant differences in haematological parameters were observed. Reductions in plasma cholesterol and triglycerides were reported.</td>
</tr>
<tr>
<td>Baboons</td>
<td>13 weeks</td>
<td>26 or 51.5%</td>
<td>No adverse effects on growth, food and water consumption, haematological parameters, or electrocardiograms were observed. Increases in serum alkaline phosphatase activity, serum alkaline transaminase, and aspartate transaminase activities also were observed.</td>
</tr>
</tbody>
</table>

## Animal Studies – Chronic Studies

### Two 2-year carcinogenicity in rats, 1-year dog study, 2-generation study in rats

<table>
<thead>
<tr>
<th>Species</th>
<th>Study Duration</th>
<th>Dietary Concentration of Mycoprotein</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rats (^1)</td>
<td>2 years</td>
<td>21 or 41%</td>
<td>No adverse effects in food consumption, growth, or reproduction were observed. Decreases in plasma cholesterol and plasma triglyceride concentrations were noted with mycoprotein administration. Slight differences in urine parameters were attributed to water retentive properties of the fibre in mycoprotein. Some histological findings were noted to be not injurious to the cell or its functions. No differences in the incidence of tumours were observed.</td>
</tr>
<tr>
<td>Rats (^2)</td>
<td>2 generation</td>
<td>12.5, 25, or 50%</td>
<td>No adverse effects in growth, reproductive function, microscopic, or pathological findings were observed</td>
</tr>
<tr>
<td>Rats (^1)</td>
<td>2 years</td>
<td>27 or 57% (in utero), and 20 or 40% (chronic)</td>
<td>No test article-related effects were observed in general condition, ophthalmoscopic examination, survival, growth, clinical chemistry, or haematology. An increase in urinary protein was observed in female animals. An increase in kidney weight was observed in rats receiving mycoprotein; no other differences in organ weights were noted. Significant increases in the incidence of renal microlithiasis and testicular tubular atrophy were noted to be attributed to mineral imbalances between the experimental diets.</td>
</tr>
<tr>
<td>Dogs (^2)</td>
<td>1 year</td>
<td>20 or 40%</td>
<td>No adverse effects in growth, clinical signs, haematology, urinalysis, growth, or histopathology were observed. Dogs exhibited lower plasma cholesterol and triglyceride concentrations.</td>
</tr>
</tbody>
</table>
Based on consumer data, the annual complaint rate represents less than **11 to 16 per million consumers or around 1 per million servings of Quorn™ product**. This compares favorably with soya and wheat with an incidence of about 1 in 200 of the general population and with egg and milk in the range of approximately 1 in 100.

Based on the amount of mycoprotein produced, the proportion of mycoprotein found in the finished products sold by Quorn, the average pack weight of a finished product sold, he average number of servings per pack, **the total number of meals consumed is about 4.8 billions**.
• 1985: United Kingdom
• 1990 - 2008: Europe (Belgium, Luxemburg, Netherlands, Sweden, Denmark, Switzerland, Norway)
  • Since European Union Novel Food EC Reg 258/97, mycoprotein can be sold in any EU member
• 2001: United states
• 2008: Australia and New Zealand
• 2013: Canada
• 2016: Thailand
• 2016: Philippines
• 2017: Singapore
20 year history of peer reviewed nutrition research

- Cummings, J (1990) Ileal digestibility of mycoprotein in ileostomy patients. Dunn Research Institute Report
### Human Studies highlights mycoprotein potential

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Route of exposure</th>
<th>Dose of mycoprotein</th>
<th>Duration of study</th>
<th>Findings</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 healthy subjects aged 18 to 59 years</td>
<td>In cookies</td>
<td>20 g/day</td>
<td>30 days</td>
<td>No reports of adverse events were observed. No differences were found in any hematologyological parameters, with the exception of a decrease in cholesterol. No changes in urinalysis parameters were observed.</td>
<td>Udall et al., 1984</td>
</tr>
<tr>
<td>17 healthy subjects aged 19 to 46 years with blood cholesterol between 5.2 and 6.2 mmol/L</td>
<td>In the diet</td>
<td>181 g/day</td>
<td>3 weeks</td>
<td>No changes in mean body weight, systolic or diastolic blood pressure, glycaemic or insulinemic variables were observed. Total cholesterol was reduced in the mycoprotein treatment group compared to baseline. LDL cholesterol was decreased in the mycoprotein group compared to baseline. No statistically significant changes in apolipoproteins A-1 and B were observed between groups, though there was a significant decrease in both variables in subjects given mycoprotein compared to baseline. No perceived differences in fluid intake were observed. 6 of 9 subjects in the mycoprotein group experienced transient flatulence. A slight perceived increase in the frequency of defecation and fecal bulk was reported in the mycoprotein group.</td>
<td>Turnbull et al., 1983</td>
</tr>
<tr>
<td>13 healthy female subjects</td>
<td>In the diet</td>
<td>Not specified</td>
<td>1 day</td>
<td>A decrease in desire to eat, hunger, and an increase fullness score was observed following consumption of the mycoprotein meal compared with chicken.</td>
<td>Turnbull et al., 1992b</td>
</tr>
<tr>
<td>21 healthy subjects aged 26 to 63 years with blood cholesterol greater than 5.2 mmol/L</td>
<td>Breakfast</td>
<td>26.9 g dry weight/day (approx. 90 g mycoprotein at normal moisture content)</td>
<td>8 weeks</td>
<td>Total cholesterol and LDL cholesterol were significantly reduced in both groups, though the effect was significantly greater in subjects given mycoprotein. No changes in HDL were observed. No changes in triglycerides were observed. No significant changes in apolipoproteins A-1 or B were noted. Subjects reported feeling less desire to eat, and reduced prospective consumption after eating a mycoprotein-containing diet compared to the chicken diet. No statistically significant changes in hunger and fullness scores were observed between treatment groups.</td>
<td>Turnbull et al., 1993</td>
</tr>
<tr>
<td>4 male and 15 female subjects, mean age of 22.6 years with sufficient intake of carbohydrates</td>
<td>In a milkshake</td>
<td>39.0 g dry weight/day</td>
<td>2 days</td>
<td>Postprandial serum glucose was lower following mycoprotein consumption compared to control. Serum insulin response was significantly lower following mycoprotein consumption compared to control. The area under the curve for serum glucose and insulin also was significantly lower in the mycoprotein treatment group. No safety endpoints were examined in the study.</td>
<td>Turnbull et al., 1995</td>
</tr>
<tr>
<td>9 male and 9 female healthy subjects</td>
<td>In a chicken-style chunk or in a frozen dried powder</td>
<td>150 g/meal, 1 meal/day</td>
<td>1 day</td>
<td>No significant differences in hunger scores were observed. A decrease in portion size of foods selected was observed in subjects consuming mycoprotein. Satiety was enhanced 4 hours post-meal. No safety endpoints were examined in the study.</td>
<td>Burley et al., 1993</td>
</tr>
</tbody>
</table>
460 – c. 370 BC

“Let food be thy medicine and medicine be thy food”
– Hippocrates

PALEOspirit.com
Mycoprotein Unique Profiles

**Physical Properties (shape)**

**Texture creation**
- Authentic meat-like texture
- Creation of fibrocity through fibre assembly

**Composition**

**General Nutrition**
- High quality protein
- Low fat content (membrane phospho-lipids)
- High fibre (cell wall)
- Low energy density

**Clinical Research Programmes**
- Lowering serum cholesterol
- Satiety
- Insulinemia and glycemia in diabetics

**Additional Interest**
- SCFA production
- Fibre (chitin and β-glucans)

<table>
<thead>
<tr>
<th>Nutrition</th>
<th>Data 1 (per 100g)</th>
<th>Data 2 (per 100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcals)</td>
<td>111</td>
<td>96</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>13.7</td>
<td>13.2</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>- Sugars (g)</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>- Saturated Fat (g)</td>
<td>0.48</td>
<td>1.0</td>
</tr>
<tr>
<td>- Mono-unsaturated Fat (g)</td>
<td>0.29</td>
<td>1.0</td>
</tr>
<tr>
<td>- Poly-unsaturated Fat (g)</td>
<td>2.2</td>
<td>0.9</td>
</tr>
<tr>
<td>- Trans-unsaturated Fat (g)</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>7.5</td>
<td>8.3</td>
</tr>
</tbody>
</table>
# Nutrition Comparison to Other Protein

<table>
<thead>
<tr>
<th></th>
<th>Quorn pieces</th>
<th>Quorn burger</th>
<th>Chicken (skinless)</th>
<th>Beef (lean)</th>
<th>Ground beef (lean)</th>
<th>Milk (2%)</th>
<th>Tofu</th>
<th>Tempeh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (kcal)</td>
<td>92</td>
<td>117</td>
<td>119</td>
<td>160</td>
<td>264</td>
<td>50</td>
<td>76</td>
<td>193</td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>3.2</td>
<td>4.6</td>
<td>3.1</td>
<td>7.8</td>
<td>20.7</td>
<td>1.9</td>
<td>4.8</td>
<td>10.8</td>
</tr>
<tr>
<td>Saturated fat (g)</td>
<td>0.6</td>
<td>2.3</td>
<td>0.8</td>
<td>2.8</td>
<td>8.3</td>
<td>1.2</td>
<td>0.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>0</td>
<td>0</td>
<td>70</td>
<td>62</td>
<td>75</td>
<td>7.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>1.8</td>
<td>5.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.8</td>
<td>1.9</td>
<td>9.4</td>
</tr>
<tr>
<td>Sugars (g)</td>
<td>0.8</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.8</td>
<td>1.5</td>
<td>ca 4.6</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>4.8</td>
<td>4.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
<td>ca 4.3</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>14</td>
<td>12.8</td>
<td>21.4</td>
<td>20.8</td>
<td>17.7</td>
<td>3.3</td>
<td>8.1</td>
<td>18.6</td>
</tr>
<tr>
<td>Sodium (g)</td>
<td>0.3</td>
<td>0.5</td>
<td>0.8</td>
<td>0.05</td>
<td>0.07</td>
<td>0.05</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>0.7</td>
<td>0.4</td>
<td>0.5</td>
<td>9.8</td>
<td>6.2</td>
<td>0.02</td>
<td>4.3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

DOI 10.1007/s00253-002-0931-x

M.G. Wiebe

**Myco-protein from *Fusarium venenatum*: a well-established product for human consumption**
Protein Quality

Recent Work Shows a PDCAAS Score of 0.996

<table>
<thead>
<tr>
<th>Test Material</th>
<th>Rat PER</th>
<th>Rat NPU</th>
<th>Man Digestibility</th>
<th>Man Biological Value</th>
<th>Man NPU (calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mycoprotein</td>
<td>2.4</td>
<td>61</td>
<td>78</td>
<td>84</td>
<td>65</td>
</tr>
<tr>
<td>Mycoprotein + methionine</td>
<td>3.4</td>
<td>82</td>
<td>79</td>
<td>92</td>
<td>73</td>
</tr>
<tr>
<td>Casein</td>
<td>2.5</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skimmed Milk</td>
<td>-</td>
<td>-</td>
<td>95</td>
<td>85</td>
<td>80</td>
</tr>
</tbody>
</table>

Using the above apparent protein digestibility of mycoprotein in man, the protein digestibility corrected amino acid score (PDCAAS) was calculated, giving a figure of 0.91, similar to beef (see Miller & Dwyer, 2001).

The research conducted at the Dunn Laboratory, Cambridge, UK, referred to below yielded an ileal digestibility of 89.8% for the protein in mycoprotein. Some of this may have been attributable to digestible non-protein nitrogen, so a more cautious figure of 86% was used for an updated PDCAAS calculation. This yielded a score of 0.996 (Edwards & Cummings, 2010).


Food Texture

SOYA

POULTRY

QUORN
Production with low environmental impact

GHGs

Comparative carbon emissions*


Quorn Mince

More than 90% lower than beef

The results are remarkable. They show that Quorn products can have a carbon footprint up to thirteen times lower than beef, and up to 4 times lower than chicken.15

Quorn Pieces

More than 70% lower than chicken

Feed efficiency

Producing protein through livestock is highly inefficient

12-24kg FEED

1kg BEEF

1kg CHICKEN

Land use

Quorn mince uses less than 1/8th of the amount of land needed for beef mince

Water

The water footprint of Quorn mince is up to 10 times smaller than that of beef

1kg of Quorn Mince requires 12-24kg of feed, which is 1/8th of the amount of land needed for 1kg of beef mince.

1kg of Quorn Pieces requires 7-8kg of feed, which is 1/8th of the amount of land needed for 1kg of chicken.

Quorn Mince and Quorn Pieces are highly efficient in terms of feed efficiency and land use compared to beef and chicken.
Partnership with Carton Trust

### ENVIRONMENTAL COMPARISON PROTEINS AND MYCOPROTEIN

<table>
<thead>
<tr>
<th></th>
<th>GHG (kg/kg)</th>
<th>LAND (ha/te)</th>
<th>WATER (m3/te)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MYCOPROTEIN</strong></td>
<td>1.6</td>
<td>0.17</td>
<td>860</td>
</tr>
<tr>
<td><strong>QUORN MINCE</strong></td>
<td>2.4</td>
<td>0.4</td>
<td>1900</td>
</tr>
<tr>
<td><strong>SOYABEAN</strong></td>
<td>0.1 - 17.8</td>
<td>0.43</td>
<td>2500</td>
</tr>
<tr>
<td><strong>BEEF (GRAZED)</strong></td>
<td>121 (114 - 130)</td>
<td>5</td>
<td>21500</td>
</tr>
<tr>
<td><strong>BEEF (MIXED)</strong></td>
<td>30 (16 - 69)</td>
<td>3.5</td>
<td>19500</td>
</tr>
<tr>
<td><strong>POULTRY</strong></td>
<td>9</td>
<td>0.7</td>
<td>3970</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Compared with Quorn mince ex factory</th>
<th>GHG</th>
<th>LAND</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef (mixed)</td>
<td>X12</td>
<td>X9</td>
<td>X10</td>
</tr>
<tr>
<td>Beef (grazed)</td>
<td>X50</td>
<td>X12</td>
<td>X11</td>
</tr>
<tr>
<td>Poultry</td>
<td>X4</td>
<td>X2</td>
<td>X2</td>
</tr>
</tbody>
</table>


- By working closely with [Carbon Trust](#) we have established that Quorn foods offer **significant environmental benefits** relative to meat.
- Quorn is the **first and only** meat free brand to have carried out such a **systematic third party** analysis of its environmental footprint.

---

Our Future
Journey continues

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>1985</td>
</tr>
<tr>
<td>Belgium</td>
<td>1992</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1992</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1996</td>
</tr>
<tr>
<td>Republic of Ireland</td>
<td>1999</td>
</tr>
<tr>
<td>Sweden</td>
<td>1999</td>
</tr>
<tr>
<td>United States of America</td>
<td>2002</td>
</tr>
<tr>
<td>Denmark</td>
<td>2006</td>
</tr>
<tr>
<td>Norway</td>
<td>2007</td>
</tr>
<tr>
<td>Australia</td>
<td>2010</td>
</tr>
<tr>
<td>Germany</td>
<td>2012</td>
</tr>
<tr>
<td>South Africa</td>
<td>2013</td>
</tr>
<tr>
<td>France</td>
<td>2015</td>
</tr>
<tr>
<td>Spain</td>
<td>2015</td>
</tr>
<tr>
<td>Italy</td>
<td>2016</td>
</tr>
<tr>
<td>Philippines</td>
<td>2016</td>
</tr>
<tr>
<td>Thailand</td>
<td>2016</td>
</tr>
<tr>
<td>Singapore</td>
<td>2017</td>
</tr>
</tbody>
</table>
Our 50-year journey produces a third category - natural, nutritious fungi

1. Animal Based Protein
2. Plant Based Protein
3. Fungi Based Protein
<table>
<thead>
<tr>
<th>Collaboration</th>
<th>Biotechnology &amp; Bioengineering</th>
<th>Interdisciplinary Product Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Identify new alternative</td>
<td>• Develop food, beverage and snacks</td>
</tr>
<tr>
<td></td>
<td>• Develop fermentation process</td>
<td>from sustainable protein (mycoprotein</td>
</tr>
<tr>
<td></td>
<td>suitable for local context</td>
<td>and others) through interdisciplinary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>approach to achieve organoleptic profile</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and nutrition profile</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Packaging &amp; Manufacturing technology</th>
<th>Nutrition &amp; Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Develop sustainable solution to packaging</td>
<td>• Create evidence to highlight potential benefit of alternative protein to consumers</td>
</tr>
<tr>
<td></td>
<td>• Develop packaging and manufacturing technology to produce shelf stable product</td>
<td>• Create studies to further understand the potential benefit of alternative protein</td>
</tr>
<tr>
<td></td>
<td>• Develop manufacturing system that produce customized product efficiently</td>
<td></td>
</tr>
</tbody>
</table>
THANK YOU

CONTACT

Andy T. Kusumo
andy.kusumo@mondenissin.com