MYCOPROTEIN: NUTRITIONAL, HEALTH AND ENVIRONMENTAL BENEFITS

There has been growing interest in the need to utilise alternative protein sources, given that world populations are expanding, yet there is limited space for sustainable agricultural production. Based on these changes, this article discusses the nutritional, health and environmental properties of mycoprotein, taking latest issues into context.

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Mycoprotein, the ingredient common to all Quorn™ products, is a vegetarian protein produced inside fermenters by adding oxygen, nitrogen, glucose and minerals to a filamentous fungus known as *Fusarium venenatum*.[1] Lord Rank first identified this rare but important fungus in the early 1960s when looking to find a micro-organism that could convert carbohydrate into proteins. This was during a time when there were concerns that population growth could lead to global food shortages and widespread famine.[2]

Now, more than five decades later, it seems that similar concerns are re-emerging. There is renewed interest in sustainable protein sources due to rising demands for meat, fuelled by accelerations in population growth.[3] In fact, demands for animal-based protein are estimated to rise by 72% between 2013 and 2050, which raises new concerns about the sustainability and environmental impacts of this.[4]

This article develops the knowledge about the nutritional profile of mycoprotein, reviews evidence in relation to its potential health benefits and brings in wider environmental perspectives.

NUTRITIONAL PROFILE

As shown in Table 1, when compared to other protein sources, mycoprotein is particularly low in energy, total and saturated fat while being high in fibre. The fibre found in mycoprotein is typically one-third chitin (poly n-acetyl glucosamine) and two-thirds β-glucan (as 1,3 and 1,6).[5]

From a health stance, for chitin fibre, there is growing interest in its antioxidant, antihypertensive, anti-inflammatory, anticoagulant, antimicrobial, anticancer and antidiabetic properties.[6] β-glucan, however, is thought to play a role in the regulation of appetite control, with its low glycaemic index and actions on gut flora being possible mechanisms behind this.[7]

With regard to the quality and digestibility of mycoprotein, the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) is a measure of this. This has been reported to be 0.99 for mycoprotein, which is higher than values previously reported for soybean protein, beef, kidneys beans and lentils.[8,9] Mycoprotein also contains all nine essential amino acids required by adults.[10]

Putting this into the context of European Commission nutrition claims, mycoprotein is: 1) 'low in fat', i.e. contains no more than 3.0 grams of fat per 100 grams of solids; 2) 'low in saturated fat', i.e. does not contain more than 1.5 grams of saturated fatty acids per 100 grams of solids and 3) 'high in fibre', i.e. contains at least 6.0 grams of Association of Official Analytical Chemists (AOAC) fibre per 100 grams.[11]

Mycoprotein also provides a spectrum of vitamins and minerals. Again, applying European Commission nutrient claims, mycoprotein falls under the category of being 'high' in zinc, phosphorous, manganese, copper, selenium and chromium and a 'source' of riboflavin.[12,13] It is also low in sodium, containing 2.0 milligrams of sodium per 100 grams; equivalent to 0.005 grams of salt.

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Table 1: Nutrient density of mycoprotein compared to other protein sources (per 100g)

	Mycoprotein[a] (wet)	Red meat[b,c]	Chicken[b,d]	Tofu[b,e]	RNI[12]
Energy (kcals)	85	176	148	76	NA
Protein (g)	14	20	21.2	8.08	NA
Carbohydrate (g)	1.2	0	0	1.88	NA
Fat (g)	1.4 'low in'	10.0	6.32	4.78	NA
Of which saturates (g)	0.3 'low in'	3.9	1.57	0.69	NA
Fibre (AOAC) (g)	6.1 'high in'	0	0	0.3	NA
Vit B1 (mg)	0.01	0.04	0.15	0.08	1.1
Vit B2 (mg)	0.23 'source'	0.15	0.21 'source'	0.05	1.4
Vit B3 (mg)	0.35	5.07 'high in'	7.48 high in'	0.20	16
Vit B6 (mg)	0.13	0.37 'source'	0.44 'source'	0.05	1.5
Vit B9 (μg)	10	6	7	15	200
Calcium (mg)	42.5	12	10	350[e] 'high in'	800
Chromium (μg)	15 'high in'	--	--	--	40
Copper (mg)	0.5 'high in'	0.07	0.09	0.19 'source'	1.0
Iron (mg)	0.5	2.24 'source'	1.09	5.36 high in'	14
Magnesium (mg)	45	20	24	30	375
Manganese (mg)	6 'high in'	0.001	0.02	0.61 'high in'	2.0
Phosphorus (mg)	260 'high in'	184 'source'	209 'source'	97	700
Potassium (mg)	100	321 'source'	251	121	2000
Selenium (μg)	20 'high in'	16.6 'high in'	15.7 'source'	8.9 'source'	55
Zinc (mg)	9 'high in'	4.79	1.40	0.80	10
Sodium (mg)	2.0	66	79	7	NA

Key: [a]Data provided by Marlow foods (wet weight); [b]Data extracted from the USDA database (for raw produce); [c]Values for beef; 90% lean; [d]Values for stewing meat; [e]Regular, prepared with calcium sulfate; (--) indicates no data; NA not applicable; RNI Reference Nutrient Intake. Values in bold meet European Commission (2008) nutrient claim guidelines.

MYCOPROTEIN AND HEALTH

As shown in Table 2, a growing number of English-language papers, identified through Medline (Pub Med) have been published looking at the potential health benefits of consuming mycoprotein.

Several have looked at the effects of mycoprotein consumption in relation to energy intake and satiety. For example, Bottin and colleagues (2012) looked at the dose of mycoprotein needed to induce satiety effects amongst 35 healthy overweight adults.[14] After a period of fasting, the ingestion of 32 grams mycoprotein led to significant reductions in energy intake and increased feelings of fullness during an *ad libitum* lunch served at the end of the day.[14]

Similarly, work by Williamson et al (2006) and Turnbull et al (1993) found that the ingestion of mycoprotein preloads led to lower food intakes later in the day, when compared to eating chicken.[15,16] One plausible mechanism could be the high fibre content of mycoprotein, with the viscosity of fibre in particular being thought to aid early signalling and enhanced feelings of satiation.[17]

With regard to blood lipid levels, Ruxton & McMillan (2010) conducted a six-week intervention trial on healthy free-living adults.[13] It was found that, amongst subjects with higher baseline blood cholesterol levels, the ingestion of 88 grams of wet weight mycoprotein daily (dry weight equivalent to 21 grams Quorn™) led to significant reductions in total cholesterol levels.[13]

Similarly, earlier work found that mycoprotein consumption led to significant reductions in total and LDL cholesterol[18] and improvements in high-density lipoprotein, when mycoprotein was eaten instead of meat amongst individuals with slightly elevated cholesterol levels at baseline[19], as well as general reductions in serum cholesterol levels.[20] Similar findings have also been reported elsewhere by Japanese scientists.[21,22,23]

Table 2: Mycoprotein and health studies

Publication	Study population	Health outcome	Study methods	Main findings
Bottin et al (2012)[14]	n=35 healthy overweight adults	Energy intake measured	Randomised laboratory study (seven occasions)	Higher intakes of MYP i.e. 32g portions sig. ↓ EI and ↑ feelings of fullness (*P*=0.06)
Bottin et al (2011)[24]	n=10 healthy overweight adults	Glucose control	Randomised laboratory study (two occasions)	Insulin levels sig. ↓ 15, 30 & 45 minutes after eating 30g MYP. MYP sig. improved PPIR compared with whey protein (*P*=0.0165)
Ruxton & McMillan (2010)[13]	n=21 healthy, free-living adults and n=10 controls	Cholesterol levels	Ate: 1) mycoprotein daily as Quorn™ or 2) normal habitual diet for six weeks	Amongst subjects with higher baseline cholesterol levels, total cholesterol levels sig. ↓ after eating MYP daily
Williamson et al (2006)[15]	n=42 overweight F	Eating behaviour and hunger	Three-day controlled laboratory study	MYP had satiating properties that persisted for several hours after eating a meal
Turnbull & Ward (1995)[25]	n=19 healthy weight subjects	Glucose and insulin levels	Two single-meal studies with crossover	Glycaemia was sig. reduced 60 mins after eating MYP vs. control. Insulinaemia ↓ after 30 mins and 60 mins after eating MYP vs control.
Burley et al (1993)	n=18 healthy subjects	Appetite and satiety	Feeding trial	After eating a lunch containing MYP (11g fibre) evening EI at an ad libitum test meal sig. ↓ by 18% vs control
Turnbull et al (1993)[16]	n=13 female non smokers	Energy intake and appetite	Two three-day study periods	EI ↓ sig. by 24% on the day of the study and by 16.5% the next day after eating MYP vs control
Turnbull et al (1992)[18]	n=21 overweight staff and students with slightly raised cholesterol levels	Blood lipid levels	Eight-week intervention study	After eating 26.9g MYP (from cookies) total cholesterol ↓ by 0.95mmol/L in the MYP and 0.46 mmol/L in the control gp. LDL ↓ by 0.84mmol/L in the MYP and 0.34 mmol/L in the control. Differences were statistically significant
Turnbull et al (1990)[19]	n=17 staff & students with slightly raised cholesterol levels	Blood lipid levels	Three-week metabolic study	After eating MYP instead of meat plasma cholesterol ↓ by 13%. LDL ↓ by 9% in the MYP gp and ↑ by 12% in the control. HDL ↑ by 12% in the MYP gp and↓ by 11% in the control. Differences were statistically significant.
Udall et al (1984)[20]	n=100 subjects	Blood serum constituents	Two double-blind crossover studies	After 30 days there was a ↓ in serum cholesterol when 20g *F. graminearium* was eaten as cookies

Key: EI energy intake; gp group; HDL High-density lipoprotein; MYP mycoprotein; LDL low-density lipoprotein; PPIR Post-prandial insulin resistance; ↓ reduced, ↑ increased.

Other work has looked at markers of glycaemic control. For example, Bottin and colleagues (2011) found that mycoprotein, when eaten as a soup containing 30 grams mycoprotein, significantly improved post-prandial insulin resistance compared to whey protein amongst a sample of 10 healthy overweight adults.[24] Similar findings were also found by Turnbull & Ward (1995), when milkshakes containing mycoprotein were provided to a sample of normal healthy adults.[25] While these results seem to indicate that mycoprotein shows promise as part of the dietary management of diabetes, randomised trials are now needed in clinical populations.

ENVIRONMENTAL

Feeding the world's growing population will require a vast expansion in agricultural production by 2050.[26] For example, whilst the world population was around 2.5 billion in 1950, this is projected to reach around 9.5 billion by 2050.[27] Subsequently, one of the greatest challenges we face is feeding nine to 10 billion people while reducing the environmental impacts of this, i.e. greenhouse gas emissions, biodiversity loss and loss of ecosystem. Climate change is also predicted to make the situation worse, further threatening the amount of land available for rearing livestock.[28]

Innovative protein sources, such as mycoprotein based Quorn™ offer one solution, potentially improving food security, as less land is needed to produce similar amounts of protein and energy.[26] The consumption of vegetarian proteins has increased over the years due to rising concerns about animal welfare[29], alongside animal diseases, economic changes, for religious (halal) reasons and now due to the global shortage of animal protein.[30]

DISCUSSION

It can be seen that mycoprotein is a valuable food ingredient, providing high-quality protein while being low in total and saturated fat and high in fibre (chitin and β-glucan).[5] Recent work has also shown that vegetarian and meat protein both appear to have a positive influence on appetite control and weight loss, influencing gut hormone profiles in a similar way.[31]

There has also been a general tendency to see mycoprotein first and foremost as a vegetarian food. However, changing demands for different sources of protein and the growing body of evidence supporting its health benefits, now mean that more people are turning to mycoprotein for different reasons. There has also been a tendency for the micronutrient profile of mycoprotein to be overlooked, yet it is an important source of zinc, phosphorous, manganese, copper, selenium, chromium and riboflavin.

Including mycoprotein with the weekly diet may also help to keep meat intakes in check. For example, the UK Scientific Advisory Committee on Nutrition (SACN) advises that up to 500 grams of cooked red meat (approximately 70 grams daily) can be eaten daily, which falls in line with colon cancer prevention advice.[32] While most people do not exceed these guidelines, males may benefit from substitution, as evidence from the UK National Diet and Nutrition Survey indicates that this population group has some of the highest meat intakes.[33] For example, mean consumption has been reported to be 85g daily for males aged 19 to 64 years.[33]

Taken together, dietitians and health practitioners can play an important role in ensuring that their patients are aware of mycoprotein. As seen in the studies reviewed, mycoprotein has the potential to play a role in weight or diabetes management programmes, as well as helping to support a healthy lipid profile and subsequent heart health. The next stage is for randomised controlled trials to be undertaken in healthcare settings.

CONCLUSIONS

In conclusion, mycoprotein should be recognised as more than a food option for vegetarians. This article has shown that mycoprotein provides good quality protein without being high in total or saturated fat. It is also high in fibre which is particularly important given that SACN (2015) guidelines have shifted fibre recommendations for those aged 16 years and over up to 30 grams of AOAC fibre daily.[34]

Mycoprotein also has the potential to improve the nutritional profile of patients' diets, along with certain health outcomes. Research, in relation to satiety benefits, looks particularly promising and, on the whole, makes sense given the high fibre-content of mycoprotein. Next, randomised trials in clinical settings are needed.

Finally, innovative protein sources such as mycoprotein, appear to be one way forward given rising concerns about feeding the expanding world's population. Given that Quorn™ has been on the market since 1985, it already has a longstanding reputation of being safe. The next stages are to communicate the nutritional, health and environmental benefits of mycoprotein to patients and the lay public.

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