



Fungi-Based Proteins: The future towards reduced carbon footprint

البروتينات الفطرية: المستقبل نحو تقليل البصمة الكربونية

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ADEQUATE NUTRITION



The measure for **hunger** compiled by FAO, defined as **undernourishment** refers to the proportion of the **population** whose **dietary energy consumption** is less than a pre-determined **threshold** or **suffering from food deprivation**.

This threshold is **country specific** and is measured in terms of the **number of kilocalories required** to conduct sedentary or **light activities**.

WHAT IS PROTEIN?

- Protein Is Used By Your Body To Produce, Maintain & Repair Its Cells

- Protein Is Constructed From Long Chains Of Amino Acids

- Complete Proteins Contain All 8 Essential Amino Acids

- Incomplete Proteins Do Not Contain All 8 Essential Amino Acids



ESSENTIAL AMINO ACIDS VERSUS NONESSENTIAL AMINO ACIDS

Essential amino acids cannot be synthesised by the human body

Nonessential amino acids can be synthesised by the human body

Adults cannot synthesise 9 amino acids

Adults can synthesise 11 amino acids

Must be obtained from the daily diet

Can be synthesized by the human body

Examples include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine

Examples include alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and tyrosine

Known as indispensable amino acids

Known as dispensable amino acids

FUNCTION OF ESSENTIAL AMINO ACIDS



Histidine supports the central nervous system, enhances immunity, and assists in tissue repair, maintenance of pH, and synthesis of hemoglobin.



Isoleucine promotes muscle recovery and repair, aids in blood clotting and wound healing, and regulates energy and blood sugar levels.

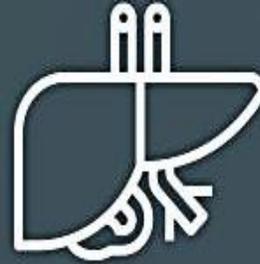


Leucine enhances muscle recovery and stamina, stimulates growth hormone production and the release of insulin, promotes growth and repair of bone tissue, and speeds wound healing.

FUNCTION OF ESSENTIAL AMINO ACIDS



Lysine assists muscle tissue growth and repair, aids in the synthesis of collagen and the absorption of calcium, boosts the immune system, and helps ward off viruses.



Methionine initiates protein synthesis, detoxes the body of lead and mercury, helps the liver metabolize fats, assists in the absorption and bioavailability of selenium and zinc, and acts as one of the main sources of sulfur in the body.



Phenylalanine acts as the precursor of tyrosine and plays a potential beneficial role in depression, vitiligo, multiple sclerosis, Parkinson's disease, attention deficit-hyperactivity disorder, and rheumatoid arthritis.

FUNCTION OF ESSENTIAL AMINO ACIDS



Threonine acts as a precursor of serine and glycine, helps form collagen and elastin, assists in preventing fat accumulation in the liver, helps build strong bones and tooth enamel, promotes wound healing, and helps maintain the integrity of gastrointestinal mucosa.



Tryptophan acts as a precursor of niacin as well as serotonin, which assists in promoting self-esteem, helps prevent heart disease and osteoporosis, and aids in the regulation of sleep, appetite, vasoconstriction, vasodilation, memory, and learning.

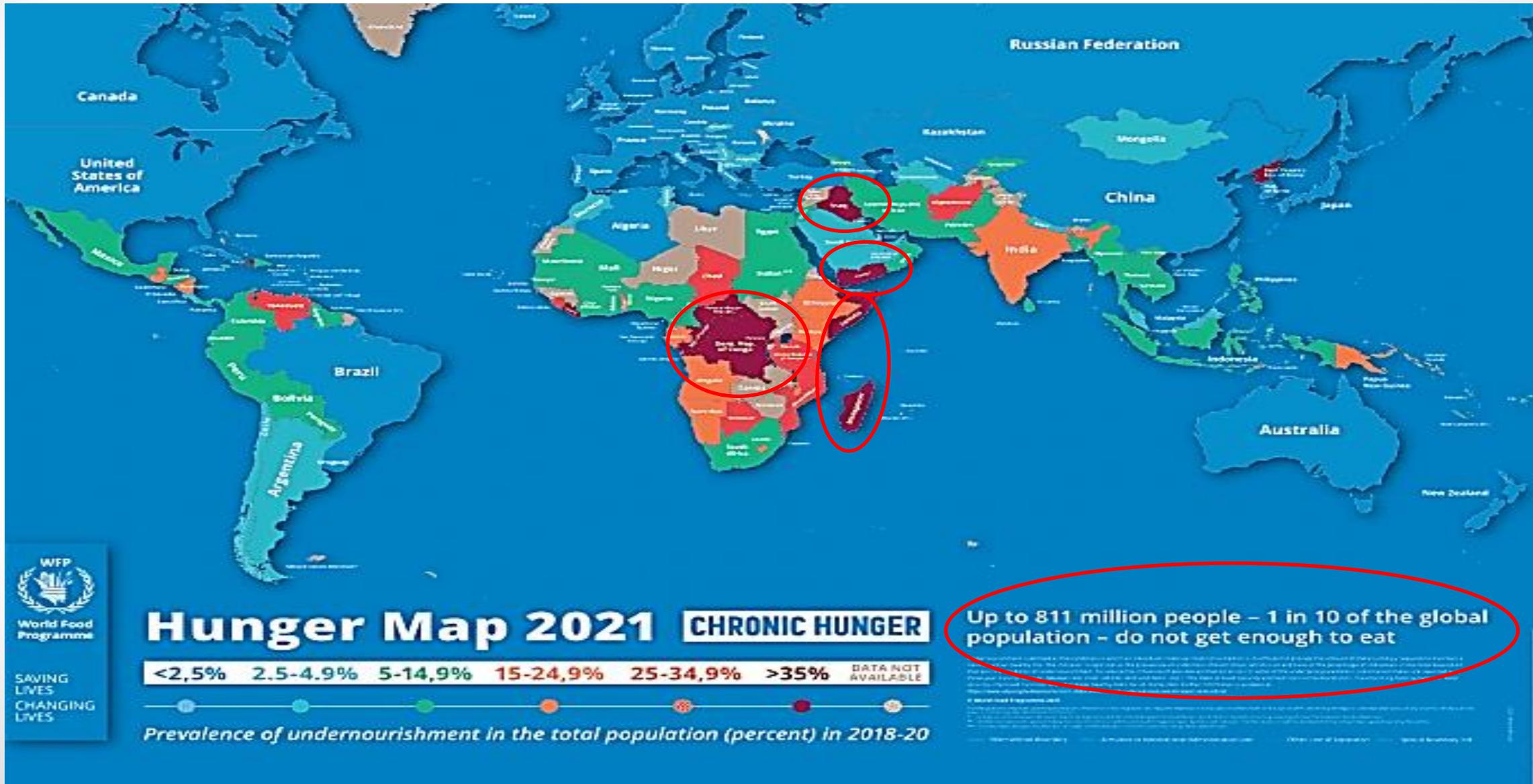


Valine helps maintain the body's nitrogen balance, supports the immune and central nervous systems as well as normal cognitive function, and aids in muscle metabolism, tissue repair, and blood sugar control.

Unfortunately, deterioration in Food security and nutrition happened in many countries during the last 2 decades



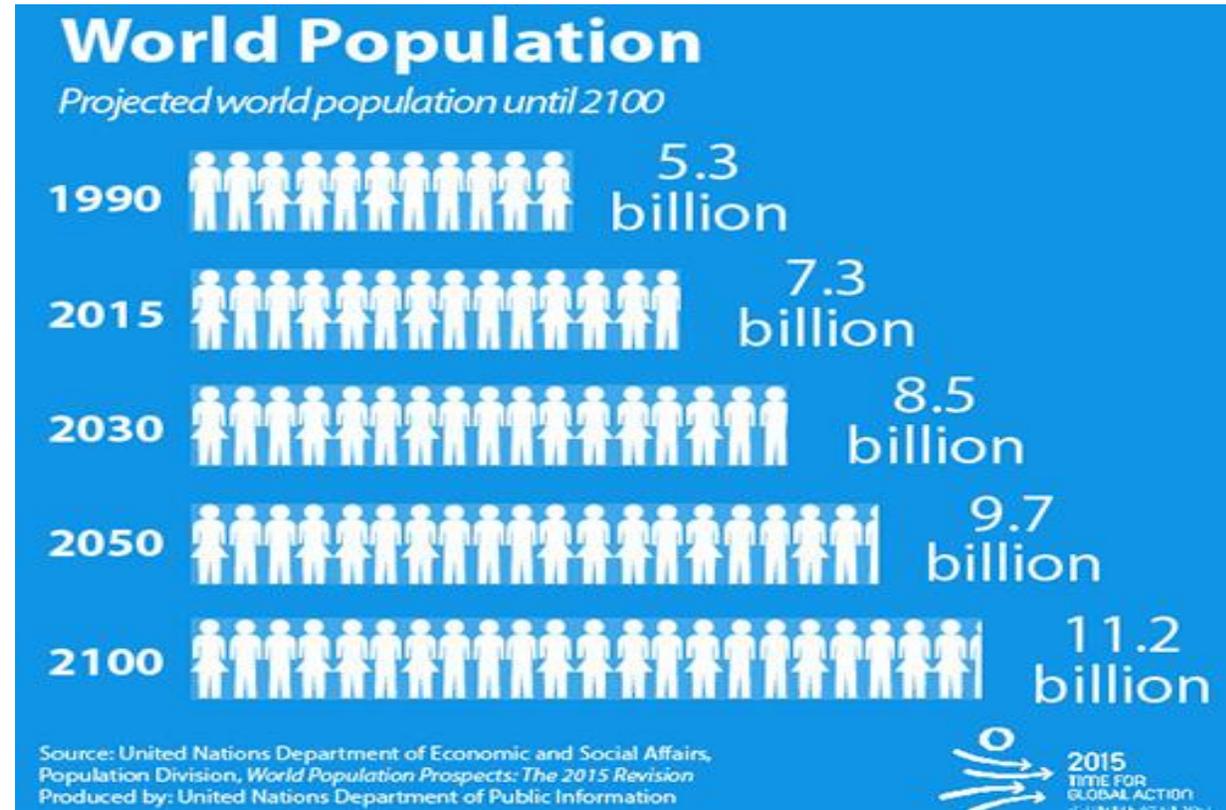
HUNGER MAP 2022



SAVE OUR PLANET

- **By 2050, global meat demand will be 70% higher than today's level.**
- **Livestock takes up 70-77% of global agricultural land**
- **Each year, 77 billion land animals are slaughtered for food**
- **Our planet simply doesn't have enough land and water to produce this much meat using animals.**
- **These are true steps towards sustainability**

Ministry of Agriculture, Forestry and Fisheries of Japan reported that **global demand for meat is on the rise; demand for meat, i.e. total of beef, pork, and poultry, which was 189.46 million tons in 1995, is forecasted to expand to 339.52 million tons by 2025.**



CARBON FOOTPRINT

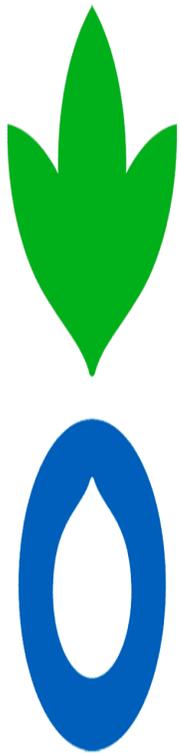
Food's carbon footprint, or foodprint measured by carbon dioxide equivalent (Kg)

-Is the **greenhouse gas emissions** [water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃)] produced by growing, rearing, farming, processing, transporting, storing, cooking and disposing food.

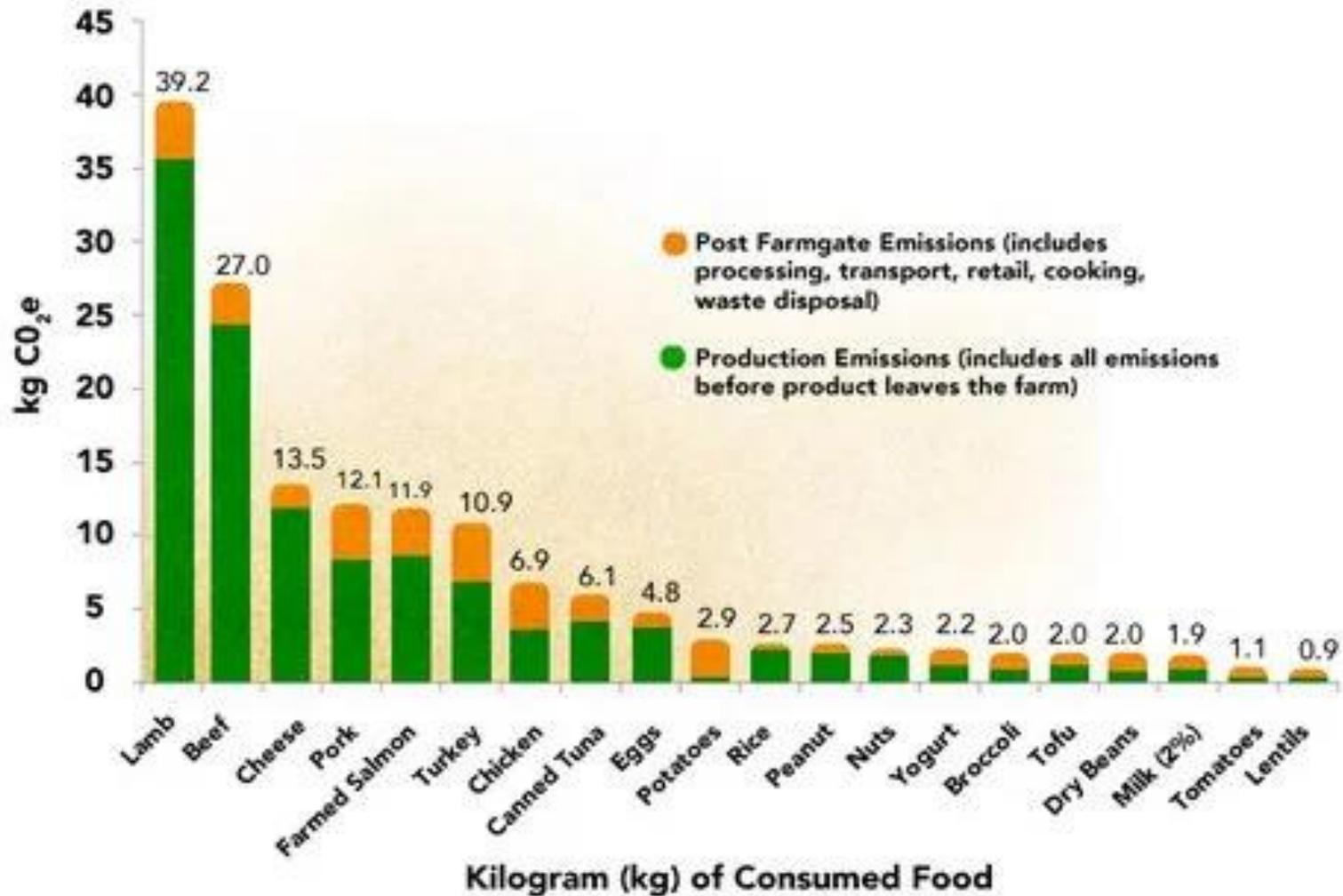
- The **new labelling** will better inform **people** who want to understand the environmental impact their food on climate change.



CARBON FOOTPRINT



**ACTION
AGAINST
HUNGER**



CARBON FOOTPRINT

		(kg CO2e/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	0.78			
	Tofu	0.57			
	Soy Protein Isolate	20.20			
	Textured Vegetable Protein	20.28			
	Beef Mince	32.13	43.02	39.93	33.03
	Chicken Breast	4.96	4.58	4.58	4.58
	Pork Primal Cut	11.09	10.14	9.95	
Quorn Protein**	Mycoprotein	0.79			
	Quorn Mince	1.29	1.39	1.58	1.50
	Quorn Pieces	1.23	1.35	1.63	1.41
	Quorn Fillets	1.26	1.46		
	Quorn Sausages	1.34			

*Average footprint

**Upper limit footprint

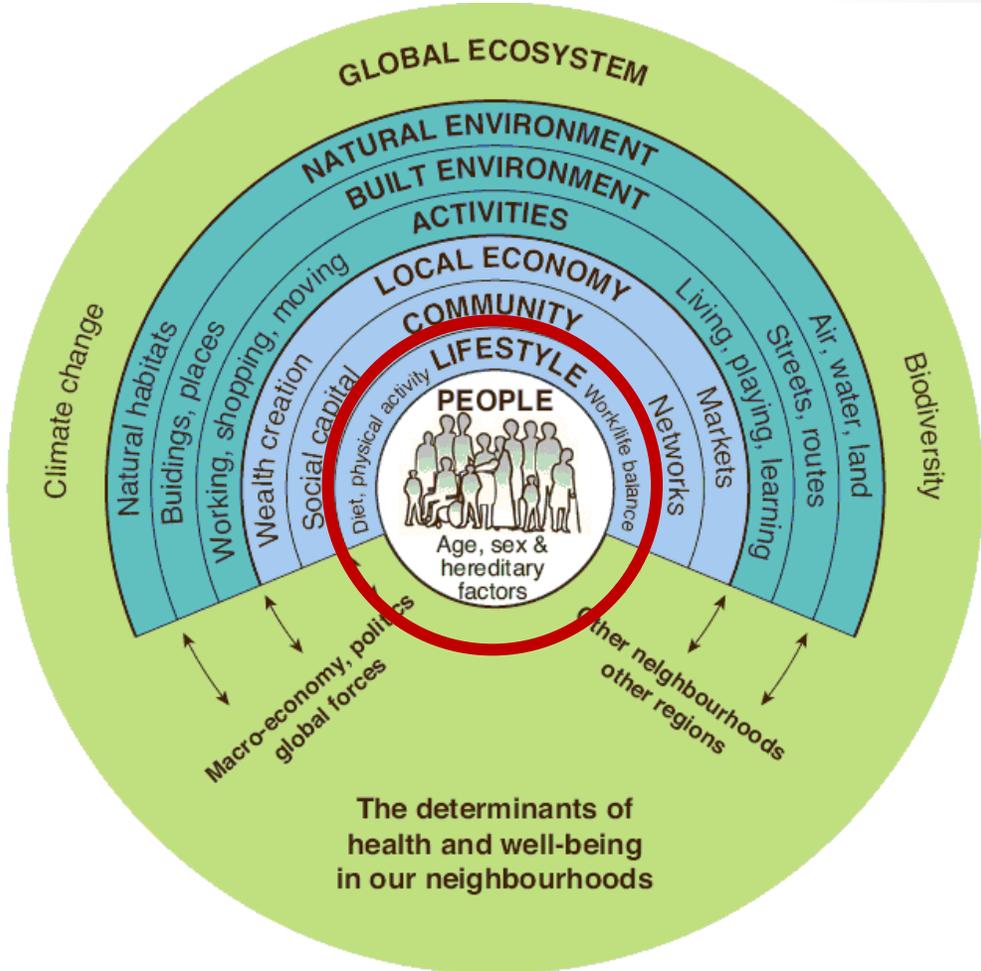
CHANGING CONSUMPTION PATTERN



ENVIRONMENTAL HEALTH

Changing consumption patterns can improve the environment

The SDGs (2015) by the United Nations are intended to be achieved by 2030.



FUNGI-BASED PROTEIN SOLUTIONS



Increased demand to food and changes in climates due to greenhouse effect have led to a trend toward alternative sources for production of protein such as microbial production e.g. mycoprotein with numerous benefits including time, energy and cost savings and environmental sustainability.

Recently, all characteristics of mycoprotein as meat alternatives including sensory, environmental, economic and marketing, health and safety aspects are studied

Production of mycoprotein does not result in changes in climates, increases in greenhouse gas emissions, degradations of lands or pollution of freshwater resources.

FUNGI-BASED PROTEIN SOLUTIONS

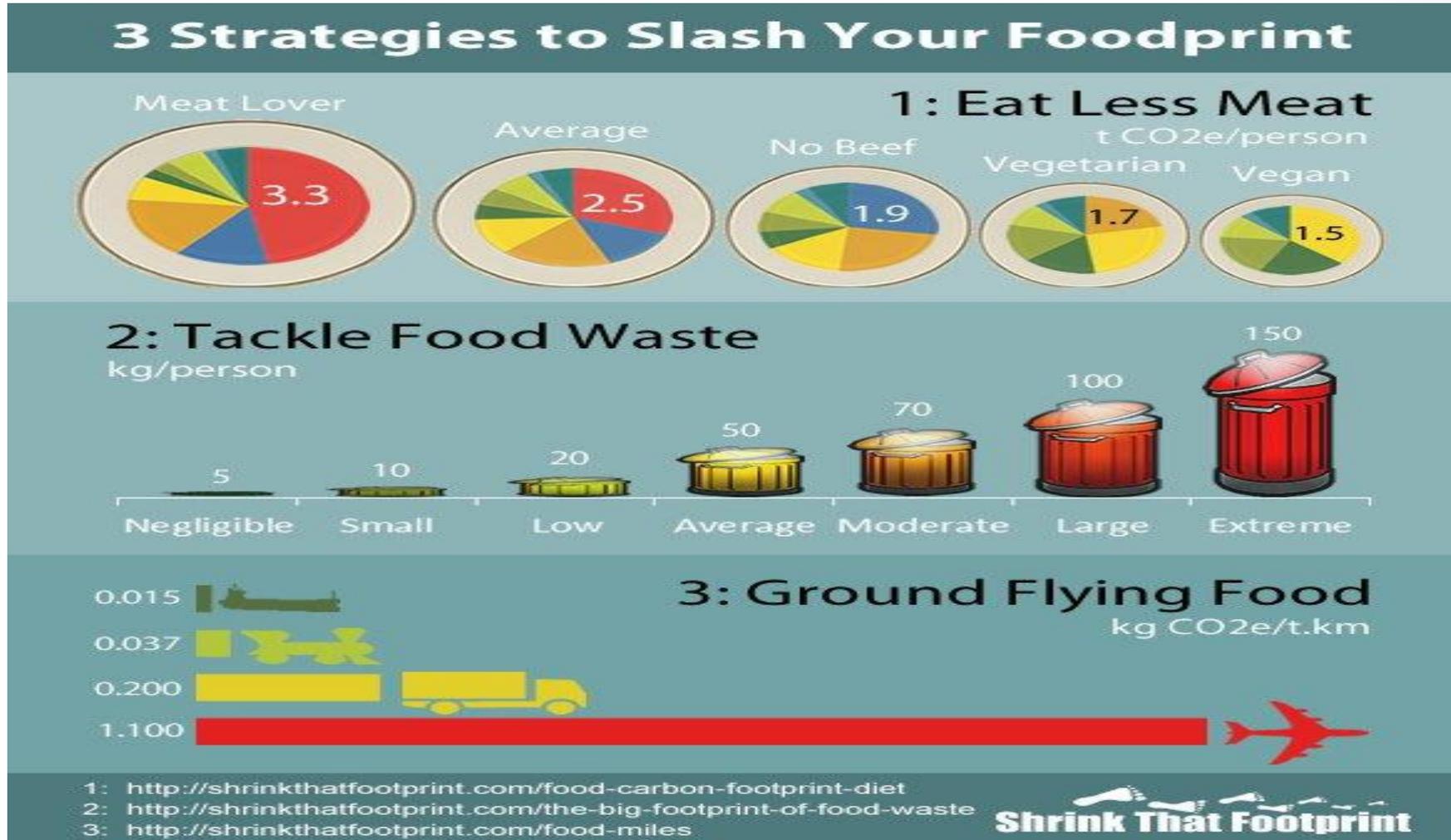


Fungal-derived mycoproteins are gaining in popularity due to their healthy nutritional profile, ability to be produced at low cost, environmental benefits and resilience to landscape limitations such as flood or drought



Why mycoprotein can be ideal to make a variety of substitute meat products?

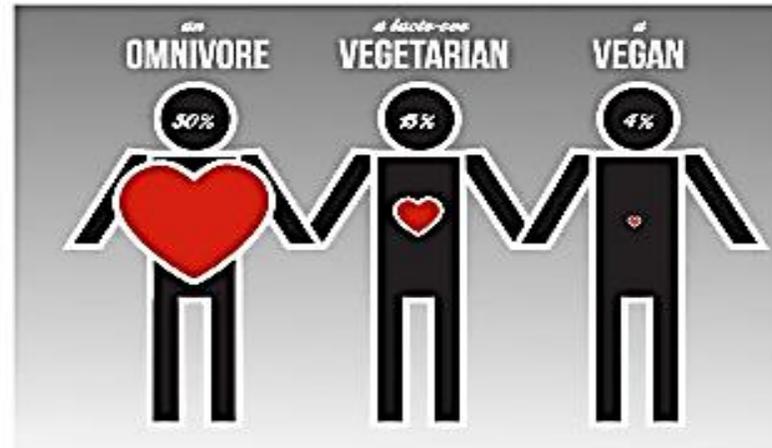
FUNGI-BASED PROTEIN SOLUTIONS



FUNGI-BASED PROTEIN SOLUTIONS

Vegans eat no animal and no animal-derived products

Vegetarians don't eat animals, but may eat products that come from them (such as dairy and eggs)



NUTRITION FACTS

Nutrition Facts
Mushrooms, white

Researchers compared milk protein with mycoprotein and found “equivalent” bioavailability.

Sources include: [USDA](#)

Amount Per 100 grams	
Calories	22
	% Daily Value*
Total Fat 0.3 g	0%
Saturated fat 0.1 g	0%
Cholesterol 0 mg	0%
Sodium 5 mg	0%
Potassium 318 mg	9%

Total Carbohydrate 3.3 g	1%
Dietary fiber 1 g	4%
Sugar 2 g	
Protein 3.1 g	6%
Vitamin C 3%	Calcium 0%
Iron 2%	Vitamin D 1%
Vitamin B6 5%	Cobalamin 0%
Magnesium 2%	

*Per cent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

NUTRITION FACTS

Macro and micronutrients	Fungi-based food proteins		Plant-based food proteins		Animal-based food proteins	
	Mycoprotein*	Mushrooms (shitake, cooked)	Tofu, soya bean (steamed)	Chickpeas (re-heated)	Chicken breast; meat only (casseroled)	Beef mince (stewed)
Energy (kcal/100 g)					160	209
Protein (g/100 g)					28.4	21.8
Carbohydrate (g/100 g)					0.0	0.0
Fat (g/100 g)					5.2	13.5
Of which satur					29.6	47.5
Fiber (AOAC)					0.9	0.0
Vitamin B6 (mg)					0.36	0.17
Vitamin B9 (folate)					6.0	5.0
Vitamin B12 (µg)					Tr	0.8
Calcium (mg)					9	11
Phosphorous (mg)					210	93
Iron (mg)	0.39			1.9	0.5	0.83
Magnesium (mg)	49	14	23	44	25	11
Zinc (mg)	7.6	N	0.7	1.1	1.1	2.1
Potassium (mg)	71	120	63	281	270	163
Choline (µg)	180	NR	NR	NR	NR	NR
Dataset code	NA	13-295	13-570	13-670	18-307	18-470

- Choline It is neither a vitamin nor a mineral grouped with the vitamin B complex due to its similarities
- Choline is required to produce acetylcholine, a neurotransmitter that plays an important role in regulating memory, mood and intelligence. It's also needed for the process that synthesizes DNA, which is important for brain function and development

NUTRITION FACTS

BENEFITS OF EATING MUSHROOMS

1 Rich Source of Essential Nutrition

2 Alleviates Adrenal Fatigue

3 Fights Inflammation

4 Helps Fight Cancer

5 Helps Manage Weight

6 Lowers Cholesterol

7 Lowers Blood Pressure

8 Enhances Memory

9 Enhances Iron Absorption

10 Boosts the Immune System

11 Helps Prevent Diabetes

12 Aids Nutrient Absorption



NUTRITION FACTS

Essential amino acids		Threonine Thr	Valine Val	Methionine Met	Isoleucine Ile	Leucine Leu	Phenylalanine Phe	Lysine Lys
Meat	Cows	11.31	10.23	6.00	4.55	2.03	1.44	0.86
	Sheep	9.07	19.11	3.85	0.88	3.16	5.90	11.67
	Chicken	5.64	3.31	5.01	9.73	26.55	3.32	5.69
	Fish	50.76	5.20	9.47	27.02	5.57	3.86	7.53
	Shrimp	9.60	3.79	25.4	6.57	65.21	6.67	3.93
Eggs		4.31	2.69	3.32	2.36	5.17	21.52	3.59
Milk	Cows	9.80	18.1	26.21	6.26	6.54	6.55	4.44
	Sheep	4.87	3.35	6.00	9.67	5.44	3.40	6.00
White soft cheese made from milk	Cows	5.56	2.87	5.12	8.99	4.56	2.93	5.59
	Sheep	4.87	2.76	6.30	9.80	4.99	3.87	5.65
Mushroom		9.14	3.70	3.26	3.31	3.54	5.14	4.48

NUTRITION FACTS

Non-essential amino acids		Aspartic acid Asp	Glutamic acid Glu	Glycine Gly	Arginine Arg	Alanine Ala	Proline Pro	Tyrosine Tyr
Meat	Cows	0.76	0.59	3.00	5.98	7.02	3.13	2.78
	Sheep	0.65	14.17	4.47	12.96	4.81	5.93	5.84
	Chicken	0.30	4.60	12.16	6.87	4.27	3.37	4.39
	Fish	2.86	2.00	5.80	3.58	37.43	5.54	3.81
	Shrimp	26.61	3.41	24.48	6.51	28.28	3.48	7.40
Eggs		6.20	8.74	2.06	3.24	3.59	2.16	2.40
Milk	Cows	22.96	35.8	4.95	6.15	3.44	7.01	31.33
	Sheep	1.54	3.99	12.09	5.86	4.27	3.62	4.47
White, soft cheese made from milk	Cows	0.45	3.87	11.13	5.98	4.18	3.34	3.95
	Sheep	2.65	4.87	12.08	6.79	3.62	2.74	4.44
Mushroom		2.52	14.53	24.13	12.01	4.44	3.45	5.80

SINGLE CELL PROTEIN (SCP)

Single cell protein (SCP)

- ❑ Is a protein produced in microbial and algal cells, is an option with potential.
- ❑ Recent interest in SCP has focused on the valorization of side streams by using microorganisms to improve their protein content
- ❑ Researchers compared milk protein with mycoprotein and found “equivalent” bioavailability.
- ❑ Increased use of mixed populations, rather than pure strains in the production of SCP.
- ❑ The use of methane as a carbon source for SCP is reaching commercial scales



SINGLE CELL PROTEIN (SCP)



ASEAN Single Cell Protein Market 2020-2030

~9.3% CAGR (2020-2030)

Key Market Strategies



Top Opportunities in Alternative Protein Space to Source Protein from Human Microbiome

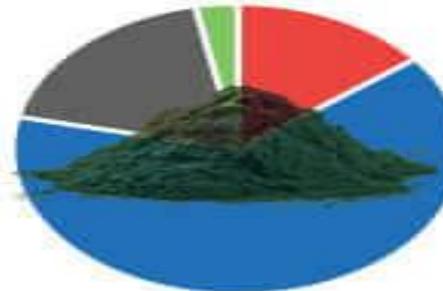


Increase R&D in Projects Focused on Enhancing Regional Food Safety and Sustainability

Species



Application



- Food and Beverage
- Animal Feed and Pet Food
- Dietary Supplement
- Others

SINGLE CELL PROTEIN (SCP)

Organism	Substrate	Protein content (%)
<i>Aspergillus flavus</i>	Rice bran	10
<i>Aspergillus niger</i>	Apple pomace	17-20
	Banana wastes	18
	Rice bran	11
	Stickwater	49
	Potato starch processing waste	38
	Waste liquor	50
<i>Aspergillus ochraceus</i>	Rice bran	10
<i>Aspergillus oryzae</i>	Rice bran (decoiled)	24
<i>Candida crusei</i>	Cheese whey	48
<i>Candida tropicalis</i>	Molasses	56
	Bagasse	31
<i>Candida utilis</i>	Poultry litter; Waste capsicum powder	29
		48
	Potato starch industry waste	46
<i>Chrysonilia sitophilia</i>	Lignin	39
<i>Cladosporium cladosporioides</i>	Rice bran	10
<i>Debaryomyces hansenii</i>	Brewery's spent grains hemicellulosic hydrolysate	32
<i>Fusarium semitectum and sp1 and sp2</i>	Rice bran	10
<i>Fusarium venenatum</i>	Glucose (Product: Quorn™)	44
<i>Hanseniaspora uvarum</i>	Spoiled date palm fruits	49
<i>Kefir sp.</i>	Cheese whey	54
	Orange pulp, molasses, brewer's spent grain, whey, potato pulp, malt spent rootlets	24-39
<i>Kluyveromyces marxianus</i>	Cheese whey	43
	Orange pulp, molasses, brewer's spent grain, whey, potato pulp	59
<i>Monascus ruber</i>	Rice bran	10
Unspecified, marine yeast	Prawn shell wastes	61-70
<i>Penicillium citrinum</i>	Rice bran	10
<i>Pleurotus florida</i>	Wheat straw	63
<i>Saccharomyces cerevisiae</i>	Orange pulp, molasses, brewer's spent grain	24
<i>Trichoderma harzianum</i>	Cheese whey filtrate	34
<i>Trichoderma virideae</i>	Citrus pulp	32
<i>Yarrowia lipolytica</i>	Inulin, crude oil, glycerol waste hydrocarbons	48-54

CARBON FOOTPRINT

Mycoprotein

“Steaks” made from fungi (*Fusarium venenatum*)... Are we ready?

A new class of fungi-based steaks, cultivated from a fast-growing micro-organism, may be a paradigm-shifting meat alternative.

Emergy “the first in market to produce whole cuts of plant-based meat in the form of steak and chicken breasts.”

Made mostly from filamentous fungi, a kind of fast-growing micro-organism that branches quickly into thread-like networks of cells called **mycelium**.

Emergy company was founded in 2016 after two PhD students at the University of Colorado, Boulder, decided to apply their scientific expertise to the realm of food. **Justin Whiteley**, a mechanical engineer focused on materials science, and **Tyler Huggins**, an environmental engineer, studied the ways biology might be used to create hyper-efficient new products.



Nationally determined contributions (NDCs) are at the heart of the Paris Agreement and the achievement of these long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change.

SINGLE CELL PROTEIN (SCP)

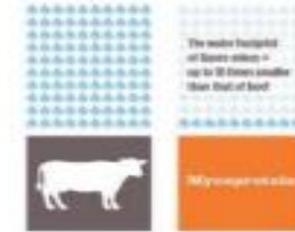
Europe
Meat Substitute Market

Regional Opportunities Analysis and Industry Forecasts, 2021-2027

Europe Meat Substitute Market is expected to reach \$3.6 billion by 2027

Growing at a CAGR of 7.9% (2021-2027)

Allied Market Research



Mycoprotein (2016)
Steaks made from
Fusarium venenatum

NUTRITIONAL AND SAFETY ANALYSES OF SCP

Nutritional values

- Nutrients content (Protein, fat, carbohydrates, moisture, ash)
- Fatty acid profile
- Amino acid profile
- Minerals

Food safety considerations

- Natural contaminants
- Including fungal toxins (mycotoxins)
 - Liquid chromatography-mass spectrometry (LC-MS)
 - High performance liquid chromatography (HPLC)
- Allergens
- Heavy metals such as lead (pb), cadmium (cd), arsenic (as) and mercury (hg)

SAFETY CONSIDERATIONS OF SCP

- ❑ Quorn™ mycoprotein underwent extensive testing for the presence of mycotoxins or other toxic compounds before being approved for human consumption
- ❑ The particular strain of *F. venenatum* does not produce mycotoxins under production conditions, but the process is still monitored to ensure none are present.
- ❑ The initial safety testing for Quorn™ mycoprotein involved 16 years,
- ❑ Many more years required to gain approval for sale outside the UK
- ❑ *Yarrowia lipolytica* is another fungus whose safety has been extensively assessed
- ❑ Demonstrating that it would be safe to use in a variety of food applications
- ❑ Commercial production of SCP is limited due to operating costs, and to the cost of nutritional and toxicological assessments

CLEAN LABEL SOLUTIONS



- **Functionality:** Function as the same replaced ingredient.
- **Cost:** Affordable
- **Availability:** of certified ingredients
- **Consumer friendly**
- **Food safety concerns**
- **Tractability:** Easy for ongoing monitoring

Clean label is a consumer driven movement, demanding a return to **real food & transparency** through **authenticity**.

Ingredients

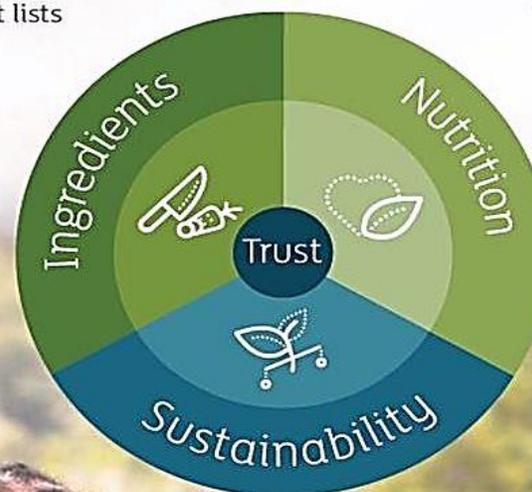
- Free-from artificial flavors, colors, and allergens
- No-no lists
- Recipe-like ingredient lists

Nutrition

- Removal of negatives (e.g., sugar)
- Addition of positives (e.g., protein)

Sustainability

- Organic, Non-GMO
- Ethical production and business practices
- Reduction in waste and packaging



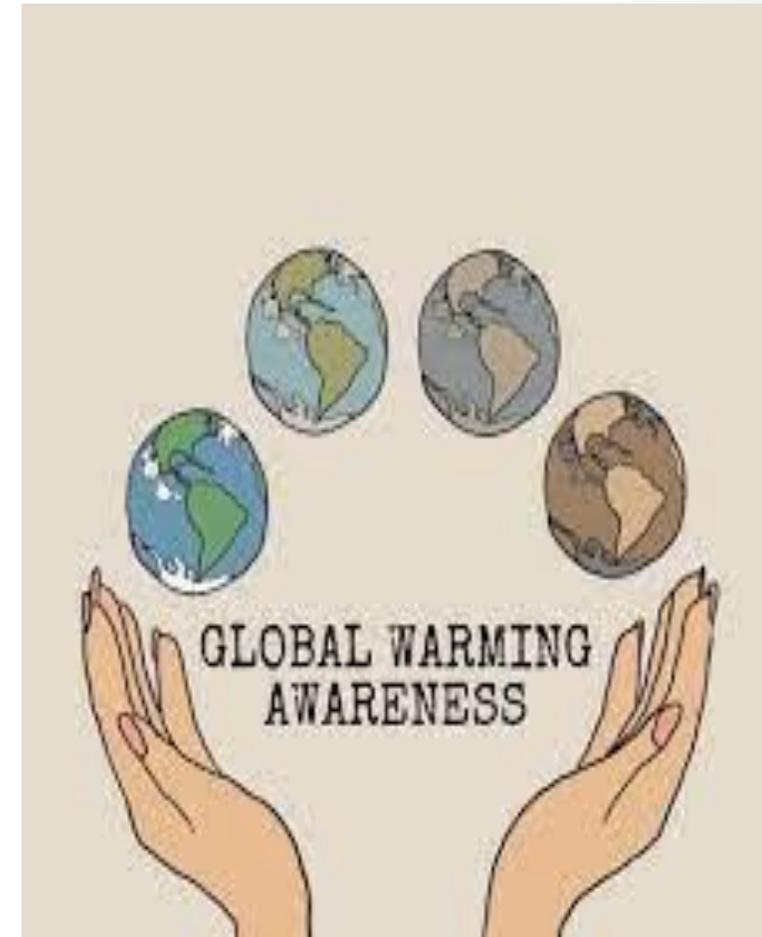
Highlighted RECOMMENDATIONS

According to Paris Agreement 2015, Nationally determined contributions (NDCs) embody efforts by each country to reduce national emissions and adapt to the impacts of climate change.

Especially in food systems activities that is responsible for about 37% of total emissions

National and International initiatives spreading awareness and changing consumption patterns, adequate nutrition and least food waste on either on household or food producers levels.

Establishment of unified international legalizations for safe production and global trade.



Highlighted RECOMMENDATIONS



Research Topic

Sports Nutrition and Sustainability: Steps Towards A Healthier Planet

<https://www.frontiersin.org/research-topics/37178/sports-nutrition-and-sustainability-steps-towards-a-healthier-planet>



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Guest Associate Editor
in Sport and Exercise Nutrition

My Research Topics



Sports Nutrition and Sustainability: Steps Towards A Healthier Planet

Manage



AS FUNGI
CAN **SURVIVE**
CLIMATE
CHANGE

THEY ALSO

CAN SERVE IN
SUSTAINABLE
SOLUTIONS



THANK
YOU

Amira Darwish